

Industry-university-government partnerships in nanotechnology

Mike Roco

NSF, NNI

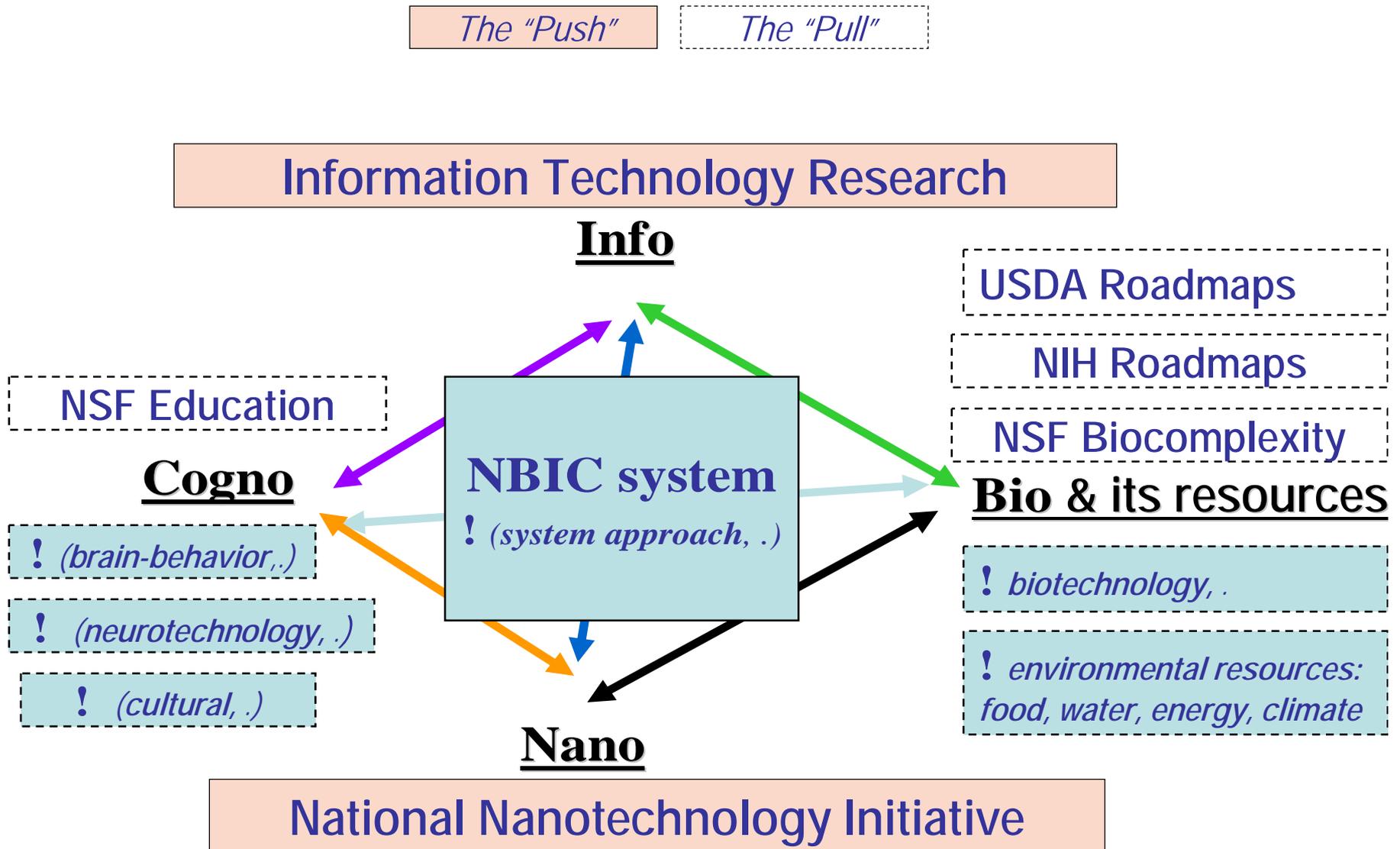
RSL Initiatives in Nanotechnology, Oklahoma City, April 2, 2009

Context: A transforming word underlying the importance of nanotechnology

- Knowledge has exponential growth, and so the potential of emerging technologies
- Education, science and technology shift in content, numbers and societal importance
- Last decade trend: transfer of wealth from "West to East"
- Demographics of discord: growing, declining, diversifying at once
- Earth resources limited: need of radically new technologies
- Governance: chances for collaboration and conflict

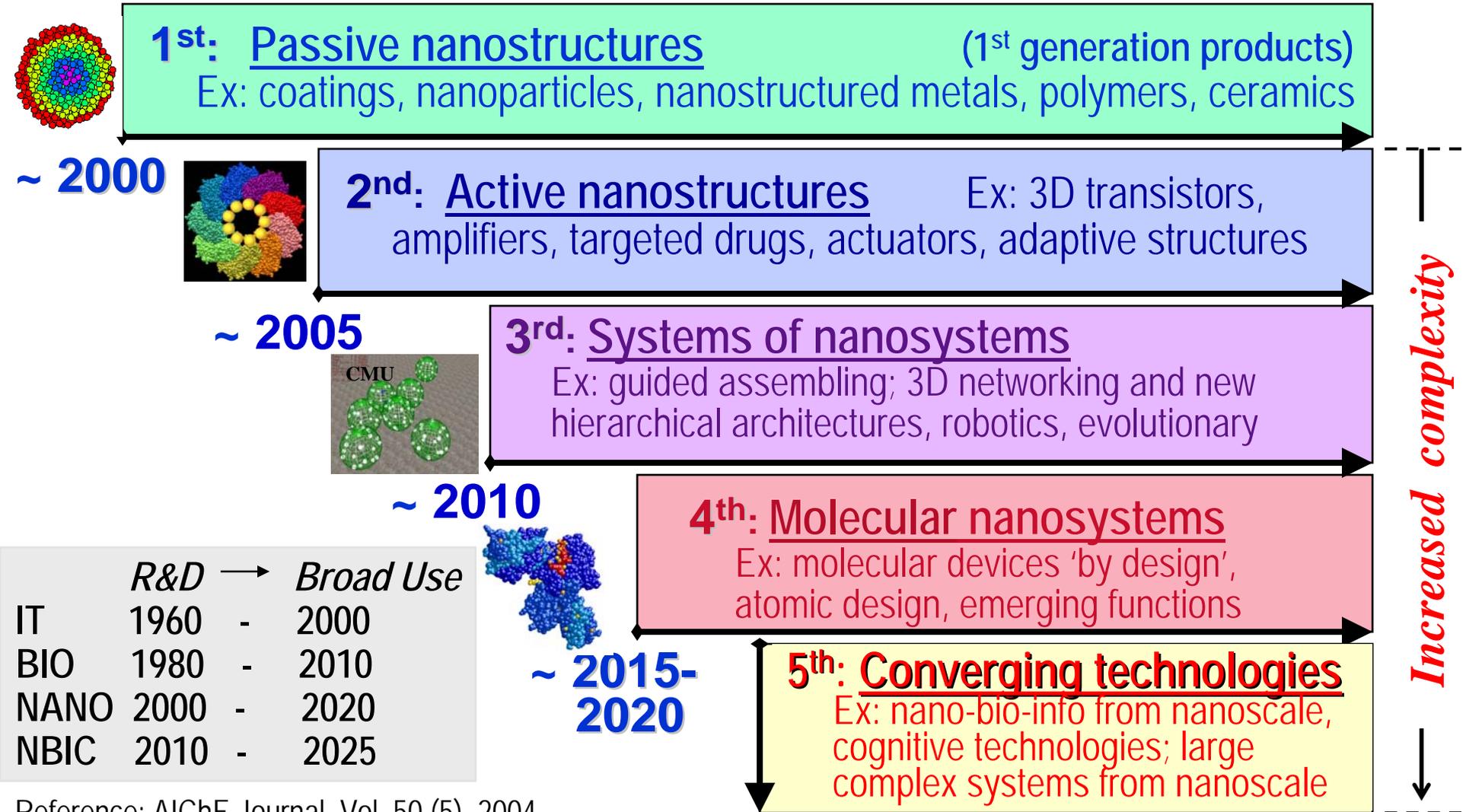
Converging New Technologies transforming tools

(overview in 2000)



Five Generations of Products and Productive Processes after the level the complexity, dynamic behavior and transdisciplinarity

Timeline for beginning of industrial prototyping and NT commercialization



Nanotechnology in 2008, still in an earlier formative phase of development

- Characterization of nanomodules is using micro parameters and not internal structure
- Measurements and simulations of a domain of biological or engineering relevance cannot be done with atomic precision and time resolution of chemical reactions
- Manufacturing Processes – empirical, synthesis by trial and error, some control only for one chemical component and in steady state
- Nanotechnology products are using only rudimentary nanostructures (dispersions in catalysts, layers in electronics) incorporated in existing products or systems
- Knowledge for risk governance – in formation

Governance of nanotechnology development

A. TRANSFORMATIVE

Results oriented investment and S&T policy, support innovation & informatics, pipeline in education, technology integration

B. RESPONSIBLE DEVELOPMENT

EHS, ELSI+, methods for risk governance, communication & participation, voluntary measures

C. INCLUSIVE and COLLABORATIVE

RLS initiatives, building national capacity, multi-sector partnerships, international capacity and leveraging

D. VISIONARY

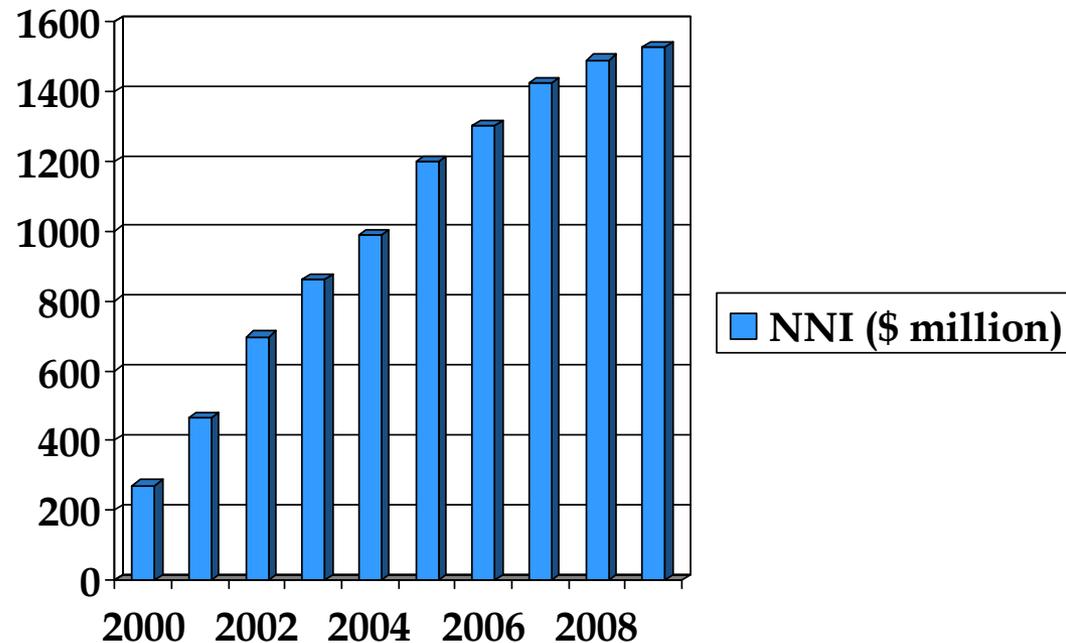
Long-term and global view in planning & investment, human development/progress

National investment

FY 2009 NNI Budget - \$1,527 million

M.C. Roco, NSF, 2009

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
2009	\$1,527M



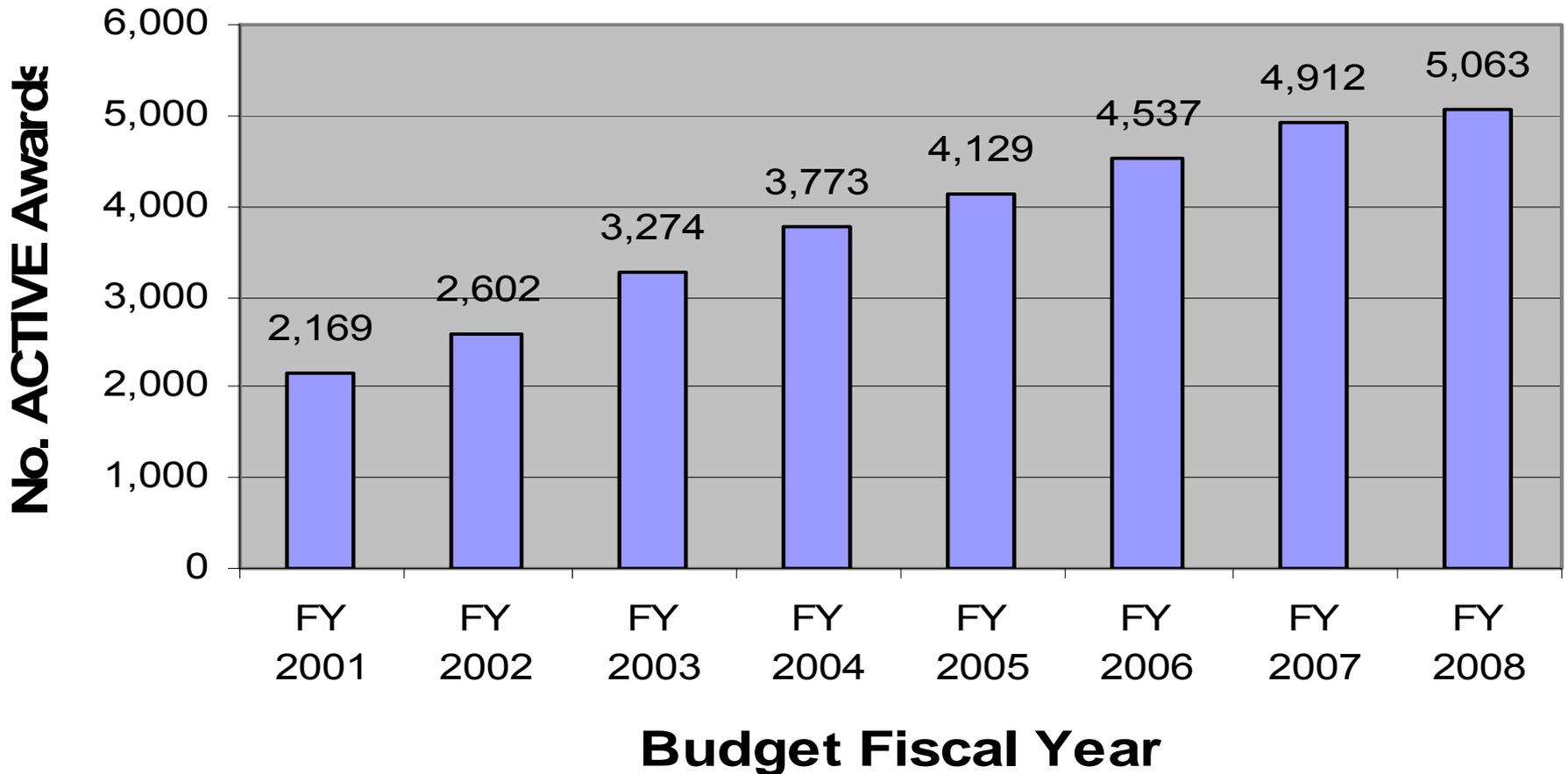
EHS 2006: \$38M - primary; \$68M total eff.
2007: \$48M - primary; \$86M total est.
2008: \$57M - primary; \$102 total est.
2009: \$76M - primary planned

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

Planned 2009 Agency Investments by Program Component Area (dollars in millions)

AGENCY	Fundamental Phenomena & Processes	Nano-materials	Nanoscale Devices & Systems	Instr. Research, Metrology, & Standards	Nano-manufacturing	Major Research Facilities & Instr. Acquisition	Environment, Health, and Safety	Education & Societal Dimensions	NNI Total*
DOD	227.8	55.2	107.7	3.6	12.8	22.1	1.8		431.0
NSF	141.7	62.5	51.6	16.0	26.9	32.1	30.6	35.5	396.9
DOE	96.9	63.5	8.1	32.0	6.0	101.2	3.0	0.5	311.2
DHHS (NIH)	55.5	25.4	125.8	5.9	0.8		7.7	4.6	225.7
DOC (NIST)	24.5	8.5	22.7	20.9	15.3	5.7	12.8		110.4
NASA	1.2	9.8	7.7			0.2	0.1		19.0
EPA	0.2	0.2	0.2				14.3		14.9
DHHS (NIOSH)							6.0		6.0
USDA (FS)	1.7	1.3	0.7	1.1	0.2				5.0
USDA (CSREES)	0.4	0.8	1.5		0.1		0.1	0.1	3.0
DOJ				2.0					2.0
DHS			1.0						1.0
DOT (FHWA)	0.9								0.9
TOTAL*	550.0	227.0	227.0	91.5	62.1	141.2	74.4	49.7	1527.9

NSF illustration: Number of ACTIVE NS&E awards by year (FY 2001 - FY2008)

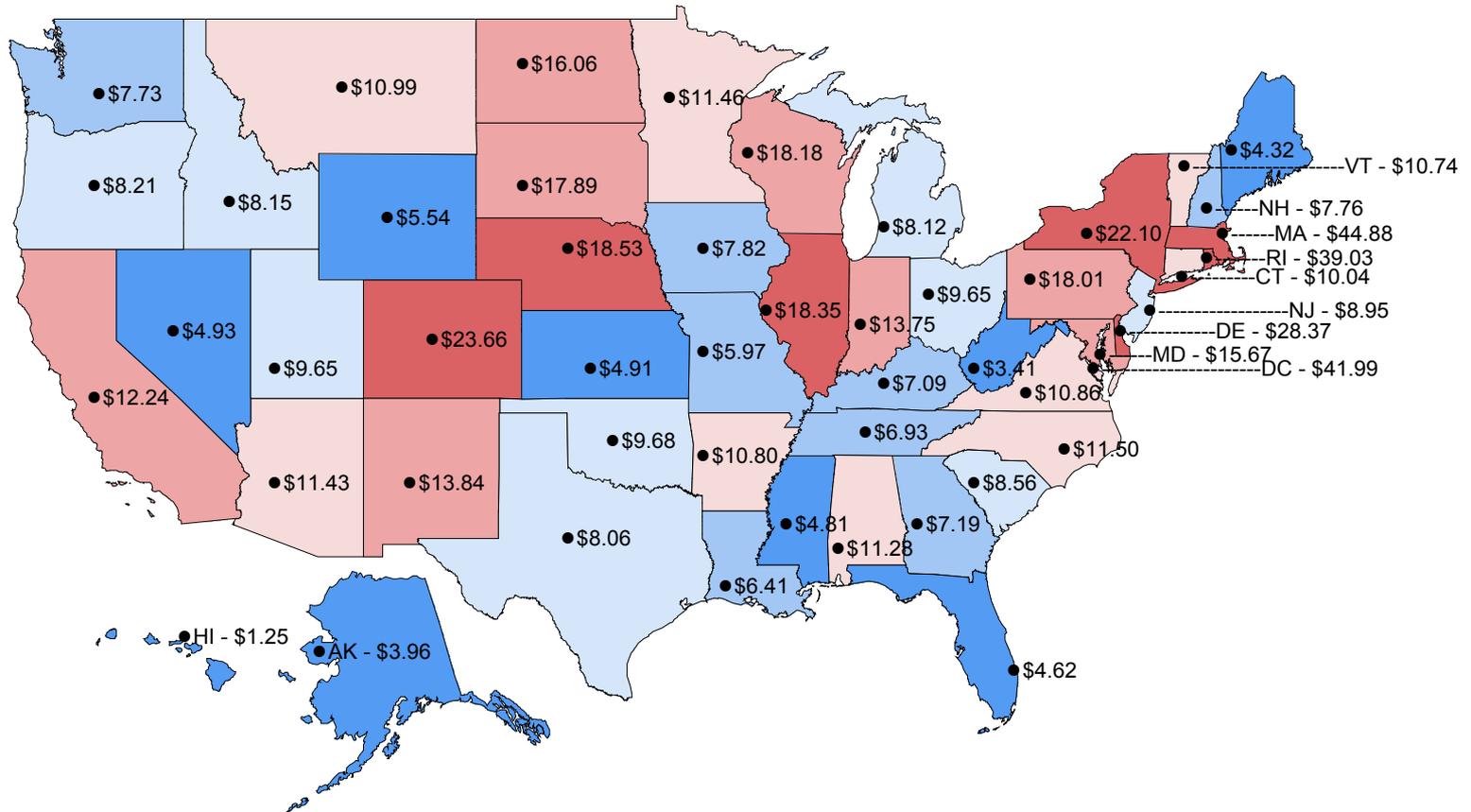


M.C. Roco, 4/2/2009

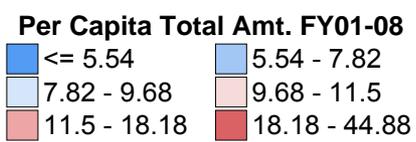
\$397 M in FY 2009 NSF budget for discovery, innovation and education
\$108 M additional funding from ARRA (stimulus) fund in FYs 2009-2010

Per Capita Total Amount for NS&E Awards (NEW and ACTIVE)

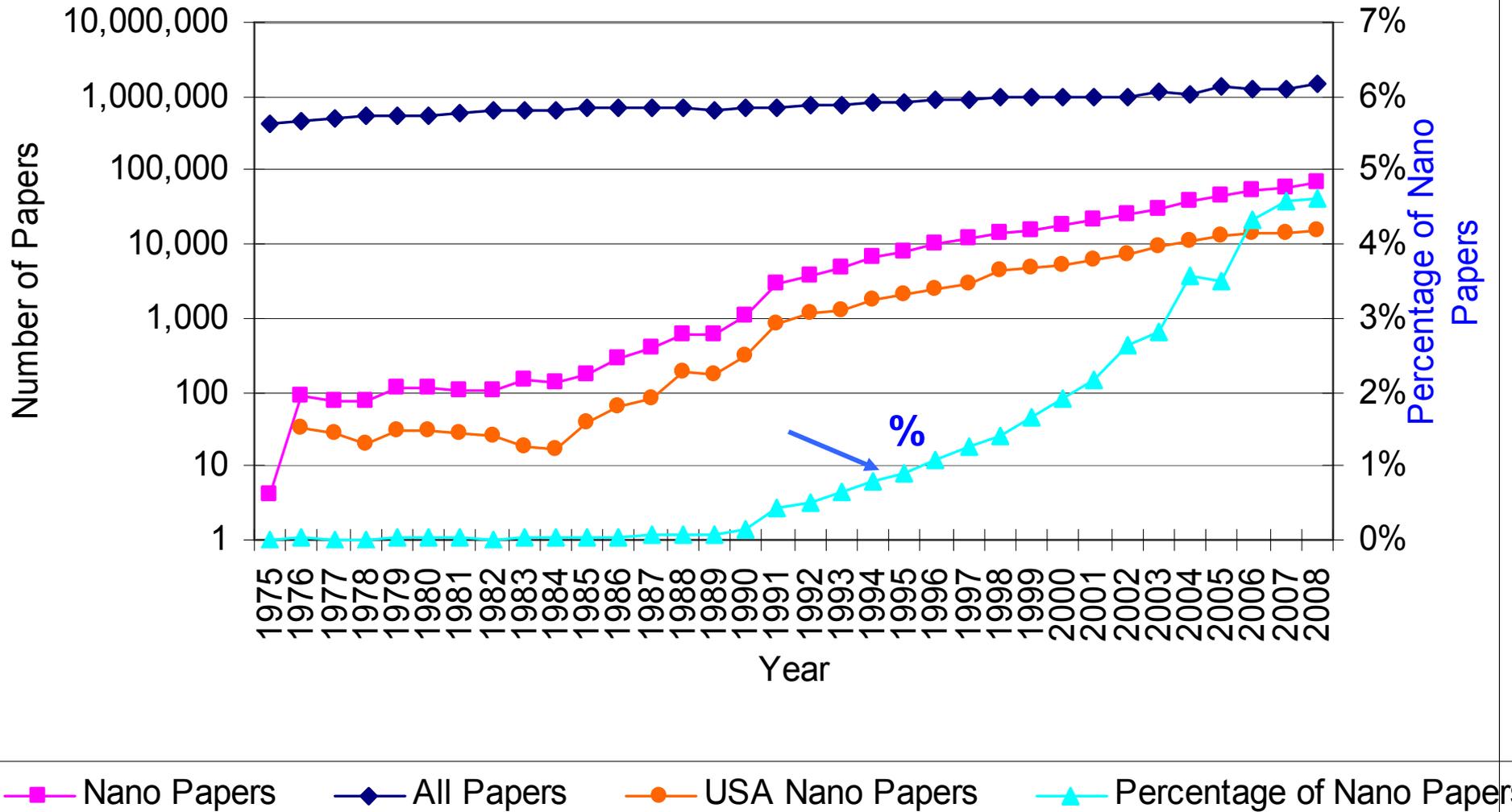
FY 2001 – 2008



AK - \$3.96; AL - \$11.28; AR - \$10.8; AZ - \$11.43; CA - \$12.24; CO - \$23.66; CT - \$10.04; DC - \$41.99; DE - \$28.37; FL - \$4.62; GA - \$7.19; HI - \$1.25; IA - \$7.82; ID - \$8.15; IL - \$18.35; IN - \$13.75; KS - \$4.91; KY - \$7.09; LA - \$6.41; MA - \$44.88; MD - \$15.67; ME - \$4.32; MI - \$8.12; MN - \$11.46; MO - \$5.97; MS - \$4.81; MT - \$10.99; NC - \$11.50; ND - \$16.06; NE - \$18.53; NH - \$7.76; NJ - \$8.95; NM - \$13.84; NV - \$4.93; NY - \$22.10; OH - \$9.65; OK - \$9.68; OR - \$8.21; PA - \$18.01; PR - \$4.56; RI - \$39.03; SC - \$8.56; SD - \$17.89; TN - \$6.93; TX - \$8.06; UT - \$9.65; VA - \$10.86; VT - \$10.74; WA - \$7.73; WI - \$18.18; WV - \$3.41; WY - \$5.54

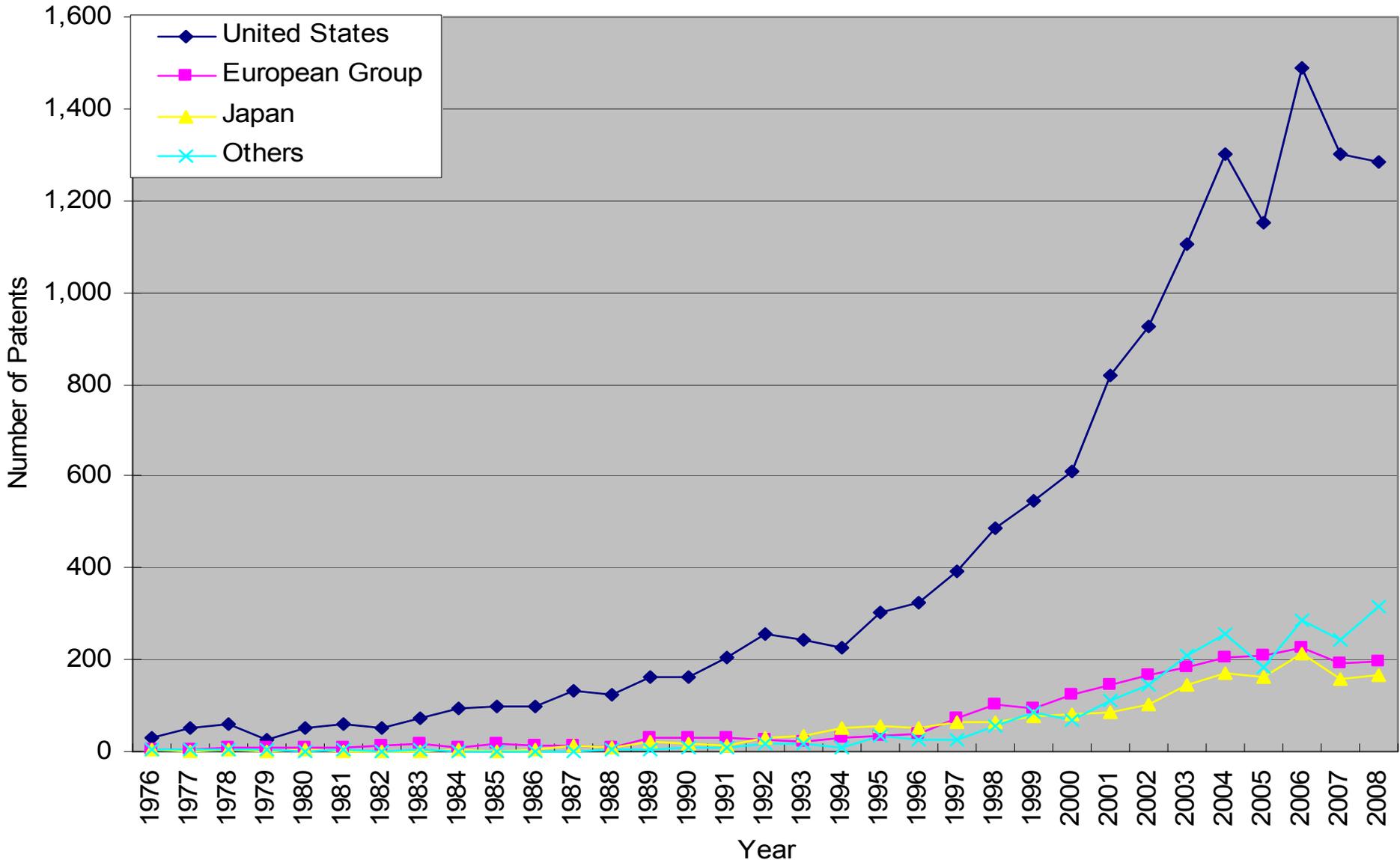


SCI Paper Publications



Keyword title-abstract search (M. Roco, H.C. Chen and X. Lin, 2009)

Nanotechnology patents in USPTO (1976-2008)



The data for 2008 are still preliminary because USPTO has not finalized its data for that year
Keyword "title-claims" search (M. Roco, H.C. Chen and X. Lin, 2009)

Long-term number of citations of Nanoscale Science and Engineering patents

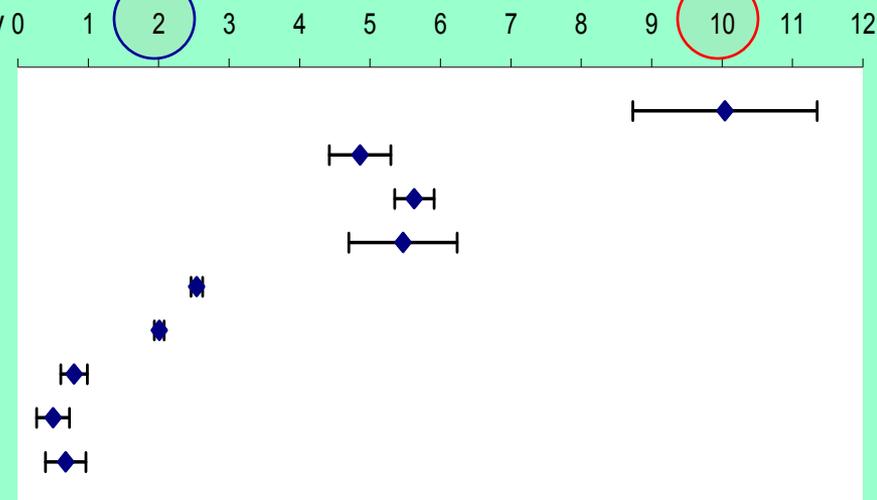
(analysis NSF sponsored research and USPTO patents)

Entire set average

NSF P.I.s

95% CIs based on pooled StDev

Group	N	Mean	StDev	Lower	Upper
NSF	307	10.04	23.6	8.731	11.349
IBM	2756	4.86	15.7	4.423	5.297
Top10	6650	5.63	22.38	5.349	5.911
UC	894	5.47	29.59	4.703	6.237
US	78227	2.54	12.29	2.458	2.622
EntireSet	108378	2.01	10.94	1.940	2.080
Japan	14837	0.8	7.89	0.612	0.988
European	9560	0.5	4.99	0.265	0.735
Others	6385	0.68	6.64	0.393	0.967



Pooled StDev = 11.70

NSF Principal Investigator's patents had significantly higher number of cites measure than most other comparison groups (1976-2006). It shows the relevance of fundamental research for nanotechnology development.

(source: NSF sponsored research)

Nanomanufacturing, Industry Liaison, and Innovation (NILI) Working Group

- **Purpose:** to advance and accelerate the creation of new products and manufacturing processes derived from discovery at the nanoscale.
- **Goals:**
 1. Facilitate nanotechnology innovation, nanomanufacturing advancement, and technology transfer in and by Federal agencies
 2. Exchange information and stimulate interactions relating to nano among Federal agencies, academe, industry, professional societies, and State and local organizations
 3. Create innovative methods for transferring technology to industry

A survey of federal agencies on these three topics will be placed on the RSL website

1. What mechanisms or programs federal agencies offer to facilitate innovation and advance nanomanufacturing?

A. Create foundation *(presentations by agency in panels)*

- **Support R&D to create the technology base** ~ 6,000 active projects
Ex: Nanomanufacturing programs at NSF, NIST and DOD; MARCO net \$1,17 million in FY 2009 Plan for fundamentals to nanomanufacturing
- **Infrastructure for instrumentation, tools, labs** ~ 80 centers & networks
Ex.: 5 DOE labs; NSF's NNIN and NCN; over 70 centers and networks; NCI; NIST metrology and standards; NSF instrumentation program \$243 million in FY 2009 Plan for instrumentation, standards, and major research facilities
- **Support research and regulatory system for nano-EHS**
Ex: EPA, NIEHS research, 3 NSF centers (2CEINs, CBEN), FDA \$76.4 million in FY 2009 Plan for nano EHS R&D
- **Prepare the workforce at all levels, and public** ~ 10,000 students /yr
Ex: NCLT; NISE; Technological, Community Colleges and in PA \$41 million for education and societal dimensions

1. What mechanisms or programs federal agencies offer to facilitate innovation and advance nanomanufacturing?

B. Interactions with industry and states

● Various mechanisms for interaction with industry

- Fund collaborations with industrial partners

Funding programs (examples):

SBIR/STTR awardees by all agencies (>\$80 million/yr)

CRADA (DOE), TIP (NIST), GOALI and IUCRC (NSF),

Industry-led NRI (NSF and NIST),

Provide user facilities, nano-informatics, patent framework: NNIN, NCN (NSF), NSRC (DOE), CNST (NIST), ISN (DOD), NCL (NIH)

- Support partnerships with industry groups

Communicate the NNI results to industry (ex: CBAN with SIA, CCR); Industry liaison groups with the electronics, organization and business, forest products, and chemical industries;

NIH - "NanoHealth Enterprise"

- Regulatory measures and services by EPA, FDA, HHR, NRA, USPTO

2. What mechanisms or programs federal agencies offer to exchange information related to NT with industry, state and local organizations? *(presentations by agency in panels)*

Illustrations:

- About 5,000 NSF projects with abstracts, funding level and contacts at www.nsf.gov/nano (first item); <http://www.nsf.gov/funding/>
- NCI Alliance for NT in Cancer site <http://nano.cancer.gov>
- EPA has research, voluntary programs and regulatory on nanotechnology
- FDA has a special focus on nanotechnology products
- The Consumer Product Safety Commission (CPSC) is a regulatory agency <http://www.cpsc.gov/library/cpscnanostatement.pdf>).
- OECD Project on Nanotechnology Impacts on Companies and Business Environments, *and Project on Nanotechnology Indicators and Statistics*, <http://www.oecd.org/sti/nano>
- USDA, Nanoscale Science and Engineering for Agriculture and Food Systems – National Planning Workshop, <http://www.nseafs.cornell.edu/>

3. What mechanisms or methods federal agencies offer to enable transfer of technology to industry?

(presentations by agency in panels)

Illustrations:

- SIA-SRC-NSF-NIST: **Nanoelectronics Research Initiative**
<http://nri.src.org/member/about/default.asp>
- NSF SBIR/STTR matching for phase 2
<http://www.nsf.gov/eng/iip/sbir/diversity/2003sbirII.xls>
- MRSEC – Materials Research Science & Engineering Centers
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5295
- Public-Private-Partnership, <http://ppp.od.nih.gov/pppinfo/focusareas.asp>
- NIH SBIR phase 3
- *NIOSH Nanotechnology Field Team (NIOSH Publication No. 2008-121:*
- *NIOSH Nanotechnology Field Research Effort;*
<http://www.cdc.gov/niosh/docs/2008-121/>
- USDA, *Competitive grants, including SBIR, formula funds, and Congressional earmarks for research, education and extension activities*
<http://cris.csrees.usda.gov/cgi-bin/starfinder/>

Nanotechnology Research Directions

Vision for Nanotechnology in the Next Decade

Edited by M.C. Roco, R.S. Williams and P. Alivisatos

Kluwer Academic Publishers

Participants in the National Nanotechnology Initiative

NIH
NIST
NASA
DOD
DOE
NSF
DOTr
DOT
EPA
DOJ
DOS
IC
USDA
FDA
NRC
DHS
DOC TA
USDA FS
DOC BIS
USPTO
ITC
CPSC
NIOSH
USGS
DOL
DOEd

2001: Six Agencies

2002: Seven New Agencies

2003-4: Four New Agencies

2005: Six New Agencies

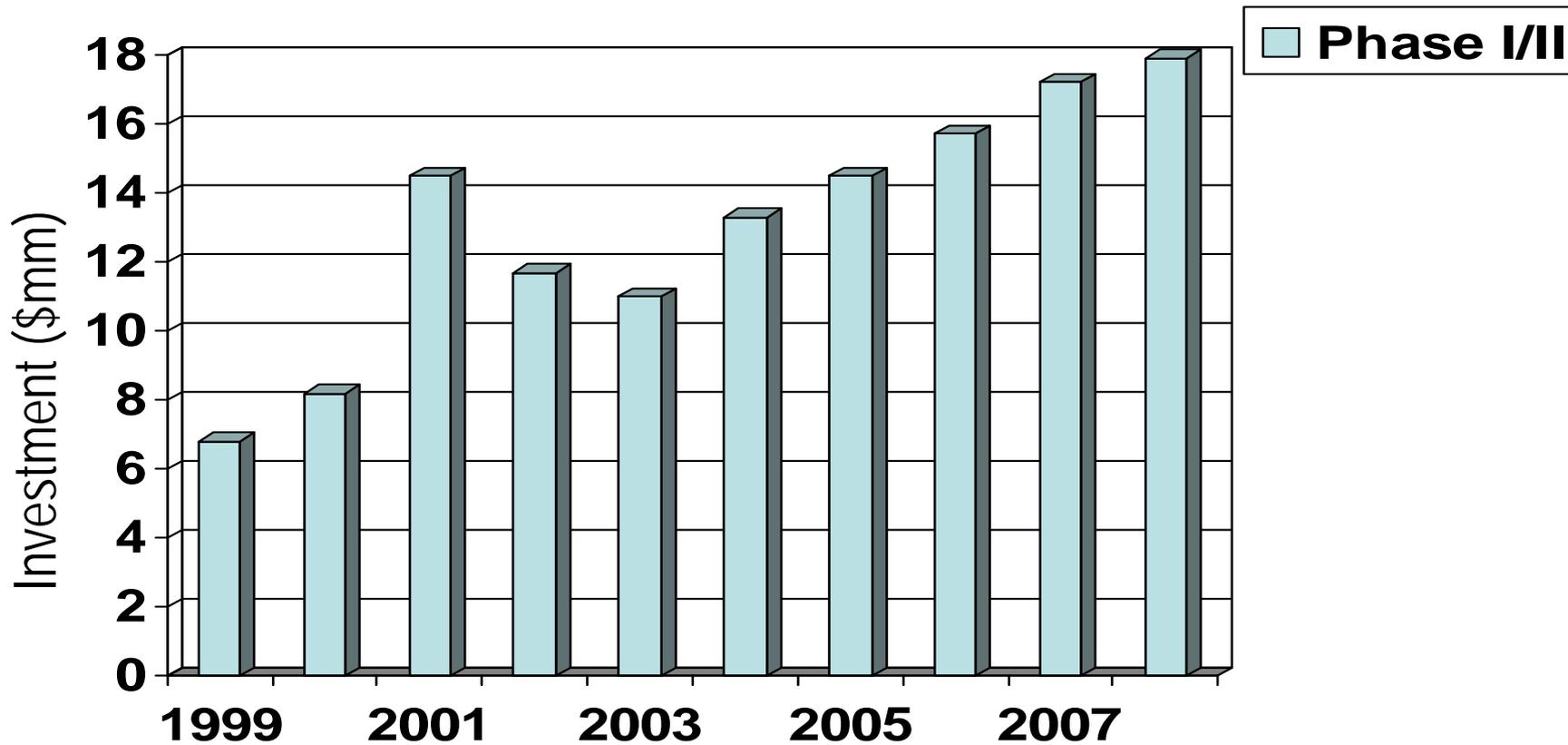
2006: Three New Agencies

SBIR – STTR Programs

- DOD, NSF, NIH, DOE and NASA support both SBIR and STTR
- EPA, NIOSH, NIST, and USDA have SBIR
- Total FY 2007 nanotechnology SBIR funding for : \$71.3 million
- Total FY 2007 nanotechnology STTR funding: 11.4 million

NSF SBIR/STTR Grants in NANOTECHNOLOGY

from FY1999 to FY2008
(million dollars)



2007: NSF - \$17.2M (65 awards); NNI - > \$80M

NNI Infrastructure & Funding: NSF

- reference slides

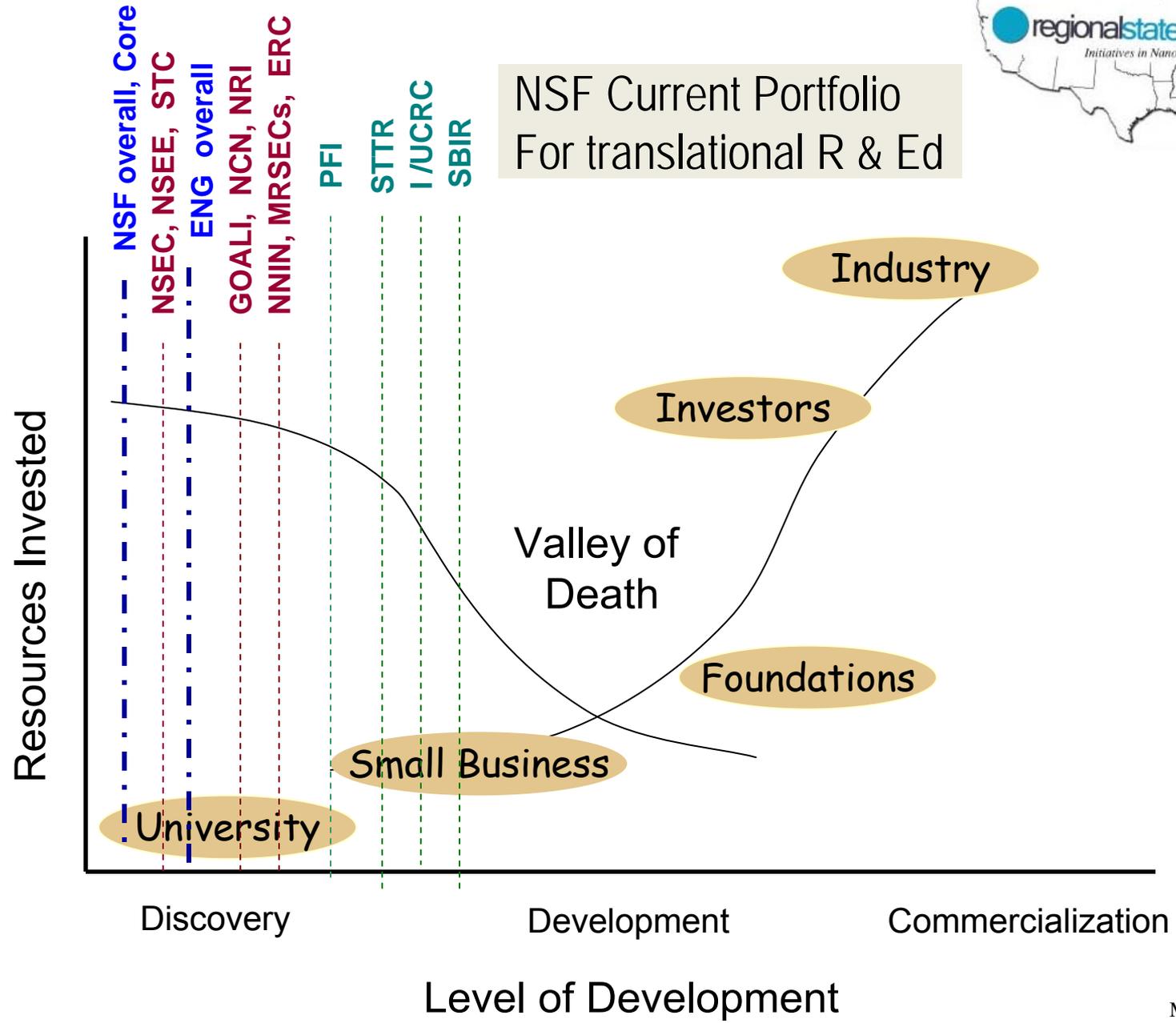


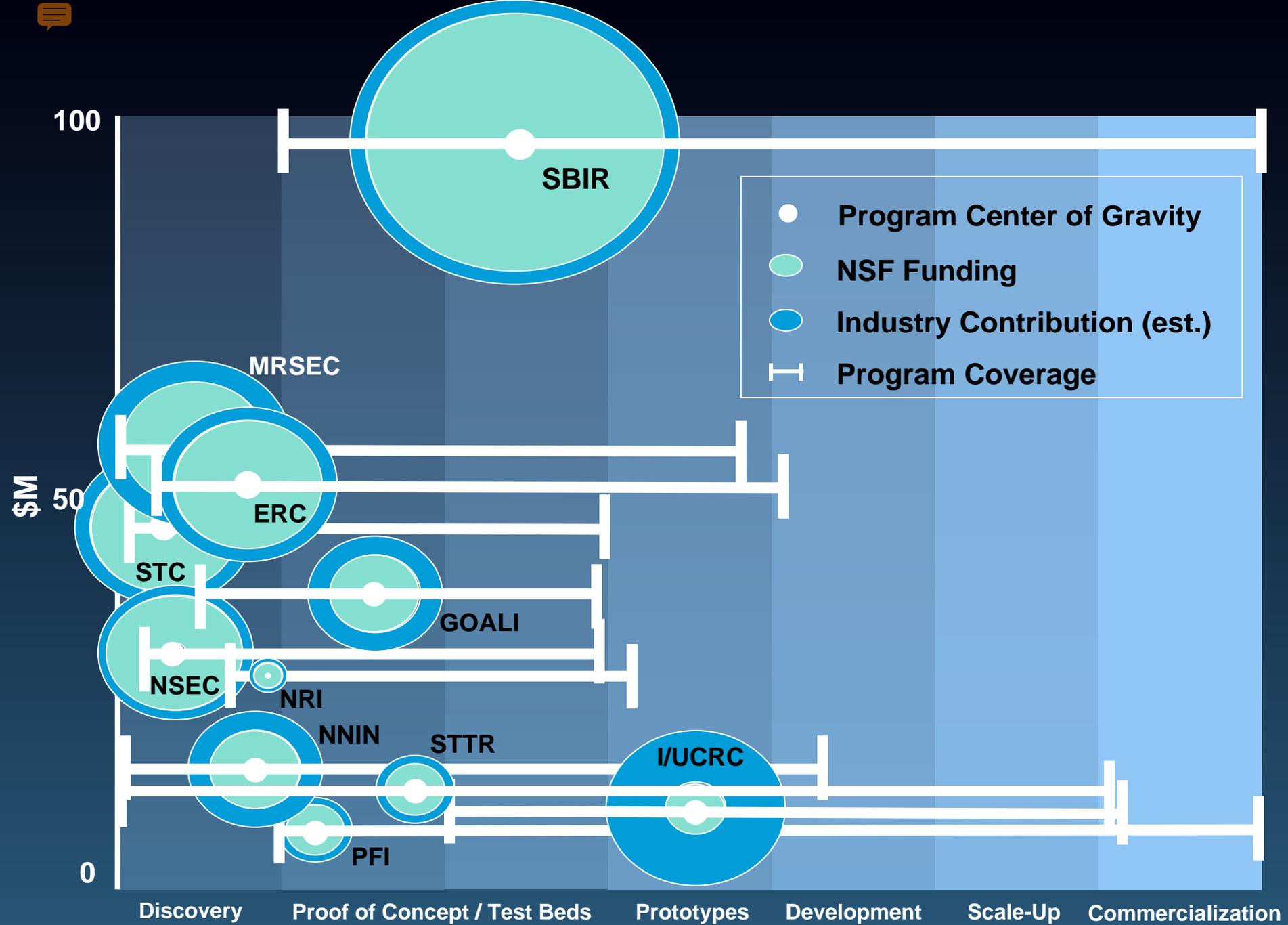
NSF Program Notations

- NSF – Core: all NSF research directorates cover nanotechnology in their topical programs
- NSEC – Nanoscale Science and Engineering Centers
- NSEE – Nanoscale Science and Engineering Education networks (NCLT, NISE)
- STC – Science and Technology Centers
- GOALI – Grant Opportunities for Academic Liaison with Industry
- MRSEC – Materials Research Science & Engineering Centers
- NCN – Nanotechnology Computational network
- NNIN – National NanoInfrastructure Networks
- MRSEC – Materials Research Science and Engineering Centers
- NRI – Nanoelectronics Research Initiative
- ERC – Engineering Research Centers
- PFI – Partnerships for Innovation
- I/UCRC – Industry/University Cooperative Research Centers
- STTR – Small Business Technology Transfer
- SBIR – Small Business Innovation Research



NNI Infrastructure & Funding: NSF





Industrial impact of NSECs, NCN and NNIN

Institution	Number start-ups	Industrial partnerships		Support from other organizations
		Number partners	Ind. Support (\$ million)	Total support (\$ million)
Totals NSEC	37	392	41.9	279.4
NCN	0	403	2.0	11.3
NNIN	38	358	86.0	300.0
NSECs + 2 Users Networks	75	1,153	129.9	590.8

NSF nanotechnology centers – educational pipeline for industry

Institution	Graduate Students			Postdoctoral Researchers		
	Total number of graduates	Graduates in industry	Percent in industry	Total number completed appointment	Number in industry	Percent in industry
Totals NSEC	528	193	36.60%	270	99	36.70%
NCN	44	22	50.0%	20	0	0.0%
NNIN	2,600	2,080	80.0%	950	475	50.0%
NSECs + 2 Users Networks	3,172	2,295	67.2%	1,240	574	44.6%

DOD/ Air Force

www.afrl.af.mil/techtran_index.asp

Illustrations

- Technology Transfer Program (T2), ex. Research Laboratory
- Technology Transfer Cooperative Research and Development Agreements (CRADAs)
- Technology Transfer Education Partnership Agreements (EPAs)
- Technology Transfer Patent License Agreements (PLAs)
- Technology Transfer Commercial Test Agreements (CTAs)
- Office of Techn. Transition Partnership Intermediary Network, DOS
 - TechLink www.twchlinkcenter.org
 - FirstLink www.DODfirstlink.com
 - SpringBoard www.gospringboard.org
 - DOD TechMatch www.DODtechmamatch
 - T2Bridge www.T2bridge.com
 - MilTech www.miltechcenter.org



Technology Innovation Program (DOC, NIST)

- *America COMPETES Act, (PL 110-69), August 9, 2007: To assist United States businesses and institutions of higher education or other organizations, such as national laboratories and nonprofit research institutions*
- Support, promote, and accelerate innovation in the United States through high-risk, high-reward research
- In areas of *critical national need*
- ~\$65 million in House/Senate marks for FY 2009, including management of ongoing Advanced Technology Program awards

NanoFab,

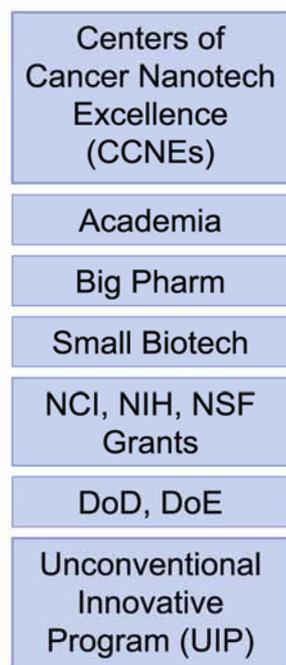
part of NIST's [Center for Nanoscale Science and Technology](http://cnst.nist.gov)

- State-of-the-art equipment and expert training available.
- The CNST NanoFab has supported advanced research projects in polymers, biology, nanoelectromechanical systems, ceramics, radiation physics, atomic physics, optics, and more.
- It also provides access to a wide variety of measurement and characterization tools and technologies

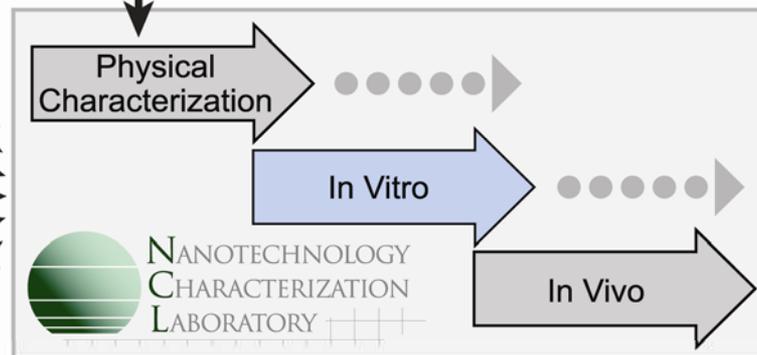
<http://cnst.nist.gov/nanofab/extUser.html>

NCL Concept of Operations

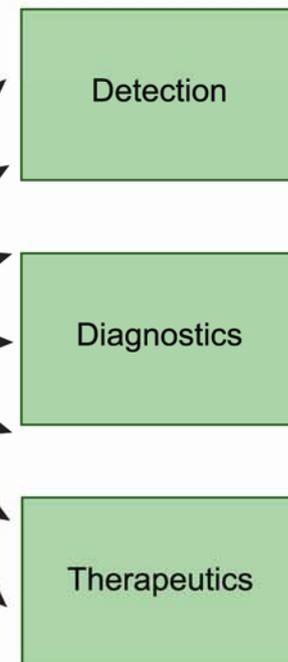
Sources of Nanomaterials



NIST



FDA



NCL is a formal collaboration between NCI, FDA and NIST

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



***Center for Nanoscale
Materials (Argonne National
Laboratory)***



***Molecular Foundry
(Lawrence Berkeley National Laboratory)***

***Center for Functional Nanomaterials
(Brookhaven National Laboratory)***



***Center for Nanophase Materials Sciences
(Oak Ridge National Laboratory)***

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



Ex: Deadline for submission: Friday, May 1, 2009
http://cnms.ornl.gov/user/call_proposals.shtm



Nine Nanoscale Science and Engineering networks with national outreach

TOOLS

Network for Computational Nanotechnology (2002-) *> 50,000 users/ 2007*

National Nanotechnology Infrastructure Network (2003-) *4,500 users/ 2007*

Nationwide Impact

TOPICAL

Nanotechnology Center Learning and Teaching (2004-) *1 million students/ 5yr*

Center for Nanotechnology Informal Science Education (2005-) *100 sites/ 5yr*

Network for Nanotechnology in Society (2005-) *Involve academia, public, industry*

National Nanomanufacturing Network (2006-) *4 NSETs, DOD centers, and NIST*

Environmental Implications of Nanotechnology (2008-) *with EPA*

GENERAL RESEARCH AND EDUCATION

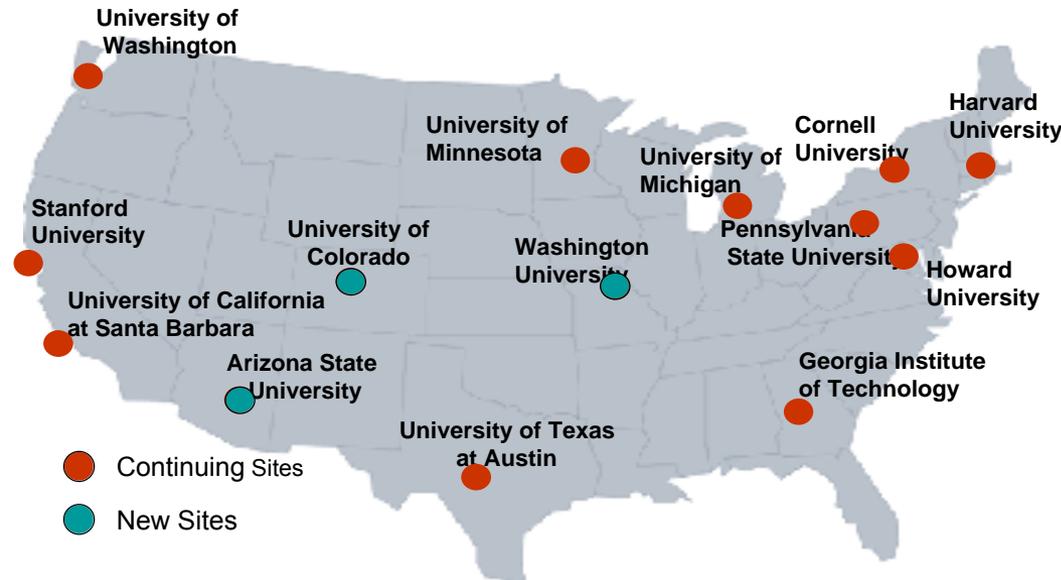
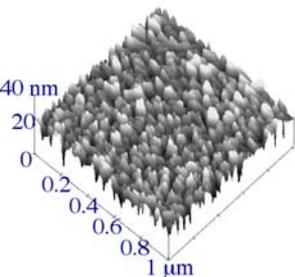
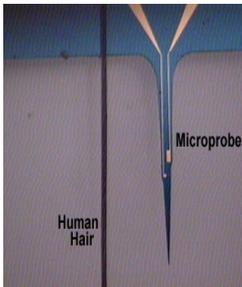
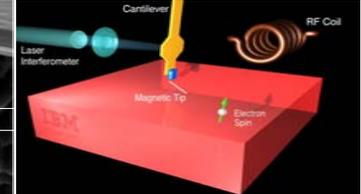
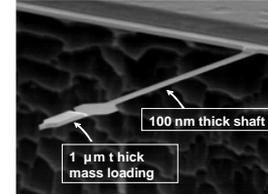
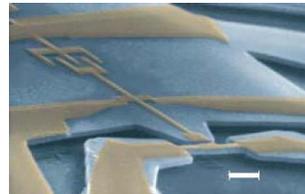
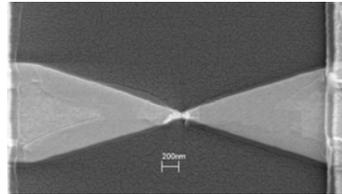
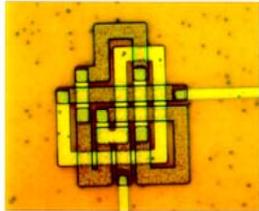
NSEC Network (2001-) *17 research & education centers*

MRSEC Network (2001-) *6 new research & education centers since 2000*



National Nanotechnology Infrastructure Network (NNIN)

www.nnin.org
Nanoscale Science,
Engineering & Technology



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. 4600 users (691 or ~ 15% industry) in 2008

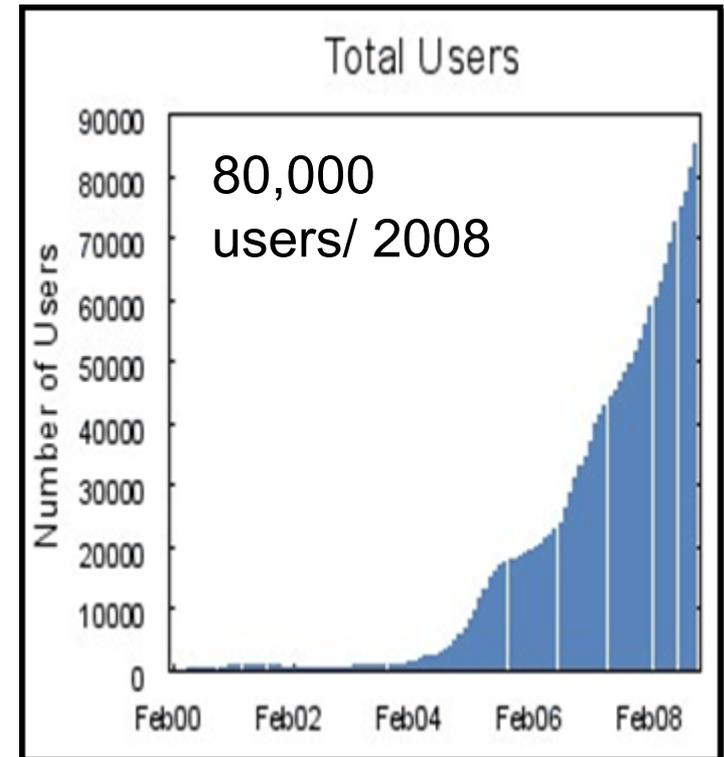


Network for Computational Nanotechnology

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



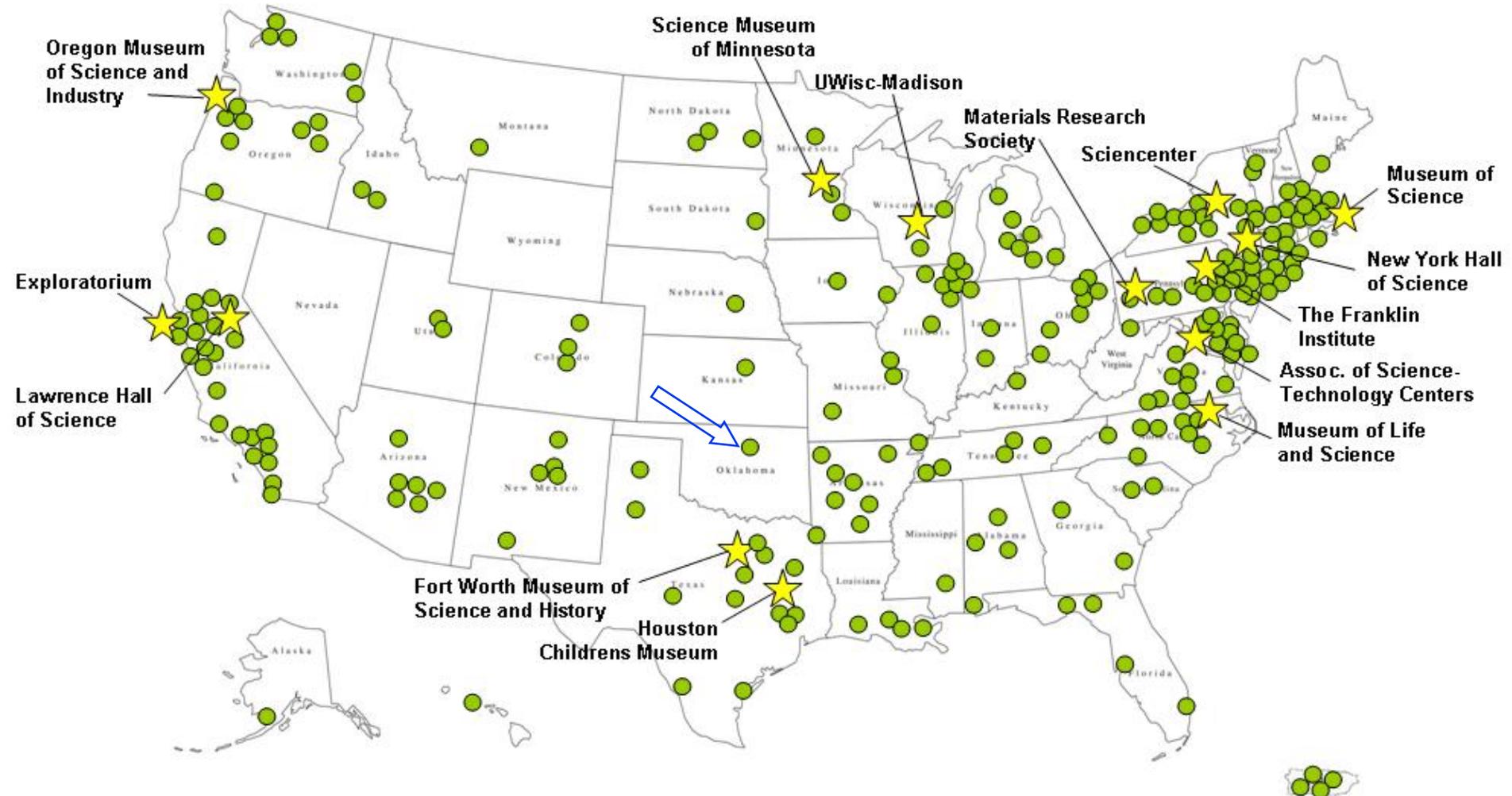
<http://www.nanoHUB.org>





NanoDays 2009 March 28-April 5

Kits have been shipped to these locations in 2008 or 2009



NNI-Industry Consultative Boards for Advancing Nanotech

Key for development of nanotechnology, Reciprocal gains

❑ **NNI-Electronic Industry (SRC lead), 10/2003 -**

Collaborative activities in key R&D areas
5 working groups, Periodical joint actions and reports
NSF-SRC agreement for joint funding; other joint funding



❑ **NNI-Chemical Industry (CCR lead)**

Joint road map for nanomaterials R&D; Report in 2004
2 working groups, including on EHS
Use of NNI R&D results, and identify R&D opportunities



❑ **NNI – Organizations and business (IRI lead)**

Joint activities in R&D technology management
2 working groups (nanotech in industry, EHS)
Exchange information, use NNI results, support new topics



❑ **NNI – Forestry and paper products (AF&PA lead, 4/2007), 10/2004-** Workshop / roadmap for R&D

Exchange information



American Forest & Paper Association