



# National Science Foundation

## Nanotechnology at the National Science Foundation

### Indo-US Workshop Nanotechnology: Issues in Interdisciplinary Research and Education

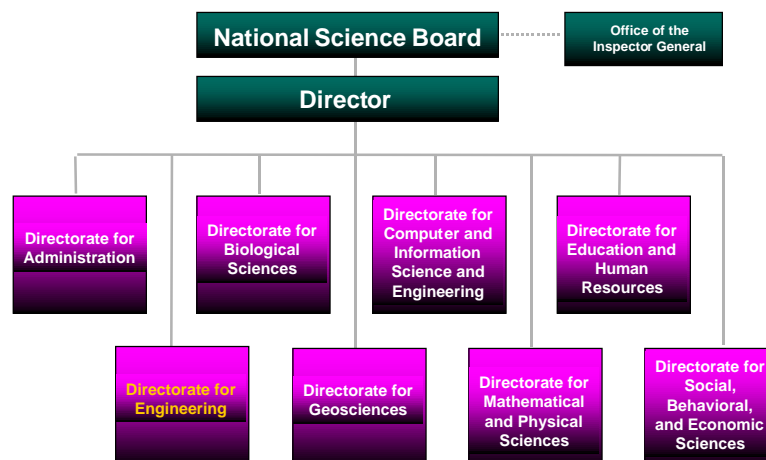
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# National Science Foundation



<http://www.nsf.gov>



## NSF Vision and Mission

- **Vision:** Enabling the Nation's future through discovery, learning, and innovation
- **Mission:** To promote the progress of science for the advancement of the national health, prosperity, and welfare
  - by supporting:
    - » Basic scientific and engineering research
    - » Programs to strengthen research potential
    - » Science and engineering education at all levels
    - » An information base for development of national and international policy



## NSF Strategies

- **Core Strategies**
  - Develop Intellectual Capital
  - Strengthen the Physical Infrastructure
  - Integrate Research and Education
  - Promote Partnership
- **Investment Strategies**
  - Strengthen Core Activities
  - Identify and Support Unmet Opportunities
  - Emphasize Thematic Areas
  - Broaden Participation and Enhance Diversity



## NSF Funding Modes

- Core Program (\$162M for FY 2004)
- Cross-cutting Programs
- Centers (\$14.5M)
- Initiatives (\$91M)
- Shared Facilities (\$16.8M)
- SBIR and STTR (\$10.0M)



## NSF Cross-cutting Programs

[www.nsf.gov/home/crssprgm/](http://www.nsf.gov/home/crssprgm/)

- ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers
- CAREER: Faculty Early Career Development Program
- EGB: Environmental Geochemistry and Biogeochemistry
- EPSCoR: Experimental Program to Stimulate Competitive Research
- ERE: Environmental Research and Education
- ESH: Earth System History
- GK-12: NSF Graduate Teaching Fellows in K-12 Education
- GOALI: Grant Opportunities for Academic Liaison with Industry
- Fellowships: Graduate, Post-doctorate
- IGERT: Integrative Graduate Education and Research Traineeships
- IOC: Innovation and Organizational Change
- ITW: Information Technology Workforce



## Centers

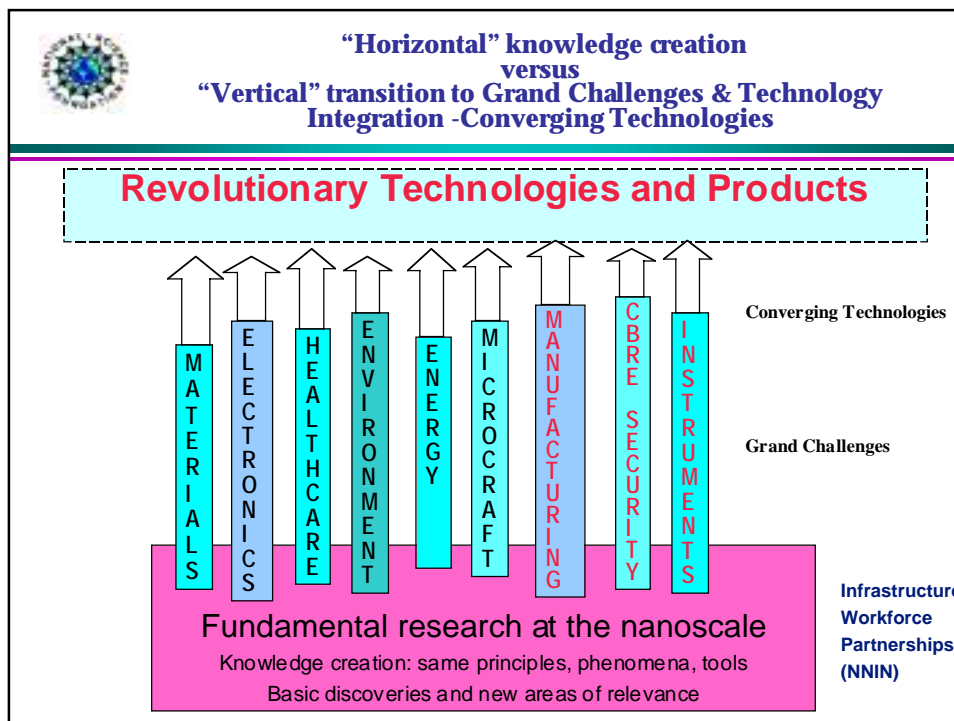
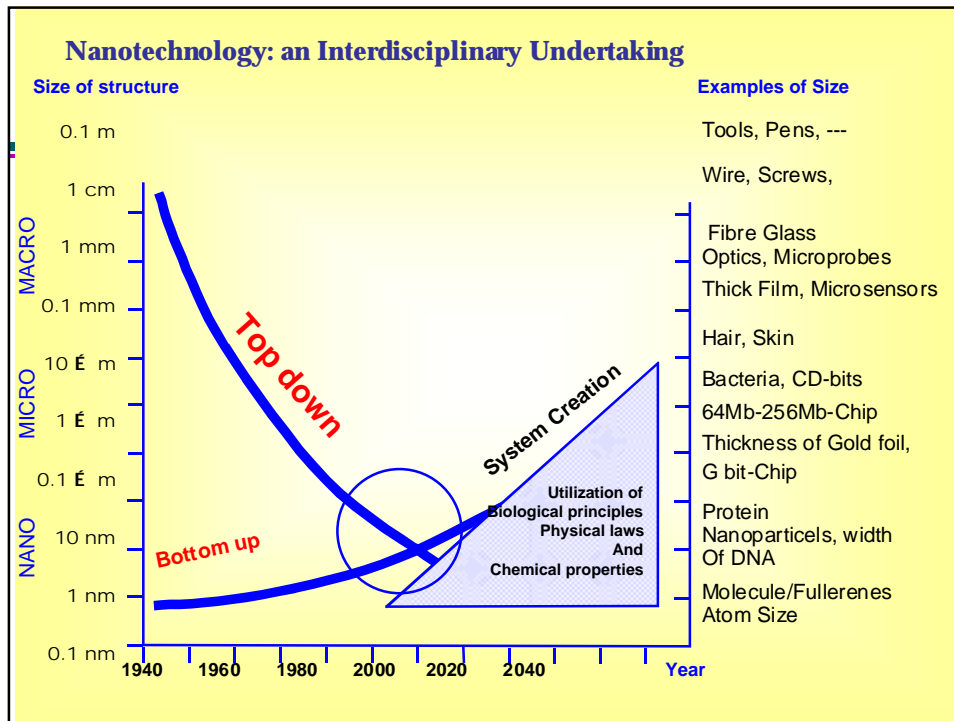
Investments that enable organizations to integrate people, ideas and tools on scales that are large enough to make an impact in cross-disciplinary areas

- Centers of Analysis and Synthesis
- Center for International Collaborations
- Chemistry Centers
- Earthquake Engineering Centers
- Engineering Research Centers
- Information Technology Centers
- Industry/University Cooperative Research Centers
- Long-term Ecological Research Sites
- Materials Research Science and Engineering Centers and Institutes
- Mathematical Sciences Research Institutes
- Nano Science and Engineering Centers
- Physics Centers
- Plant Genome Centers
- Science and Technology Centers
- Science of Learning Centers
- Social, Behavioral and Economic Sciences Centers
- Geosciences Centers



## NSF FY 2005 Budget Request (Priority Areas)

	Millions of Dollars	
	FY 2004	FY2005
Information Technology Research	\$303	NA
Nanoscale Science and Engineering	\$253	\$305
Workforce for the 21 <sup>st</sup> Century	n/a	\$20
Biocomplexity in the Environment	\$100	\$100
Mathematics Sciences	\$89	\$89
Human and Social Dynamics	\$24	\$23





## NSF Funding for FY 2000-05

Fiscal Years	Dollars in Millions
2000	\$97
2001	\$150
2002	\$204
2003	\$221
2004	\$249
2005(Req.)	\$305

103% Change from FY 2001-2005



## Nanoscale Science and Engineering (NSE)

### Research Themes:

- Biosystems at the Nanoscale
- Nanoscale Structures, Novel Phenomena, and Quantum Control
- Nanoscale Device and System Architecture
- Nanoscale Processes in the Environment
- Multi-Scale, Multi-Phenomena Theory, Modeling and Simulation at the Nanoscale
- Manufacturing Processes at the Nanoscale
- Societal and Educational Implications of Nanotechnology
- [Silicon Nanoelectronics and Beyond](#)

### Modes of support:

- Nanoscale Interdisciplinary Research Teams (NIRT)
- Nanoscale Science and Engineering Centers (NSEC)
- Nanoscale Exploratory Research (NER)

NSF 03-043 (\$79 M)



## ***NS&E Program Emphasis***

### **Nanoscale Interdisciplinary Research Teams (NIRT)**

- An Integrating Research Focus
- A Clearly Defined Team of three or more Investigators
- Components aimed at the Development of a skilled workforce and an informed public in NS&E

### **Nanoscale Exploratory Research (NER)**

- Exploratory, High-risk, High-quality NS&E Research
- Preliminary Feasibility work on Untested and Novel Ideas
- Ventures into Emerging, Far-reaching Ideas
- Application of New Expertise or New Approaches
- Efforts likely to Catalyze rapid and Innovative Advances



## ***NS&E Program Emphasis***

### **Nanoscale Science and Engineering Centers (NSEC)**

- Focus on one or a combination of the seven research and education themes in the NS&E program
- Will address opportunities that are too complex and multi-faceted for individuals or small group of researchers to tackle on their own
- Bring together researchers with diverse expertise-in partnership with industry, government laboratories, and/or partners from other sectors
- Will integrate research with education both internally and through a variety of partnership activities
- Will span the range from exploratory research-focused on discovery- to technology innovation, and will involve a broad spectrum of disciplines.



## Nanoscale Science and Engineering Centers in FY 2001 (1)

### *Six Centers awarded by NSF in September 2001*

- **Northwestern University**, Argonne National Lab, Harold Washington College; U. Illinois, Urbana-Champaign, U. Chicago, Chicago Museum of Science and Industry, Lawrence Livermore (NASA, Dupont, Exxon Mobil, Rohm and Hass, Motorola; IBM, Unilever)  
**Integrated Nanopatterning and Detection Technologies**  
(also, a complementary a DOD award)
- **Cornell University**, Brigham Young U., Colgate U., U. New Mexico, Pomona College  
**Nanoscale Systems in Information Technologies**
- **Harvard University**, MIT, Princeton, UC Santa Barbara, Boston Museum of Science, (Brookhaven National Lab; Oak Ridge National Lab; Sandia National Lab; Delft U., The Netherlands; U. Tokyo)  
**Science of Nanoscale Systems and their Device Applications**



## Nanoscale Science and Engineering Centers in FY 2001 (2)

- **Columbia University**, Barnard College, CUNY City College, Rowan University; (Lucent, IBM)  
**Electronic Transport in Molecular Nanostructures**
- **William Marsh Rice University**, Oak Ridge National Lab (TDA Research Inc.; Geosciences Environmental Lab, France)  
**Nanoscience in Biological and Environmental**  
(also, a complementary DOD award)
- **Rensselaer Polytechnic Institute**, U. Illinois, Urbana-Champaign, Los Alamos National Lab., Colleges: Morehouse, Mount Holyoke, Smith, Spelman, Williams, (Industry: ABB, Albany International, IBM, Eastman Kodak, Philip Morris, State of New York)  
**Directed Assembly of Nanostructures**

**Note: 20 new centers and networks supported by NNI since 2001 including 8 NSF, 4 DOE, 4 NASA and 4DOD**



## Nanoscale Science and Engineering Centers in FY 2003/2004

*Two New NS&E Centers awarded in September 2003 with Theme of Manufacturing Processes at the Nanoscale*

- University of California at Los Angeles with Stanford, UC Berkeley, UC San Diego, University of North Carolina at Charlotte and HP Labs.

Scalable and Integrated Nano Manufacturing Systems (SINAM) based on plasmonic imaging lithography, ultra-mold imprint lithography and field-assisted parallel nano- assembly for Optoelectronics

- University of Illinois, Urbana- Champaign with CALTECH, and NCAT

Nanoscale Chemical-Electrical-Mechanical manufacturing Systems (Nano-CEMMS) with a novel array of molecular gates dispensing reacting fluid in att-liter quantities to build photonic and bioelectronic systems and Sensors

- *Six new NSECS will be added in the fall of 2004*



## Nanoscale Instrumentation and Metrology (Challenges)

- Analysis of biomolecules and polymers ('soft')
- Measurements of large domains, as compared to the characteristic nanoscale feature
- The ability to precisely manipulate nanostructures
- Depth-dependent measurements
- The chemical identification at the nanoscale
- Measure multiple features and properties of a nanostructure with a single platform tool
- Metrology: - Standards to ensure reliability and repeatability  
- Standard reference materials
- Priorities: - 3-D measurements with high L and T resolution  
- Simultaneous measurements several properties  
- Instrumentation for properties not yet measured



## Education and Training

- **Integrated Research and Education - Make Every Lab a Place of Learning: looking for systemic changes**  
~ 6,000 students/2002, technicians, teachers, and faculty
- **Curriculum development**  
new courses, course modules, summer courses, 8 IGERT,  
  
NUE ~ 40 awards in FY 2003 K-12 education: systemic changes
- **All NSF centers have education and outreach programs from K-12 up; includes science museums**
- **International education opportunities**



## Nanoscale Science and Engineering (NSEE)

To produce systemic changes in Nanoscale Science and Engineering Education.

- **Centers for Learning and Teaching (NCLT):** Create educational leadership for nanotechnology education (doctoral programs representing collaborations of researchers in nanoscale science and engineering, education, and cognitive and behavioral sciences)
- **Informal Science Education (NISE):** Foster public awareness and understanding of nanoscale science and engineering through development of media projects (film, radio, television) and exhibits.
- **Instructional Materials Development (NIMD):** Support development of prototype instructional materials that promote student learning and interest in nanoscale science, engineering, and technology concepts for grades 7-12.
- **Nanotechnology Undergraduate Education (NUE):** Introduce nanoscale science and technology through a variety of interdisciplinary approaches into undergraduate education, particularly in the first two collegiate years.

NSF 03-044 (\$12M)



## **Broad Societal Implications** (examples of societal implications; estimations made in 2000)

- **Knowledge base:** better comprehension of nature, life
- **A new world of products: ~ \$1 trillion / year in 2010-2015**

- **Materials** beyond chemistry: **\$340B/y** (all estimations worldwide)
- **Electronics** **\$300B/y** for semiconductor industry; + integr. circuits
- **Pharmaceuticals** in 10-15 years: **\$180 B/y**
- **Chemical plants** in 10-15 years: **\$100B/y**
- **Aerospace** (about **\$70B/y** in 10 years)
- **Tools** (measurement, simulations) ~ **\$22 B/y**

Estimation in 2000: about **\$40B** for catalysts, GMR, materials, etc.

Estimation in 2002: about **\$116B** for materials, pharmaceuticals and chemicals (DB)

### **Would require worldwide ~ 2 million nanotech workers**

- **Improved healthcare:** extend life-span, its quality, human physical capabilities (~ **\$31B** in tools for healthcare in 10 years)
- **Sustainability:** agriculture, food, water, energy (~**\$45B/y** in 10 years), materials, environment; ex: lighting energy reduction ~ 10% or **\$100B/y**