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National Nanotechnology Investment in the FY 2003 Budget Request

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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 2003 funding request for nanoscale science, engineering and technology (in brief, *nanotechnology*) research and development (R&D) in ten federal departments and independent agencies is summarized in Table I-10. This investment is known as the National Nanotechnology Initiative (NNI).[2] The initiative emphasizes long-term, fundamental research aimed at discovering novel phenomena, processes, and tools; addressing NNI Grand Challenges; supporting new interdisciplinary centers and networks of excellence including shared user facilities; supporting research infrastructure; and addressing research and educational activities on the societal implications of advances in nanoscience and nanotechnology. Funding is provided on competitive basis with other programs and within NNI.

SUMMARY FOR ALL AGENCIES

Priorities in FY 2003: The FY 2003 President's request of about $710 million ($679 million reported in the FY 2003 budget, plus $31 million in associated programs at NASA and USDA) for federal investment in nanoscale science, engineering and technology, a 17.5 percent increase over FY 2002, is shown in Table I-10. The FY 2002 nanoscale R&D

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[2] http://nano.gov

budget appropriated by Congress is approximately $604 million ($579 million in the FY 2003 budget, plus $25 million in associated programs at NASA and USDA).

The initiative focuses on long-term research on the manipulation of matter at the atomic and molecular levels, giving us an unprecedented ability to create building blocks for advanced products such as new classes of devices as small as molecules and machines as small as human cells. This research could lead to continued improvement in electronics for information technology; higher-performance, lower-maintenance materials for manufacturing, defense, transportation, space, and environmental applications; and accelerated, biotechnical applications in medicine, health care, and agriculture. In FY 2003, the Initiative will focus on fundamental nanoscale research through investments in investigator-led activities, centers and networks of excellence, and infrastructure. Three new R&D areas of focused are planned in all federal departments and agencies: manufacturing processes at the nanoscale, use of nanotechnology for chemical-biological-radioactive-explosive detection and protection, and development of instrumentation and metrology at the nanoscale.

Priority in funding will be given to: (1) research to enable the nanoscale as the most efficient manufacturing domain; (2) innovative nanotechnology solutions to biological-chemical-radiological-explosive detection and protection; (3) development of instrumentation and standards; (4) the education and training of the new generation or workers for the future industries; and (5) 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.

Collaborative activities: 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 coordination will: identify the most promising research directions, 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, complex implications on society such as effect of nanostructured material manufacturing on environment and effect of nanodevices on health, and avoid of unnecessary duplication of efforts. The coordination also will address NNI management issues.

DEPARTMENT OF DEFENSE (DOD)

The FY 2003 request is $201 million, $21 million over FY 2002 (see Table 1). The principal DOD participants in the NNI are DDR&E(R), DARPA, the Air Force, the Army and the Navy. While the NNI is a fundamental science (DOD's "6.1" funding category) based initiative, one of the principal NNI goals is to transition science discovery into new technology. The DOD structures its S&T investment into basic research ("6.1"), applied research ("6.2") and exploratory development ("6.3"); the latter two focus on transitioning science discovery into innovative technology. Beginning in FY 2002, the DOD will track and encourage the transitions into these applied programs, under the label "6.2/6.3" in Table 1.

Table 1. DOD investments in nanoscience
(in millions of dollars)

	FY 2001 Actual		FY 2002 Current		FY 2003 Request	
	"6.1"	6.2/6.3	"6.1"	6.2/6.3	"6.1"	6.2/6.3
DUSD(R)	36	0	26	0	28	0
DARPA	28	12	9	88	11	90
Army	6	0	18	2	18	5
Air Force	6	4	8	7	13	5
Navy	31	0	21	1	26	5
Total DOD Nanoscience	107	16	82	98	96	105

The University Research Initiative program in FY 2001 added 16 nanoscience projects as part of a Defense University Research Initiative on Nanotechnology (DURINT) competition and another 5 nanoscience projects under the traditional competition; the projects carry a 5-year commitment in FY 2003. DARPA plans a significant enhancement in

nanoscience/nanotechnology for its investment portfolio in FY 2003. The Air Force is looking to increase its investment in nanoscience. It is anticipated that its basic research activities will expand research in nanocomposites- hybrid polymer-inorganic nanocomposites; self-assembly and nanoscale processing for the realization of 3-D optical and electronic circuitry; highly efficient space solar cells; nanoenergetics—understanding the factors that control reactivity and energy release in nanostructured systems; nanostructures for highly selective sensors and catalysts; as well as nanoelectronics, nanomagnetics and nanophotonics; nanostructured coatings, ceramics and metals. The Army will allocate $10 million of basic research funds for a University Affiliated Research Center (UARC)—the Institute for Soldier Nanotechnologies. The purpose of this center of excellence is to develop unclassified nanometer-scale science and technology solutions for the soldier. A single university will host this center, which will emphasize revolutionary materials research toward advanced soldier protection and survivability capabilities. Reprogramming $10 million of its core funds since FY 2002, the Naval Research Laboratory has initiated a Nanoscience Institute to enhance multidisciplinary thinking and critical infrastructure.

Nanoscience shows great promise for arrays of inexpensive, integrated, miniaturized sensors for chemical / biological / radiological / explosive (CBRE) agents, for nanostructures enabling protection against agent, and for nanostructures that neutralize agents. The recent terrorist events motivate accelerated insertion of innovative technologies to improve the national security posture relative to CBRE. DOD will play a major role in this multiagency effort. The DOD Advisory Group on Electronic Devices (AGED) will perform a special technical area review (STAR) on nanoelectronics. A key goal for that review will be guidance for the "Nano-Electronics, -Optoelectronics and –Magnetics" basic science investment, and for the 6.2/6.3 funding necessary to accelerate the development of information technology devices.[3]

DEPARTMENT OF ENERGY (DOE)

In FY 2003, the total request is $139.3 million, including funding of $6.3 million for defense programs. This is an increase of $48.2 million over

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

FY 2002. Fundamental research to understand the properties of materials at the nanoscale will be increased in three areas: synthesis and processing of materials at the nanoscale, condensed matter physics, and catalysis. In addition, the FY 2003 request includes $35 million for centers. These centers are the Molecular Foundry (Foundry) at Lawrence Berkeley National Laboratory, the Center for Nanophase Materials Sciences (CNMS) at Oak Ridge National Laboratory, and the Center for Integrated Nanotechnology (CINT) at Sandia National Laboratories and Los Alamos National Laboratory. Construction will begin on one Nanoscale Science Research Center (NSRC), and engineering and design will continue on two others. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. NSRCs were conceived within the context of the NSTC Interagency Working Group on Nanoscale Science, Engineering, and Technology as part of the DOE contribution to the National Nanotechnology Initiative. They involve conventional construction of a simple laboratory building, usually sited adjacent to or near an existing BES synchrotron or neutron scattering facility. The research activity will also benefit by new work proposed in FY 2003 by the Office of Advanced Scientific Computing Research (ASCR) in the area of computational nanoscale science engineering and technology. ASCR will develop the specialized computational tools for nanoscale science. The estimate of FY 2003 DOE funding includes $6.3 million in the Office of Defense Programs (NNSA), $0.2 million over FY 2002.

DEPARTMENT OF JUSTICE (DOJ)

In FY 2003 the budget request is steady at $1.4 million. The DOJ National Institute of Justice (NIJ) has two separate projects areas that incorporate nanotechnology—DNA Research ($1 million) and Development and Chemical and Biological Defense ($0.4 million). 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 have 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.

DEPARTMENT OF TRANSPORTATION (DOT/FAA)

The FY 2003 research request is approximately $2 million to address one of the agency's most critical missions today: ensuring the security of our nation's air transportation system by improving the detection of explosives and chemical/biological weapons. The Department's Federal Aviation Administration (FAA) Aviation Security Division is pursuing R&D programs to detect explosives and hazardous chemicals at the nanometer level and to characterize the interactions of explosives on material surfaces at this scale. Further research will yield sensor technologies that are cheaper and lighter yet far more sensitive, selective, and reliable than current systems. The NNI activities proposed for FY 2003 will build on current efforts to expedite the fielding of far more accurate and effective security technology at our nation's airports.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

FY 2003 research is expected to be similar to FY 2002 at approximately $5 million. 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 evaluated.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

The FY 2003 request is approximately $51 million. In addition to the $22 million in both Basic Nanoscience and Nanotechnology Research, NASA plans to invest approximately an additional $29 million in the area of Nanotechnology Science and Applications. These investments are embedded within several Program areas and within the Office of Biological and Physical Research and the Office of Aerospace Technology (OAT). The Basic NASA Nanoscience Program comprises

Bio-Molecular Systems Research, which is a joint NASA/NCI (National Cancer Institute) Initiative, and the second is in Biotechnology and Structural Biology. 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.

Collaboration is particularly important for NASA, since it recognizes the importance of importing technologies from other federal agencies. Given the infancy of nanotechnology, there is a broad area of basic research knowledge performed by other federal agencies (particularly NSF, DOD, NIH, and DOE) that would benefit NASA. NASA will focus primarily on NASA-unique needs; examples are low power devices and high strength materials that perform with exceptional autonomy in the hostile space environment. NASA will significantly increase university participation in nanotechnology programs by competitively awarding three University Research, Engineering and Technology Institutes (RETIs) in FY 2003. NASA plans to select one RETI in each of three areas: (1) aerospace materials, (2) electronics and computing and (3) bio-nanotechnology fusion. Each award will be for about $3 million a year for 5 years with the option to extend award for up to an additional 5 years.

NATIONAL INSTITUTES OF HEALTH (NIH)

The FY 2003 request is $43.2 million, $2.4 million over FY 2002. NIH will receive nanoscience and nanotechnology grant applications under existing and renewed programs. These programs are managed individually by the Institutes and Centers, with peer review conducted for the most part by the NIH Center for Scientific Review. Overall nanotechnology program coordination occurs through the NIH Bioengineering Consortium (BECON).[4]

[4] The NIH nanoscience program announcements are available from www.nano.gov/nihnano.doc and http://grants.nih.gov/grants/becon/becon_funding.htm

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

The FY 2003 request is $43.8 million, a $6.2 million increase over FY 2002. 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 have been used to increase current 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, and new information technologies. Areas of focus are: (a) Nanomagnetics research for measurement and standards for current and near-term applications of nanotechnology in the semiconductor, communications, and health care industries; (b) Nanocharacterization research to produce standards and tools for visualization and characterization at the nanoscale, which are in high demand by a broad base of U.S. industries; (c) 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 about a decade. 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. NIST has a large range of collaborations with industry.

NATIONAL SCIENCE FOUNDATION (NSF)

The FY 2003 request is about $221 million, a $22 million increase over FY 2002 (see Table 2).

The Nanoscale Science and Engineering (NSE) Group coordinates the NNI activities. Each directorate has two representatives in the NSE Group. The Chair of the Group is the NSF representative in NSEC, and

its current chair.[5] The NSF investment will be expanded to develop and strengthen critical fields 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, national science and engineering centers, exploratory research and education projects, and education and training.

Table 2: NSF budgets for Nanoscale Science and Engineering
(in millions of dollars)

	FY 2001 Enacted	FY 2002 Current	FY 2003 Request
Biological Sciences	2.33	2.33	2.98
Computer and Info. Sci. and Eng.	2.20	10.20	11.14
Engineering	55.27	86.30	94.35
Geosciences	6.80	6.80	7.53
Mathematical and Physical Scis.	83.08	93.08	103.92
Social and Behavioral Scis.	0.00	0.00	1.11
Education and Human Resources	0.00	0.00	0.22
Total, NSF Nanoscale Sci. and Eng.	149.68	198.71	221.25

Totals may not add due to rounding.

The investment will expand a wide range of research and education activities in this priority area, including approximately 15 nanotechnology research and education centers, which focus on electronics, biology, optoelectronics, advanced materials and engineering.

Long-term objectives include laying a foundation of fundamental research for NNI Grand Challenges; 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

[5] The FY 2002 program solicitation can be found at http://www.nsf.gov/nano (NSF 01-157), with two modes of research support: Nanoscale Interdisciplinary Research Teams and Nanoscale Exploratory Research.

health, advanced agriculture, conservation of materials and energy, and sustainability of the environment. This investment will be expanded in FY 2003 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. In addition to single investigator research, support will be focused on interdisciplinary research and education teams, national science and engineering centers, exploratory research and education projects, and education and training,

Long-term objectives include building a foundation of fundamental research for understanding and applying novel principles and phenomena for nanoscale manufacturing and other NNI Grand Challenges; 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. These goals will enable development of revolutionary technologies that contribute to improvements in health, advance agriculture, conserve materials and energy, and sustain the environment.

NSF's planned investment for Nanoscale Science and Engineering in FY 2003 will have five programmatic foci: 1) Fundamental Research and Education, $140.93 million; 2) Grand Challenges, approximately $10.70 million; 3) Centers and Networks of Excellence, approximately $38.64 million; 4) Research Infrastructure, approximately $21.70 million; and 5) Societal and Educational Implications of Science and Technology Advances, approximately $9.28 million.

US DEPARTMENT OF AGRICULTURE (USDA)

The FY 2003 request is approximately $2.5 million without having a special line item in the budget. USDA conducts its research both extramurally through the partnership between Cooperative State Research, Education, and Extension Service (CSREES) and Land Grant Universities (LGUs), 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 U.S. through the LGUs. According to the USDA Current Research Information System (CRIS) database, the combined research expenditure (with matching funds) related to nanoscale science and technology was about $9.2 million in FY 2001.