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Advancing the Frontiers of Nanotechnology Through Fundamental Academic Research

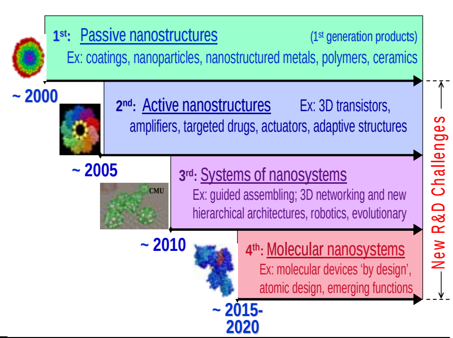
Chairman Stevens, Co-chairman Inouye, and distinguished members of the committee, my name is Richard Buckius, and I am the acting assistant director of the National Science Foundation for Engineering. I am pleased to be here today to discuss the NSF's strong commitment to fundamental academic research in the area of nanoscale science and technology.

Before I begin, I wish to express my thanks for your ongoing support for basic research, which is absolutely necessary to ensure our nation's leadership in innovation in an increasingly competitive world.

Nanotechnology is truly our next great frontier in science and engineering, and it represents an entirely new realm of technological capabilities. By tailoring molecules and even manipulating individual atoms, scientists and engineers now have the ability to design materials, medicines, electronics, and machines at the tiniest, most fundamental level.

This is an amazing capability, and it will have profound and lasting impact on our industry and economy, our national and homeland security, and our commitment to sustain the quality of life for all through advances in areas such as affordable healthcare and reliable energy.

In its earliest stages, nanotechnology referred simply to passive materials, such as nanoparticles found in composite materials and paint. We are now moving beyond passive systems and are beginning to see active nanostuctures, such as sub-100-nm transistors in commercial electronics and the LEDs used in traffic lights. As our ability to create new materials and technologies increases over the next decades, we can expect to see complete nanosystems with complex three-dimensional structures and the ability to respond and perform multiple functions.



Four generations of products: timeline for beginning of industrial prototyping and nanotechnology

Currently, U.S. industry and government agencies are working individually and collectively to enable these important developments. NSF, however, has a clearly defined yet vitally important role to play in this enterprise. Our focus is on fundamental science and engineering research and education. This research is supported primarily through grants to individuals and teams at our nation's academic institutions.

One successful mechanism is through the NSF's support of interdisciplinary research teams and centers. These group awards related to nanoscale science and engineering are incredibly effective in helping advance our understanding of the nanoscale because they encourage collaborative and synergistic research.

These grants enable faculty-level scientists and engineers from diverse fields to come together as teams to conduct frontier, nanoscale research. Their efforts have been particularly fruitful because nanoscale research and education are inherently interdisciplinary pursuits, often combining elements of chemistry, biology, manufacturing, physics, optics and photonics, and nearly every other field of basic science. By fostering this type of research, NSF is able to accelerate innovation in this burgeoning field.

Within NSF's total FY 2007 investment for the National Nanotechnology Initiative of $373 million, $65 million will be allocated to support such interdisciplinary research teams.

Since the inception of the National Nanotechnology Initiative (NNI) in FY 2001, NSF investments have led to significant accomplishments.

- NSF has created an interdisciplinary nanotechnology research community through support for large and small research groups and individual investigators, as well as a variety of programs for training and education. For example:
    - NSF supports approximately 3,000 active R&D projects.
    - NSF has founded 24 centers, networks, and user facilities (nearly half of the total created by the entire NNI).
    - NSF has educated or trained about 10,000 students and teachers in nanotechnology in 2005 alone.

- Two user networks established by NSF, the Network on Computational Nanotechnology (established in 2002) and the National Nanotechnology Infrastructure Network (established in 2003) have attracted over 12,000 academic, industry, and government users in 2005.

  - The Network for Computational Nanotechnology has a mission to connect theory, experiment, and computation to address the challenges in nanotechnology through new algorithms, approaches, and software tools with capabilities not yet available commercially.
  - The National Nanotechnology Infrastructure Network (an outgrowth of the National Nanotechnology Users Network) broadly supports nanotechnology activities by providing users across the nation access to leading-edge fabrication and characterization tools and instruments in support of nanoscale science and engineering research. In addition, this effort seeks to develop and maintain advanced research infrastructure, contribute to the education and training of a new workforce skilled in nanotechnology and the latest laboratory techniques, conduct outreach to the science and engineering communities, and explore the social and ethical implications of nanotechnology.

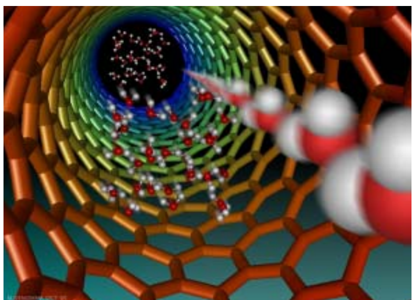
- The NSF has established recently three other NSF networks with national outreach addressing education and societal dimensions.
  - The Nanoscale Center for Learning and Teaching aims to reach one million students in all 50 states in the next five years.
  - The Nanoscale Informal Science Education network will develop, among others, about 100 nanoscale science and technology museum sites in the next five years.
  - The Network on Nanotechnology in Society was established in September 2005 with four nodes at the Arizona State University, University of California at Santa Barbara, University of South Carolina, and Harvard University. The Network will address both short-term and long-term societal implications of nanotechnology, as well as public engagement.

- NSF has funded a research theme on nanoscale processes in the environment since FY 2001. In the first five years of NNI, the NSF investment for fundamental research supporting environmental, health, and safety aspects of nanotechnology is about $82 million, or 7 percent of the NSF nanoscale science and engineering investment. Research has addressed the sources of nanoparticles and nanostructured materials in the environment (in air, water, soil, biosystems, and work environment), as well as the non-clinical biological implications. The safety of manufacturing nanomaterials is investigated in four NSF centers/networks.

- The support for research in nanomanufacturing and Small Business Innovative Research has seen increases in funding and is helping industrial growth. More than 200 small businesses with a total budget of approximately $60 million have received support form NSF since 2001.

This growth is clearly demonstrated in three NSF nanomanufacturing centers, which will advance our ability to integrate reliable, cost effective manufacturing of nanoscale materials, structures, devices, and systems.

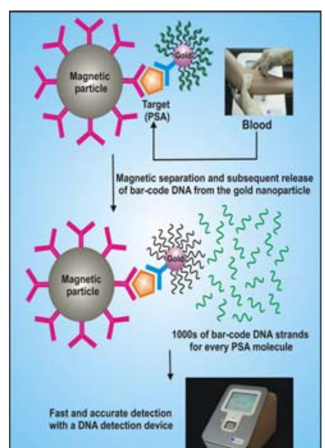
The NSF investment in nanotechnology is further leveraged and augmented through partnering among academic, industry, and state and local government organizations; today there are over 20 nanotechnology-related regional alliances and associations. An important example of this is the International Institute for Nanotechnology (IIN) at Northwestern University in Illinois. With support from NSF, NIH, DOE, and NASA, this institute has developed partnerships with the state of Illinois, the city of Chicago, and private foundations to create a new kind of science-and-technology-driven regional coalition. With $300 million in funding for nanotechnology research, educational programs, and infrastructure, IIN has established a large pre-competitive nanoscale science and engineering platform for developing applications, demonstrating manufacturability, and training skilled researchers.


Simulation of water moving through carbon nanotubes (Courtesy: Univ. Kentucky)

To conclude my remarks, let me quickly share with you two examples of how this fundamental academic research is paying off.

First, researchers at the University of Kentucky have predicted that membranes can be made from billions of aligned carbon nanotubes. The nanotubes have interiors that are nearly friction free, allowing some fluids to flow through them 100,000 times faster than we would normally expect. Filters based on these highly efficient nanotubes may one day contribute to the purification of products ranging from industrial chemicals and pharmaceuticals to dairy products.

Next, researchers at Northwestern University's Nanoscale Science and Engineering Center in Chicago have developed a rapid and simple test to both diagnose HIV infection in patients, and monitor disease progression. This nanotechnology approach is capable of detecting a protein associated with HIV at concentrations several orders of magnitude smaller than is possible with current technology.



Nano Bio-Bar-Code Assay (Courtesy: Northwestern University and spin-off Nanosphere, Inc.)

As you can see, even though we are just beginning to scratch the surface of this powerful new field of science and engineering, we have already witnessed remarkable achievements that promise great things to come.

The United States currently is the world leader in nanotechnology, and that offers tremendous advantages as the field grows and matures over the next decade. The current vision for the U.S. investment in nanotechnology has proven remarkably fruitful. We realize that nanoscale science and technology represent a major opportunity for the nation. It is a strategic area for NSF, and we seek your continued encouragement and support.

National Science Foundation
Nanotechnology Centers and Networks

Nanoscale Science and Engineering Centers (NSECs)	
Columbia University	Center for Electron Transport in Molecular Nanostructures
Cornell University	Center for Nanoscale Systems
Rensselaer Polytechnic Institute	Center for Directed Assembly of Nanostructures
Harvard University	Science for Nanoscale Systems and their Device Applications
Northwestern University	Institute for Nanotechnology
Rice University	Center for Biological and Environmental Nanotechnology
University of California, Los Angeles	Center for Scalable and Integrated Nanomanufacturing
University of Illinois at Urbana-Champaign	Center for Nanoscale Chemical, Electrical, Mechanical, and Manufacturing Systems
University of California at Berkeley	Center for Integrated Nanomechanical Systems
Northeastern University	Center for High Rate Nanomanufacturing
Ohio State University	Center for Affordable Nanoengineering
University of Pennsylvania	Center for Molecular Function at the Nanoscale
Stanford University	Center for Probing the Nanoscale
University of Wisconsin	Center for Templated Synthesis and Assembly at the Nanoscale
Arizona State University University of California, Santa Barbara University of Southern California Harvard University	Nanotechnology in Society Network
Centers from the Nanoscale Science and Engineering Education Solicitation	
Northwestern University	Nanotechnology Center for Learning and Teaching
Boston Museum of Science	Nanoscale Informal Science Education
NSF Networks and Centers that Complement the NSECs	
Cornell University	National Nanotechnology Infrastructure Network
Purdue University	Network for Computational Nanotechnology
Cornell University	STC: The Nanobiotechnology Center