

NATIONAL NANOTECHNOLOGY INITIATIVE

NSF's contribution to the multiagency National Nanotechnology Initiative (NNI) encompasses the systematic understanding, organization, manipulation, and control of matter at the atomic, molecular, and supramolecular levels in the size range of 1 to 100 nanometers. Novel materials, devices, and systems – with their building blocks designed on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to control and manipulate matter at this scale, science, engineering, and technology are realizing revolutionary advances in areas such as individualized pharmaceuticals, new drug delivery systems, more resilient materials and fabrics, catalysts for industry, and order-of-magnitude faster computer chips.

National Nanotechnology Initiative Funding

(Dollars in Millions)

	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 Information Science and Engineering	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	-	-
Mathematical and Physical Sciences	158.24	156.42	169.91	13.49	8.6%
Social, Behavioral and Economic Sciences	1.56	1.67	1.67	-	-
Office of International Science and Engineering	0.48	-	-	-	-
Subtotal, Research and Related Activities	\$356.47	\$370.18	\$386.80	16.62	4.5%
Education and Human Resources	3.24	3.00	3.10	0.10	3.3%
Total, National Nanotechnology Initiative	\$359.71	\$373.18	\$389.90	16.72	4.5%

FY 2008 NNI Funding. NSF's contributes to the goals and seven program-component areas (PCAs) outlined in the NNI Strategic Plan (www.nano.gov). The modes of support include single investigator, multidisciplinary team, center, and network awards.

(1) Fundamental nanoscale phenomena and processes. The FY 2008 Request includes \$142.67 million for fundamental research and education, with special emphasis on:

- *Novel phenomena, quantum control, and basic engineering processes* – to discover and understand phenomena and design processes specific at the nanoscale, including new phenomena in materials, mechanics, chemistry, biology, electronics, and optics. A focus will be on understanding and use of self assembly from basic principles and on multiple scales. Potential applications include use of quantum phenomena in systems and quantum computing, and new devices and processes for advanced communications and information technologies.
- *Biosystems at the nanoscale* – to support study of biologically based or inspired systems that exhibit novel properties and potential applications. Potential applications include improved drug delivery, biocompatible nanostructured materials for implantation, exploiting of functions of cellular organelles, devices for research in genomics, proteomics and cell biology, and nanoscale sensory systems, such as miniature sensors for early detection of cancer. A focus will be on understanding and simulation of cells, tissues, and nervous systems, with application to biomedicine and neuromorphic engineering.
- *Converging science and engineering at the nanoscale* – The convergence of nanotechnology with information technology, modern biology, and social sciences will reinvigorate discoveries and

innovation in almost all areas of the economy. This theme includes investments in (a) nano-biology interface and improving human performance, and (b) nano-information interface research.

- *Multi-scale, multi-phenomena theory, modeling, and simulation at the nanoscale* - to support theory, modeling, large-scale computer simulation and new design tools, and infrastructure in order to understand, control, and accelerate development in new nanoscale regimes and systems. A special focus will be on simulations with atomic precision, time resolution of chemical reactions, and for domains of engineering and biological relevance.

(2) Nanomaterials. The FY 2008 Request includes \$60.19 million for discovery of novel nanoscale and nanostructured materials, and improving the comprehensive understanding of the properties of nanomaterials (ranging across length scales and including interface interactions). A special focus will be gaining control of nanoscale features and devices with the atomic level of precision. Another focus will be design and synthesis, in a controlled manner, of nanostructured materials with targeted properties. Research on the discovery, understanding, and control of materials at the nanoscale will be critical to the development and success of innovative technologies, including communications, catalysts, energy, healthcare, and manufacturing.

(3) Nanoscale devices and systems. The FY 2008 Request includes \$51.10 million for R&D that applies the principles of nanoscale science and engineering to create novel, or to improve existing, devices and systems. This includes the incorporation of nanoscale or nanostructured materials to achieve improved performance or new functionality, and developing new concepts to understand interactions among nanoscale devices in complex systems, including the physical, chemical, and biological interactions between nanostructures and device components. A special focus will be on nanomanufacturing of active nanostructures and nanosystems.

Nanoelectronics beyond silicon nanotechnology and complementary metal-oxide superconductors (CMOS) research will explore ultimate limits to scaling of features and alternative physical principles for devices employed in sensing, storage, communication, and computation. The research activity in this area will help develop innovative technologies, including replacing electron charge as information carrier, bottom-up device assembly technologies at the atomic and molecular levels, and new system architectures using nanoscale components.

A special focus will be on nano-informatics for better communication and nanosystem design. It includes defining the ontology of terms, interconnecting databases, using specific informatics tools, and connecting to bioinformatics.

(4) Instrumentation research for nanotechnology. The FY 2008 Request includes \$14.50 million for R&D to create new tools needed to advance nanotechnology research and commercialization, including next-generation instrumentation for characterization, measurement, synthesis, and design of materials, structures, devices, and systems. A special challenge is developing tools for measuring and restructuring matter with atomic precision, for time resolution of chemical reactions, and for domains of biological and engineering relevance.

(5) Nanomanufacturing. The FY 2008 Request includes \$26.90 million to support new concepts for high rate synthesis and processing of nanostructures, nanostructured catalysts, fabrication methods for devices, and assembling them into nanosystems and then into larger scale structures of relevance in industry and in the medical field. R&D is aimed at enabling scaled-up, reliable, cost effective manufacturing of nanoscale materials, structures, devices, and systems. A special focus will be creating active nanostructures and complex nanosystems. This will include R&D and integration of ultra-

miniaturized top-down processes, increasingly complex bottom-up or self-assembly processes, and developing novel concepts for high-rate synthesis and processing of nanostructures and nanosystems.

(6) Major research facilities and instrumentation acquisition. The FY 2008 Request includes \$31.62 million for user facilities, acquisition of major instrumentation, and other activities that develop, support, or enhance the scientific infrastructure for the conduct of nanoscale science, engineering, and technology research and development. It also supports ongoing operations of the National Nanotechnology Infrastructure Network (NNIN), Network for Computational Nanotechnology (NCN) and National Network for Nanomanufacturing. The investment will support facilities for 16 ongoing Nanoscale Science and Engineering Centers (NSEC).

(7) Societal Dimensions. The FY 2008 Request includes \$62.92 million, an increase of \$3.90 million over FY 2007, 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 (\$28.75 million). Research will address the 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 nanoparticles 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). New measurement methods for nanoparticle characterization and toxicity of nanomaterials will be investigated. Support is requested for a new multidisciplinary center to conduct fundamental research on the interactions between nano-particles and materials and the living world at all scales. An essential element of this will be research on methods and instrumentation for nano-particle detection, characterization, and monitoring, including interactions of nano-materials with cellular constituents, metabolic networks and living tissues, bioaccumulation and its effects on living systems, and the impacts of nanostructures dispersed in the environment. This work will support regulatory and mission agencies in developing science-based standards for risk assessments, such as the standards needed by the EPA to regulate nano-materials.
- 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 (\$28.38 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 (\$5.79 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 be fully operational in FY 2008.

Coordination with Other Agencies

The NSF program is coordinated with 25 departments and agencies through the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology (NSET). Examples of specific coordination efforts are: Nanomanufacturing (DOD/NIST); Environmental issues (EPA/NIOSH/NIEHS/ USDA); NSECs, NNIN and NCN centers and networks (DOD/NASA/DOE/NIH); simulations in nanoelectronics (DOD/NASA); and research and training activities (DOD/NIH).

NNI by Program Component Area
(Dollars in Millions)

	FY 2006 Actual	FY 2007 Request	FY 2008 Request	Change over	
				FY 2007 Amount	FY 2007 Percent
Fundamental Nanoscale Phenomena & Processes	\$147.34	\$131.84	\$142.67	\$10.83	8.2%
Nanomaterials	52.52	57.97	60.19	2.22	3.8%
Nanoscale Devices & Systems	43.68	50.26	51.10	0.84	1.7%
Instr. Research, Metrology, & Standards for Nanotech	6.59	15.00	14.50	-0.50	-3.3%
Nanomanufacturing	20.31	27.24	26.90	-0.34	-1.2%
Major Research Facilities & Instrumentation Acquisition	37.20	31.85	31.62	-0.23	-0.7%
Societal Dimensions: Environmental Health & Safety	21.03	25.65	28.75	3.10	12.1%
Societal Dimensions: Education	25.00	28.00	28.38	0.38	1.4%
Societal Dimensions: Ethical, Legal and Other Social Issues	6.03	5.37	5.79	0.42	7.8%
Total, National Nanotechnology Initiative	\$359.71	\$373.18	\$389.90	\$16.72	4.5%

Totals may not add due to rounding.