Nanotechnology in the United States and National Science Foundation

National Science Foundation

November 6, 2008

NSF/WTEC benchmarking with experts in over 20 countries

"Nanostructure Science and Technology"

Book Springer, 1999

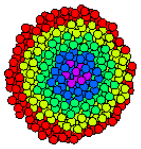
Nanotechnology

is the ***control and restructuring of matter*** at dimensions of roughly 1 to 100 nanometers

where new phenomena

enable new applications.

Four Generations of Products (200-2020): Timeline for beginning of industrial prototyping and nanotechnology commercialization



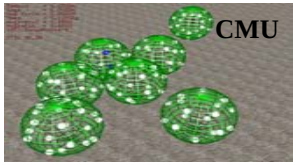
1st: Passive nanostructures (1st generation products)

Ex: coatings, nanoparticles, nanostructured metals, polymers, ceramics

~ 2000

2nd: Active nanostructures Ex: 3D transistors, amplifiers, targeted drugs, actuators, adaptive structures

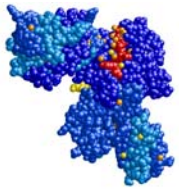
~ 2005



3rd: Systems of nanosystems

Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary

~ 2010



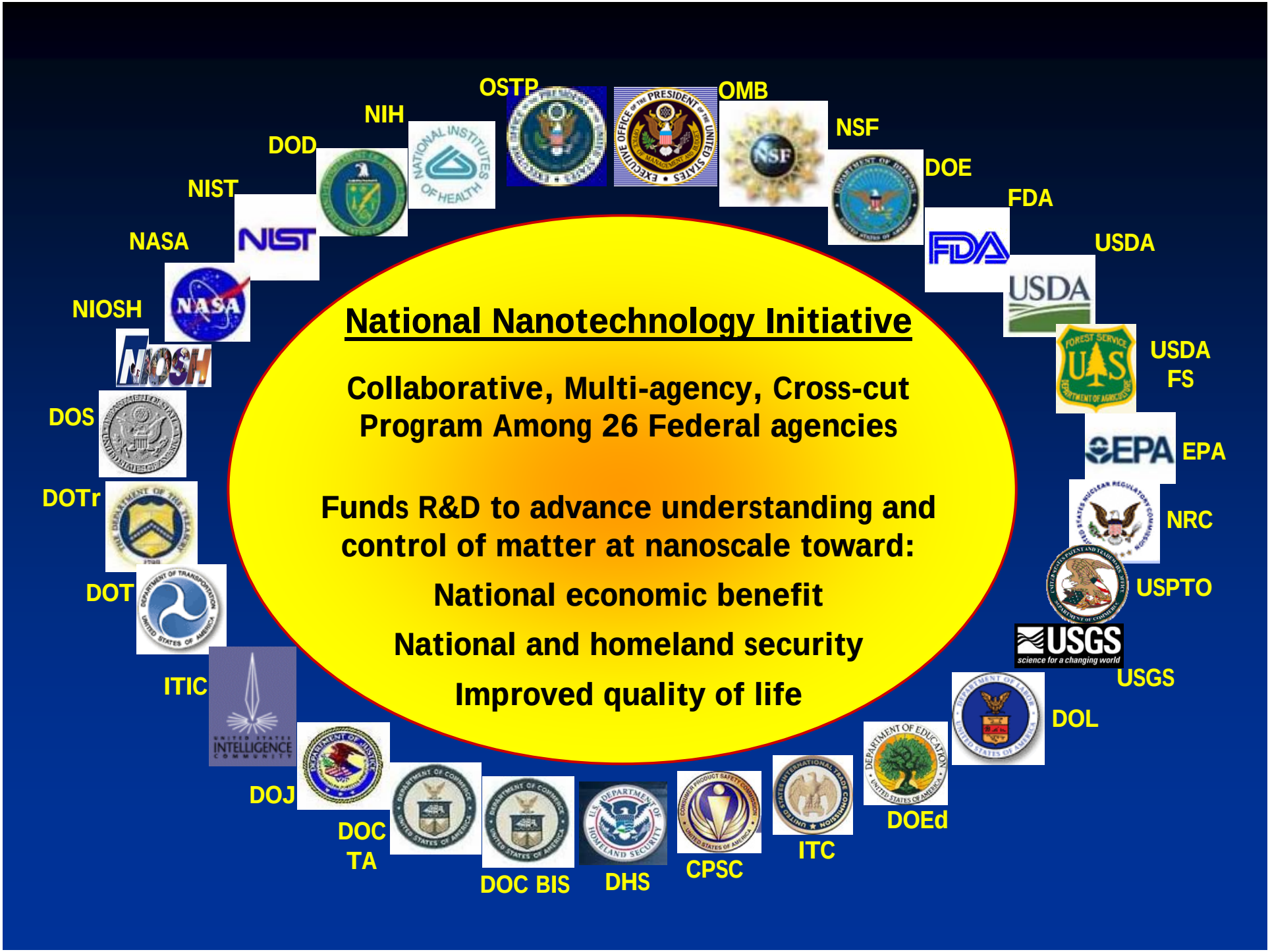
4th: Molecular nanosystems

Ex: molecular devices 'by design', atomic design, emerging functions

~ 2015-2020

New R&D challenges

AIChE Journal, 2004, Vol. 50 (5), M. Roco


National Nanotechnology Initiative
Collaborative, Multi-agency, Cross-cut Program Among 26 Federal agencies
Funds R&D to advance understanding and control of matter at nanoscale toward:
National economic benefit
National and homeland security
Improved quality of life
OSTP
OMB
NIH
NSF
DOD
DOE
NIST
FDA
NASA
USDA
NIOSH
USDA FS
DOS
EPA
DOTr
NRC
USPTO
DOT
USGS
ITIC
DOL
DOJ
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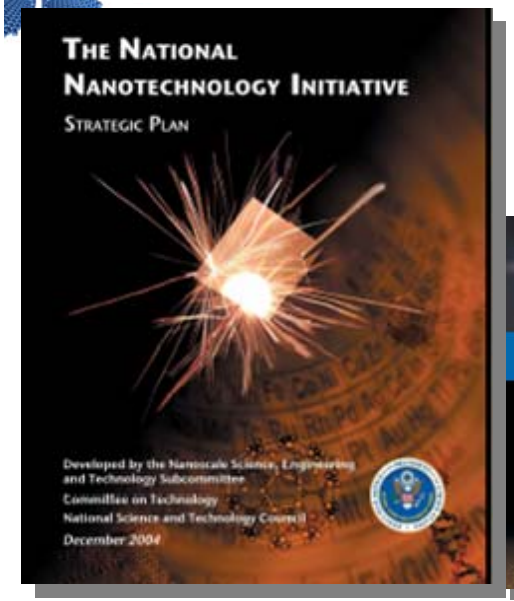
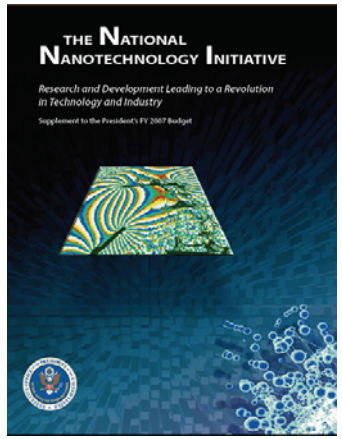
DOC TA
ITC
DOC BIS
DHS
CPSC

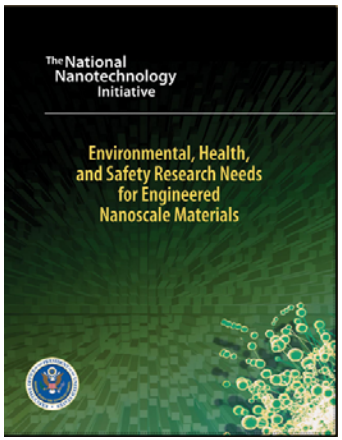
NATIONAL NANOTECHNOLOGY INITIATIVE

A sampling of NSET Subcommittee publications for second strategic plan (2006-2010)



Supplement to the President's FY 2007 Budget





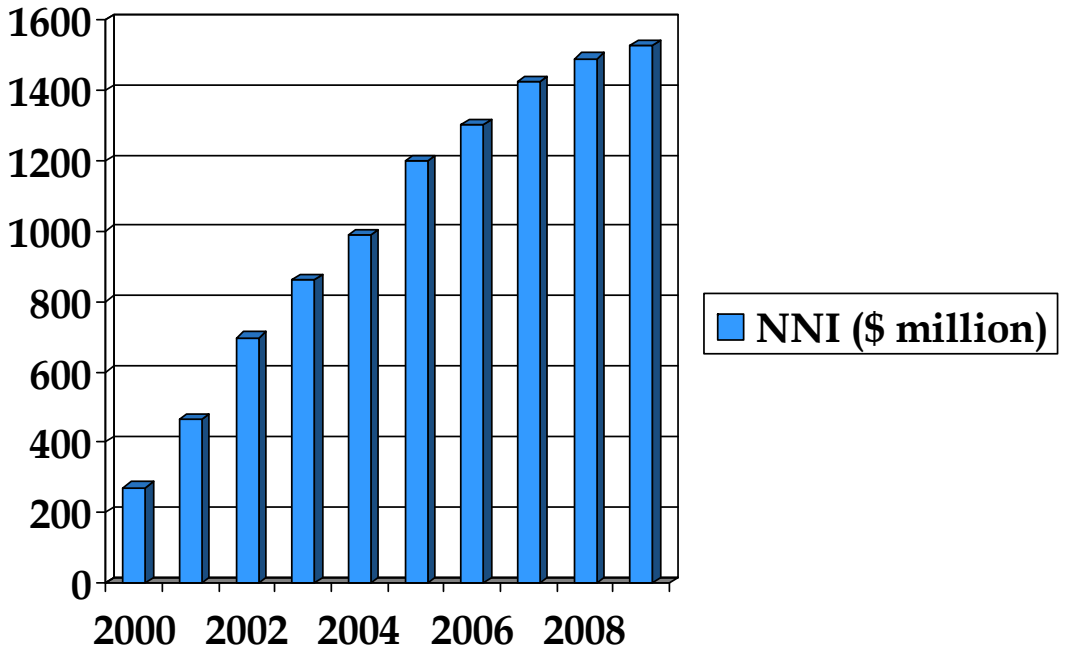
Environmental, Health, and Safety Research Needs

Changing national investment

FY 2009 NNI Budget Request - $1,527 million

M.C. Roco, NSF, 2008

Fiscal Year	NNI
2000	$270M
2001	$464M
2002	$697M
2003	$862M
2004	$989M
2005	$1,200M
2006	$1,303M
2007	$1,425M
2008	$1,491M
R 2009	$1,527M



EHS 2006: $38M (primary; $68M total eff.)
2007: $48M (primary; $86M total est.)
2008: $57M (primary; $102 total est.)
2009: $76M (primary - planned)

NNI / R&D ~ 1/4 of the world R&D

NNI / EHS ~ 1/2 of the world EHS R&D

National Nanotechnology Initiative activities at NSF in FY 2008

Actual budget : $389M

- **Program solicitations**
  - Nano-EHS with EPA and DOE
  - Nanotechnology Undergraduate Education (ENG and EHR)
- **Support in the "core" program with focus on single investigator & other core**

  Research and education programs in all directorates
  Interdisciplinary fellowships; NSEC, STC, MRSEC and ERC centers
  Instrumentation (REG, MRI); Collaboration industry (GOALI, PFI)
  Network for Computational Nanotechnology ($3.8M/yr)
  National Nanotechnology Infrastructure Network ($14M/yr)
  Nanoscale Informal Science and Education network
  Interagency collaborations: Manufacturing, Societal Implic., EHS
- **SBIR/STTR** (additional ~ $16M/year)

NSF Program Emphasis in FY 2008

Increased investments will be dedicated to research and education on:

- **Increased focus on complex large nanosystems.** Research on nanoscale devices and system architecture, dynamic and emerging behavior, and their respective fabrication, will be emphasized
- **Increased focused on three-dimensional measurements of domains of engineering relevance with good time resolution**
- **Converging science, engineering and technology from the nanoscale, by integrating nanosystems into applications** (in manufacturing, information systems, medicine, environment, etc.)
- **Expanded joint research program addressing societal implications of nanotechnology;** partner with NIOSH, EPA and FDA, USDA and NIST
- **Earlier educational programs and teaching materials**, including for K-12, by using remote access to NSF educational networks (NU, NISE, NNIN)
- **Expand partnerships of academic researchers with industry, medical facilities and states** through two programs (GOALI, PFI), using the CBAN (Collaborative Board for Advancing Nanotechnology)

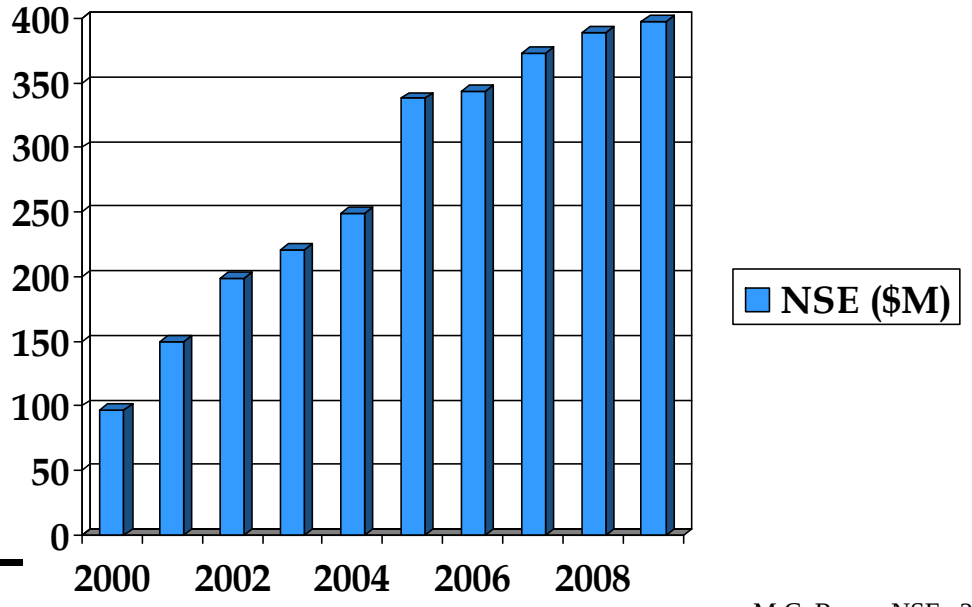
NSF – discovery, innovation and education in Nanoscale Science and Engineering (NSE)

www.nsf.gov/nano , www.nano.gov

FY 2009 Request: $397M ~1/4 of Federal and ~1/12 of World Investment

- Fundamental research - seven PCAs with new priorities
- Establishing the infrastructure - over 4,000 active projects; 24 large centers, 2 user facilities (NNIN, NCN), multidisciplinary teams
- Training and education – over 10,000 students and teachers/yr

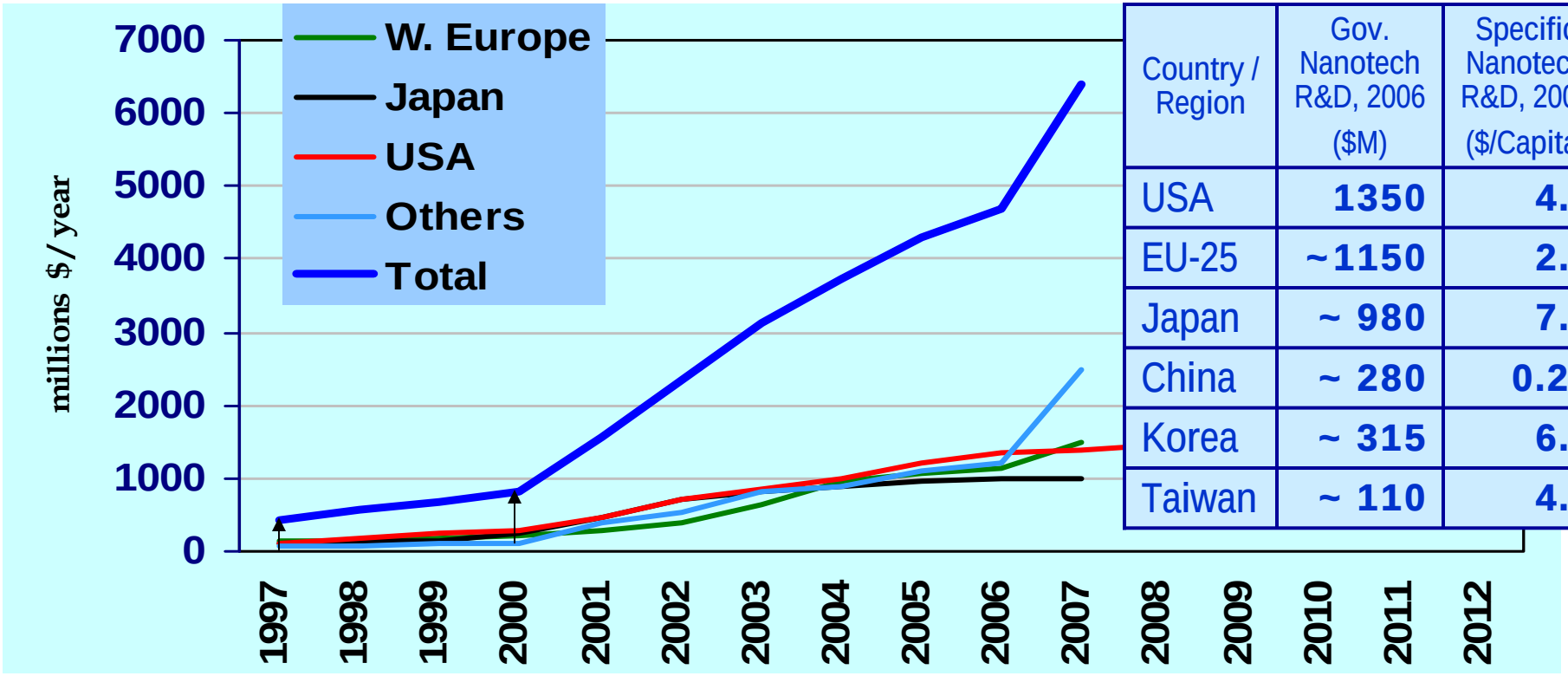
Fiscal Year	NSF
2000	$97M
2001	$150M
2002	$199M
2003	$221M
2004	$254M
2005	$338M
2006	$344M
2007	$373M
2008	$389M
R 2009	**$397M**



M.C. Roco, NSF, 2008

Context – Nanotechnology in the World

National government investments 1997-2006 (est. NSF)



Country / Region	Gov. Nanotech R&D, 2006 ($M)	Specific Nanotech R&D, 2006 ($/Capita)
USA	1350	4.5
EU-25	~1150	2.5
Japan	~ 980	7.6
China	~ 280	0.23
Korea	~ 315	6.5
Taiwan	~ 110	4.7

Seed funding (1991 -)

NNI Preparation (vision / benchmark)

1st Strategic Plan (passive nanostructures)

2nd Strategic Plan (active ns. & systems)

Industry R&D ($6B) has exceeded national government R&D ($4.6B) in 2006

J. Nanoparticle Research, 7(6), 2005, MC. Roco

NNI Networks and User Facilities

(over 80 centers established by NNI)

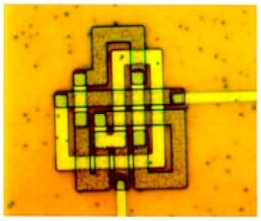
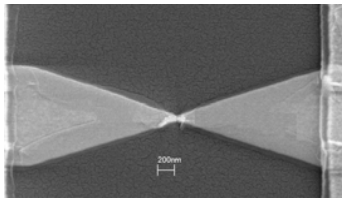
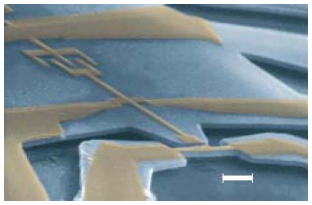
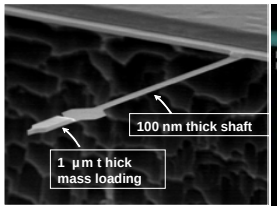
- NSF: eight networks with national goals and service in key areas of nanoscale science and engineering
- NIH: four networks for medical research, cancer, metrology
- DOE: one network with five large facilities
- NASA: one network of four centers on convergence
- DOD: three centers on nanoscale science and technology
- NIST: instrumentation and manufacturing user facility
- NIOSH: particle characterization center

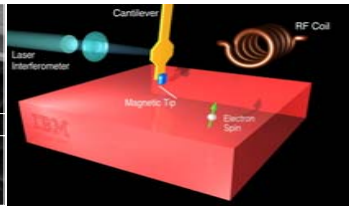
NSF Nanoscale S&E Centers

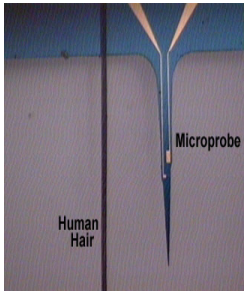
Nanoscale Science and Engineering Centers (NSEC)

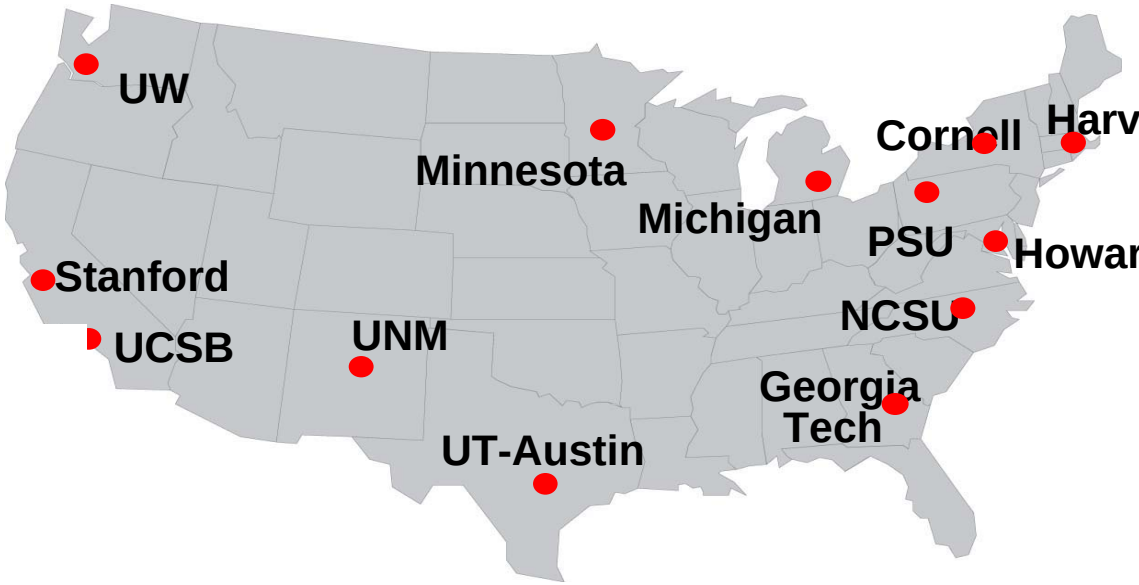
- **Electron Transport in Molecular Nanostructures, Columbia**
- **Nanoscale Systems, Cornell**
- **Directed Assembly of Nanostructures, RPI**
- **Science for Nanoscale Systems and their Device Applications, Harvard**
- **Institute for Nanotechnology, Northwestern**
- **Biological and Environmental Nanotechnology, Rice**
- **Scalable and Integrated Nanomanufacturing, UCLA**
- **Nanoscale Chem-Electr-Mechanical Manufacturing, U Illinois-Urbana Champ.**
- **Integrated Nanomechanical Systems, UC Berkeley**
- **High Rate Nanomanufacturing, Northeastern**
- **Affordable Nanoengineering, Ohio State**
- **Molecular Function at the Nanoscale, U Pennsylvania**
- **Probing the Nanoscale, Stanford**
- **Templated Synthesis and Assembly at the Nanoscale, U Wisconsin**
- **Nanotechnology in Society Network, ASU, UCSB, U South Carolina, Harvard**
- **Network for Hierarchical Manufacturing, U Mass-Amherst**
- **The Nanobiotechnology Science and Technology Center, Cornell**

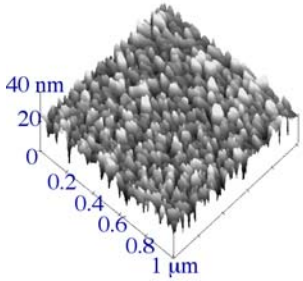
National Nanotechnology Infrastructure Network (NNIN)









Cornell U (Lead)
Stanford U
U Michigan
Georgia Tech
U Washington
Penn State U
UC Santa Barbara
U Minnesota
U New Mexico
U Texas –Austin
Harvard U
Howard U
No. Carolina State U

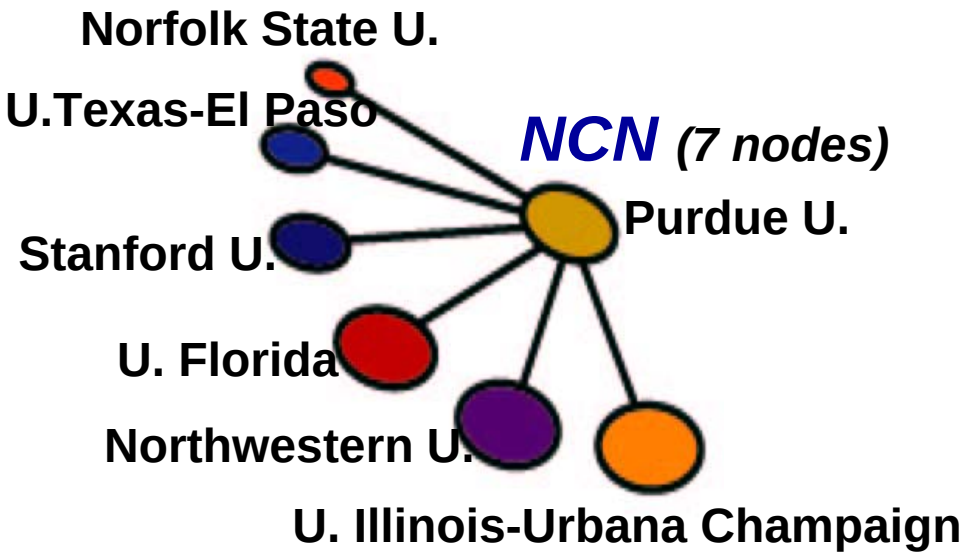
An integrated national network of user facilities providing researchers open access to resources, instrumentation and expertise in all domains of nanoscale science, engineering and technology

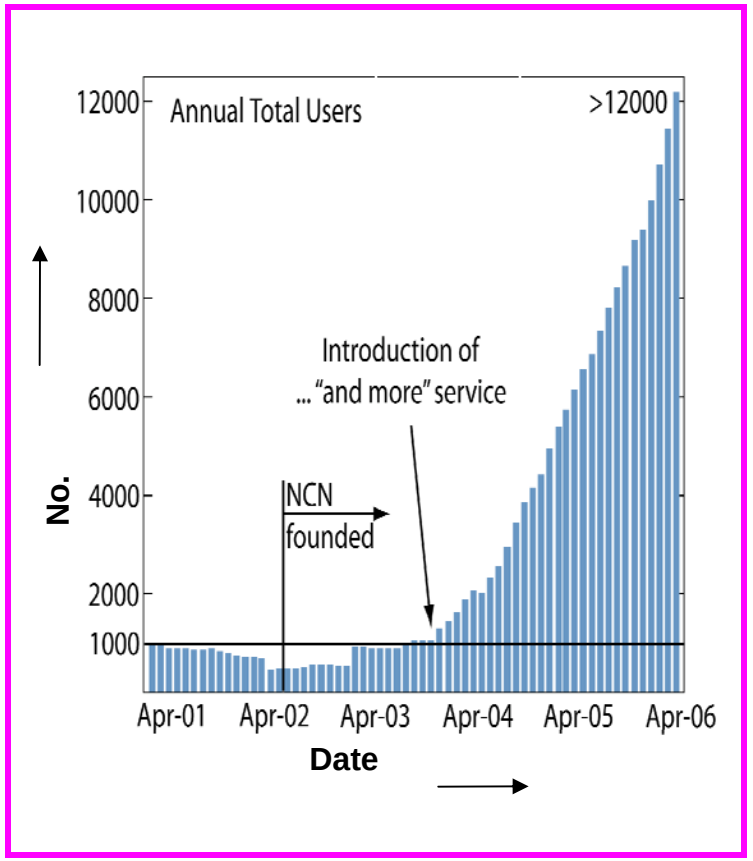
http://www.NNIN.org; Est. 4,000 users in 2006, NSF 3,500/ user

MC Roco, 12/12/07

Network for Computational Nanotechnology

A national resource for research, education and user-facility to accelerate the transformation of nanoscience to nanotechnology through theory, modeling, and simulation and collaboration enabled by cyberinfrastructure





Focus: "from atoms to systems";
"same equations for various applications"

http://www.nanoHUB.org

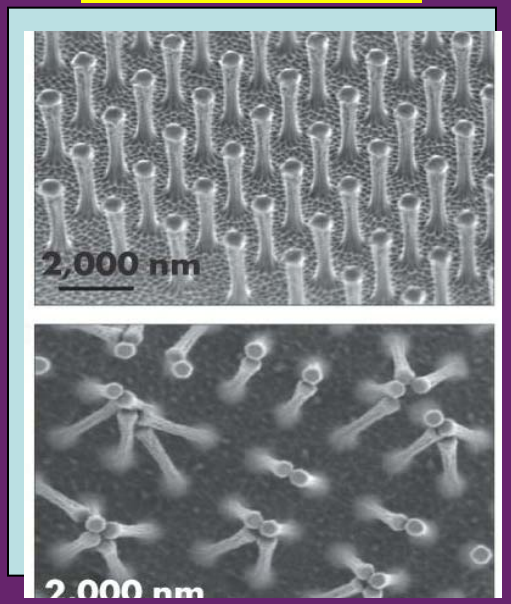
Est. 12,000 users / 2006; NSF $350 / user

National Nanomanufacturing Network

- Four NSECs (NSF)
  - Center for Scalable and Integrated Nanomanufacturing, UCLA (2004-
  - Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems, University of Illinois at Urbana-Champagne (2005-)
  - Center for High Rate Nanomanufacturing, Northeastern University (2005-)
  - Network for Hierarchical Manufacturing U. Mass. - Amherst (2006-) (Main Node)
- DOD, MURI centers
- NIST, Laboratory for Nanoscale Science and Technology

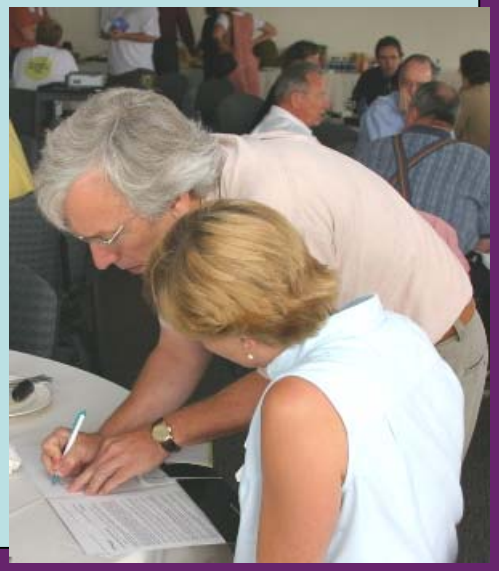
Nanotechnology Informal Science Education Network

Center for NISE Research
Exploratorium San Francisco



- **Visualization Lab**
- **Resource Center**
- **Research and Evaluation**
- **Professional Development**
- **Public Website**

Center for Public Engagement
Museum of Science Boston



- **Network Media**
- **Forums**
- **Network Administration**

Center for Exhibits & Programs
Science Museum of Minnesota

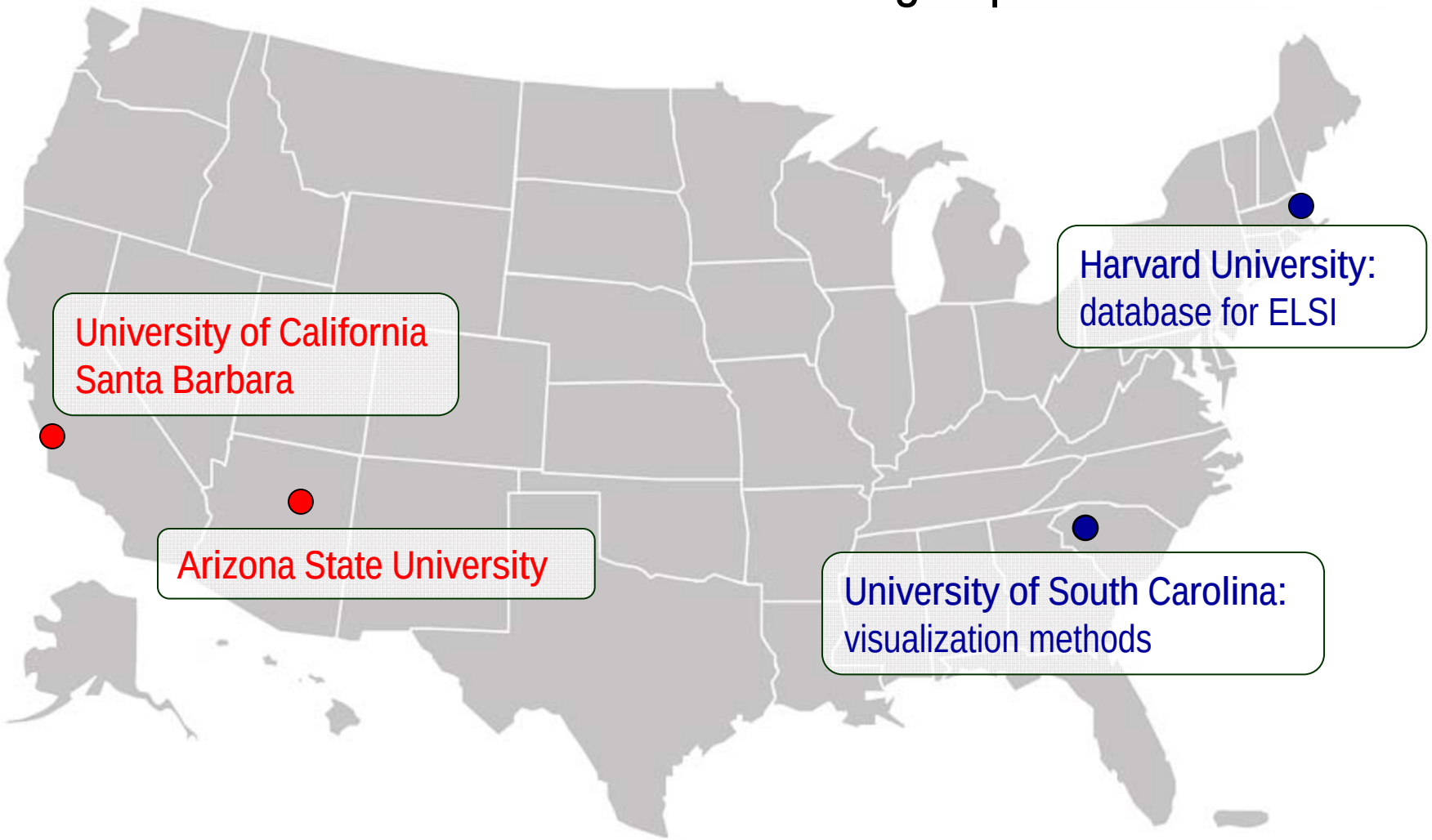
- **Exhibit and Program Packages**

To create 100 science museum sites in U.S. by 2010

NSEC: Nanotechnology in Society

Four nodes established in September 2005:

● 2 centers and ● 2 small-groups



To address Ethical, Legal and other Social Issues related to Nanotechnology

DOE: Construction is complete and initial operations are underway at four NSRCs

Center for Nanoscale Materials (Argonne National Laboratory)

Center for Functional Nanomaterials (Brookhaven National Laboratory)

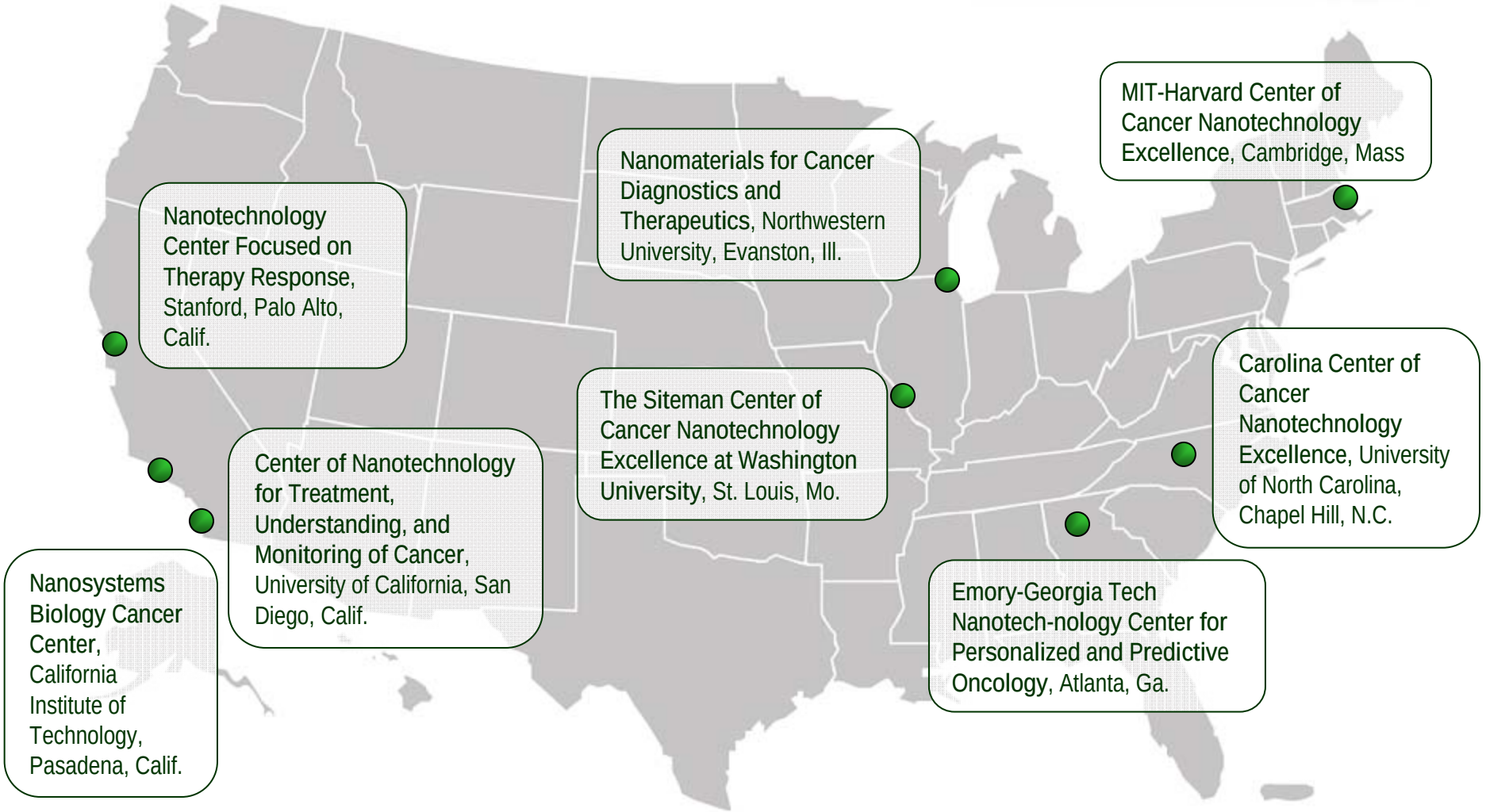
Molecular Foundry (Lawrence Berkeley National Laboratory)

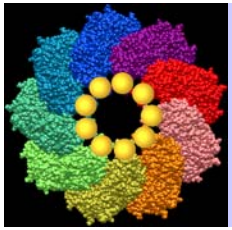
Center for Nanophase Materials Sciences (Oak Ridge National Laboratory)

Center for Integrated Nanotechnologies (Sandia & Los Alamos National Labs)

Cancer Centers of Nanotechnology Excellence (8 established in October 2005)

NCI Alliance for Nanotechnology in Cancer





Several NNI Accomplishments

- Developed foundational knowledge for control of matter at the nanoscale:
  over 4,000 active projects in > 500 universities, private sector institutions and gov. labs in all 50 states
- "Created an interdisciplinary nanotechnology community" [1]
- R&D / Innovation Results: With ~25% of global government investments, the U.S. accounts worldwide for
  - ~ 50% of highly cited papers,
  - ~ 60% of USPTO patents[2], and
  - ~70% of startups[3] in nanotech.
    Over 2,000 companies with nanotechnology products in 2006 (U.S.)
- Infrastructure:
  80 new large nanotechnology research centers, networks and user facilities; about 30,000 users in 2 academic-based networks

([1]) NSF Committee of Visitors, 2004; ([2]) Journal of Nanoparticle Research, 2004; ([3]) NanoBusiness Alliance, 2004

U.S. International partnerships for Nanotechnology

- Nanotechnology included in bilateral (e.g. U.S.- Japan, EU, India, etc.), and international organizations (e.g. OECD, APEC, etc.) S&T agreements
- Typical NSF activities
  - Bottom-up by individual partnerships in research
  - Periodical NanoForums (annual); other workshops
  - Using networks: NNIN / NCN and partner networks / facilities
  - Young scientists exchange programs
- Areas and modes of increased collaboration:

  - fundamental knowledge (precompetitive) - *by twinning and networking*
  - education - *by visits, int. courses, books, int. accreditation, study institutes*
  - broad societal implications: health, environment, energy, water filtration, ethics - exchanges
  - contribute to international S&T "grand challenges"
  - industry partnerships, precompetitive nanotechnology platforms

US NSF - Nanoscale Science and Engineering - NSF ACTIVITIES, Solicitations and Their Outcomes - Microsoft I...

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WHERE DISCOVERIES BEGIN

www.nsf.gov/nano
or link www.nano.gov

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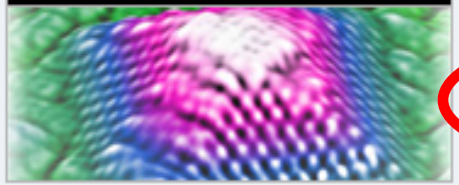
NNI



Solicitations & Outcomes

New Items

Activities

Program Reviews

NSF & NNI Symposia

NSF & NNI Reports

NSF & NNI Reports

Links to Related Reports

NNI Endorsements

NNI Presentations

NSF National Nanotechnology Initiative (NNI)

Search for NSF awards by keywords
(go to the "Full text search", and complete the box with your keywords; Examples of keywords are nano*, selfassembl* and nanoparticle)

NSF press releases on Nanotechnology Research since January 2004

NSF press releases on Nanotechnology Research from 2003 to 2001

SOLICITATIONS AND OUTCOMES IN FY 2005

NSF Announcement 05-543: Nanoscale Science and Engineering Education (NSEE)
"Preparation workshop: Public Engagement in Nanoscale Science and Engineering"(PDF, 776KB)

NSF Announcement 04-043: Nanoscale Science and Engineering (NSE)
NSEC on "Nanotechnology in Society" workshop

Joint EPA-NSF-NIOSH solicitation for research in Environmental and Human Health Effects of Manufactured Nanomaterials