NATIONAL NANOTECHNOLOGY INITIATIVE

Nanoscale science and engineering (NS&E) is NSF's major contribution to the multiagency National Nanotechnology Initiative (NNI). NS&E at NSF encompasses the systematic understanding, organization, manipulation, and control of matter at the atomic, molecular and supramolecular levels. Novel materials, devices, and systems – with their building blocks on the scale of nanometers – open up new directions in science, engineering, and technology with potentially profound implications for society. With the capacity to 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 2005 Actual	FY 2006 Current Plan	FY 2007 Request	Change over FY 2006 Amount	Change over FY 2006 Percent
Biological Sciences	46.78	49.00	52.55	3.55	7.2%
Computer and Information Science and Engineering	7.78	12.00	12.87	0.87	7.2%
Engineering	123.77	127.77	137.02	9.25	7.2%
Geosciences	7.94	9.00	9.65	0.65	7.2%
Mathematical and Physical Sciences	143.27	141.54	156.42	14.88	10.5%
Social, Behavioral and Economic Sciences	1.57	1.56	1.67	0.11	7.1%
Office of International Science and Engineering	0.72	-	-	-	N/A
Subtotal, Research and Related Activities	331.83	340.87	370.18	29.31	8.6%
Education and Human Resources	3.16	2.90	3.00	0.10	3.4%
Total, National Nanotechnology Initiative	$334.99	$343.77	$373.18	$29.41	8.6%

Totals may not add due to rounding.

FY 2007 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. The Nanoscale Interdisciplinary Research Teams (NIRT) awards encourage team approaches to address research and education themes where a synergistic blend of expertise is needed to make significant contributions. Within the total investment for NNI, $65.0 million will be allocated to 50 new awards on Nanoscale Interdisciplinary Research Teams or other NIRT-like activities.

FY 2007 Areas of Emphasis:

Fundamental nanoscale phenomena and processes. The FY 2007 Request includes $131.84 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. Potential applications include 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.

- *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.

Nanomaterials. The FY 2007 Request includes $57.97 million for discovery of novel nanoscale and nanostructured materials, and at gaining a comprehensive understanding of the properties of nanomaterials (ranging across length scales and including interface interactions). Another focus will be on 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, energy, healthcare, and manufacturing.

Nanoscale devices and systems. The FY 2007 Request includes $50.26 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. Interdisciplinary teams will investigate methods for design of systems composed of nanodevices.

Silicon nanotechnology and beyond complementary metal-oxide superconductors (CMOS) is an area of focus. 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 and bottom-up device assembly technologies at the atomic and molecular levels.

Instrumentation research for nanotechnology. The FY 2007 Request includes $15.0 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.

Nanomanufacturing. The FY 2007 Request includes $27.24 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 aimed at enabling scaled-up, reliable, cost-effective manufacturing of nanoscale materials, structures, devices, and systems. It includes 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.

Major research facilities and instrumentation acquisition. The FY 2007 Request includes $31.85 million for establishment of 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) and Network for Computational Nanotechnology (NCN). The investment will support facilities for 15 ongoing Nanoscale Science and Engineering Centers (NSEC).

Societal Dimensions. 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:

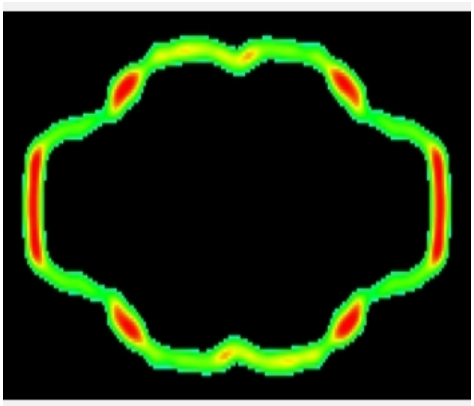
- Research directed at environmental, health, and safety impacts of nanotechnology development and basic research supporting risk assessment of such impacts ($25.65 million). Research will addresses three sources of nanoparticles and nanostructured materials in the environment (in air, water, soil, biosystems, 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.

Coordination with Other Agencies

The NSF program is coordinated with 24 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); NSECs, NNIN and NCN centers and networks (DOD/NASA/DOE); simulations in nanoelectronics (DOD/NASA); and research and training activities (NIH).

Recent Research Highlight

► **Vaults: From Biological Mystery to Nanotech Workhorse?** In the nearly two decades since the naturally occurring nano-capsules known as "vaults" were discovered, researchers have found that these hollow, barrel-like structures circulate by the tens of thousands in just about every cell of the human body, as well as in the cells of monkeys, rats, frogs, electric rays and even slime molds. Researchers have also come to believe that these vaults could find a wide range of uses in nanotechnology – even though no one can figure out how nature itself uses them.



A vault particle in cross-section.

At UCLA, for example, researchers have gained a good understanding of the particles' structures and how they assemble themselves out of protein molecules and RNA. By using the standard techniques of biotechnology, vaults may soon be engineered to give them different properties, which could lead to their use as structural elements for nanoscale machines or as switches for nanoscale electrical circuits. Better yet, researchers have shown that vaults can function as nanoscale Trojan Horses, carrying foreign molecules past cellular membranes that are expressly designed to keep such interlopers out. Researchers are now working to bioengineer vaults that will hone in on specific cell surface receptors, so that they can be directed to enter only certain types of cells.