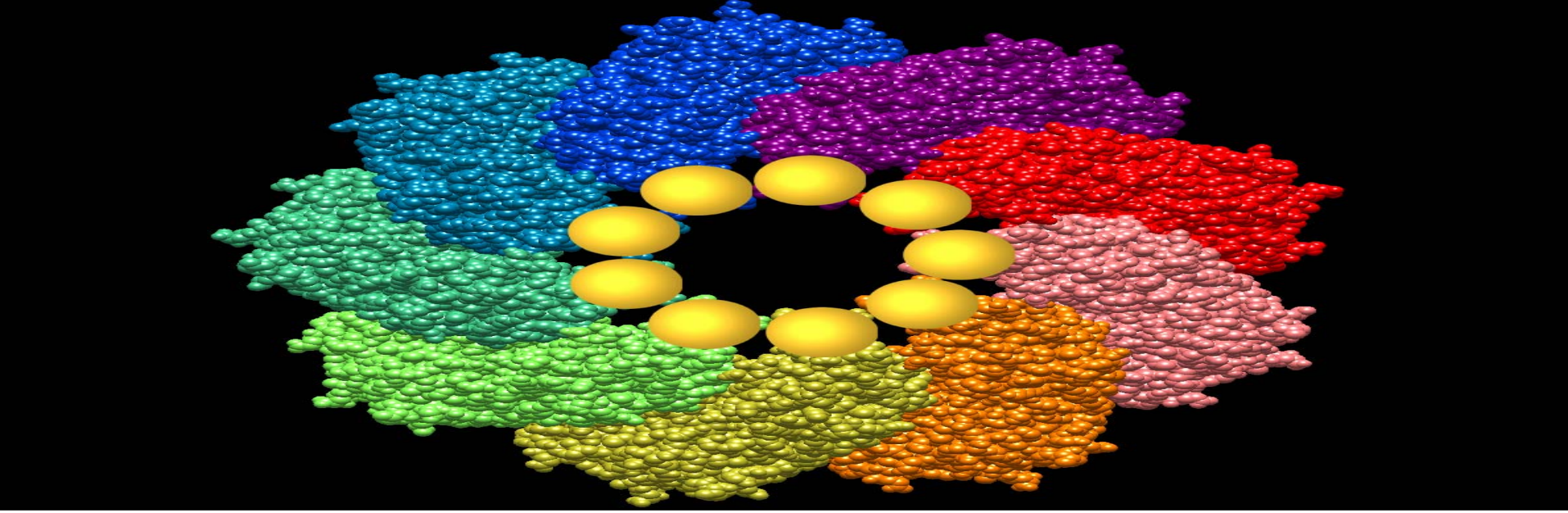


National Nanotechnology Initiative: The Long-term View

M.C. Roco
Senior Advisor for Nanotechnology, NSF
Chair, Subcommittee on Nanoscience, Engineering and Technology (NSET),
National Science and Technology Council (NSTC)

- **Motivation and timeline**
- **Outcomes in the first four years of NNI**
- **New frontiers in 2005 and long-term planning**

EPA, April 18, 2005

Sept. 2000

Nanotechnology

Definition on www.nano.gov/omb_nifty50.htm

- Working at the atomic, molecular and supramolecular levels, in the length scale of approximately 1 – 100 nm range, in order to understand and create materials, devices and systems with fundamentally new properties and functions because of their small structure

- **NNI definition encourages new contributions that were not possible before.**

  - novel phenomena, properties and functions at nanoscale, which are nonscalable outside of the nm domain

  - the ability to measure / control / manipulate matter at the nanoscale in order to change those properties and functions

  - integration along length scales, and fields of application

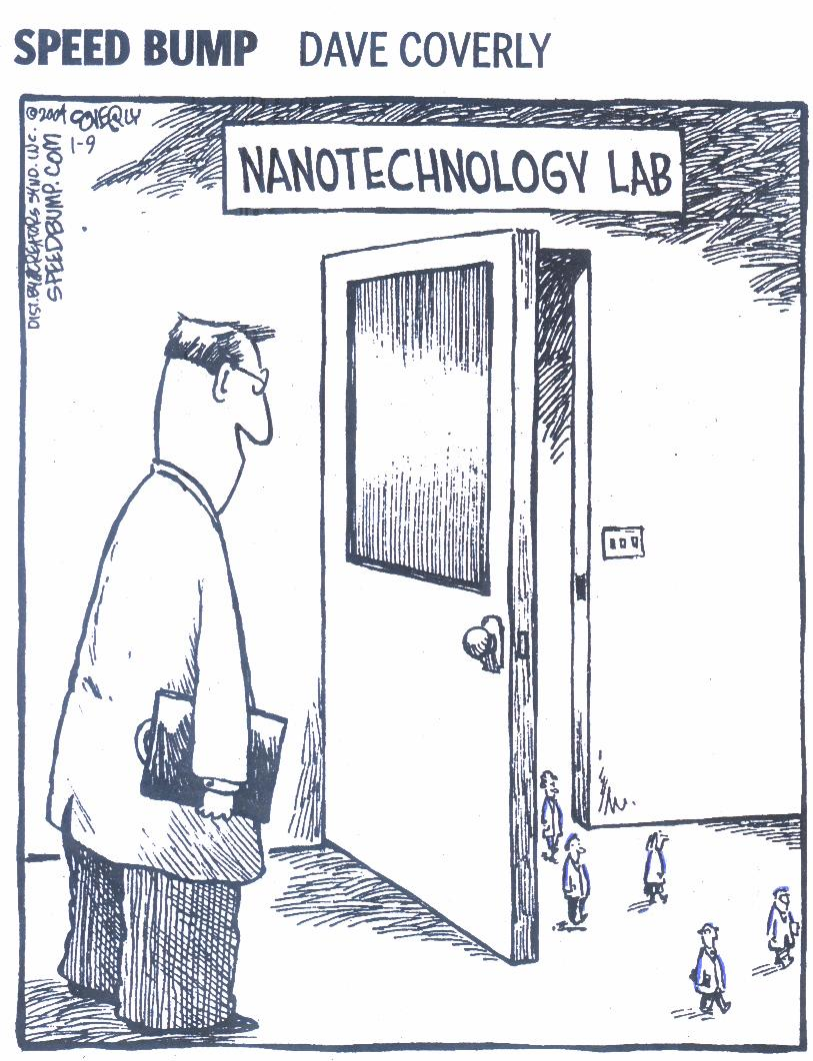
NNI - Why nanotechnology is important?

- **A. Reaching at the foundation of matter**
  Historical event in understanding, control and transformation of natural/living and manmade systems (natural threshold between discontinuous and continuous behavior; where first level organization of matter defines properties and functions)

- **B. The long term societal implications**
  Improved knowledge, quality of life, and environment
  Create foundation for a technological and industrial revolution

- **C. Higher purpose goals than development of NT**
  - More basic and unifying science and education
  - Higher efficiency processes and novel products
  - Molecular medicine
  - Extend the limits of sustainable development
  - Increased coherence/integration of S&T policies

Nanotechnology development cannot be decided only by nanotechnologists



Nanotechnology promises to broadly affect society, from new products to art

B. Broad societal implications
(Ex: worldwide estimations made in 2000, NSF)

- **Knowledge base**: better comprehension of nature, life
- **New technologies and products: ~ $1 trillion/year by 2015**
  (With input from industry US, Japan, Europe 1997-2000, access to leading experts)

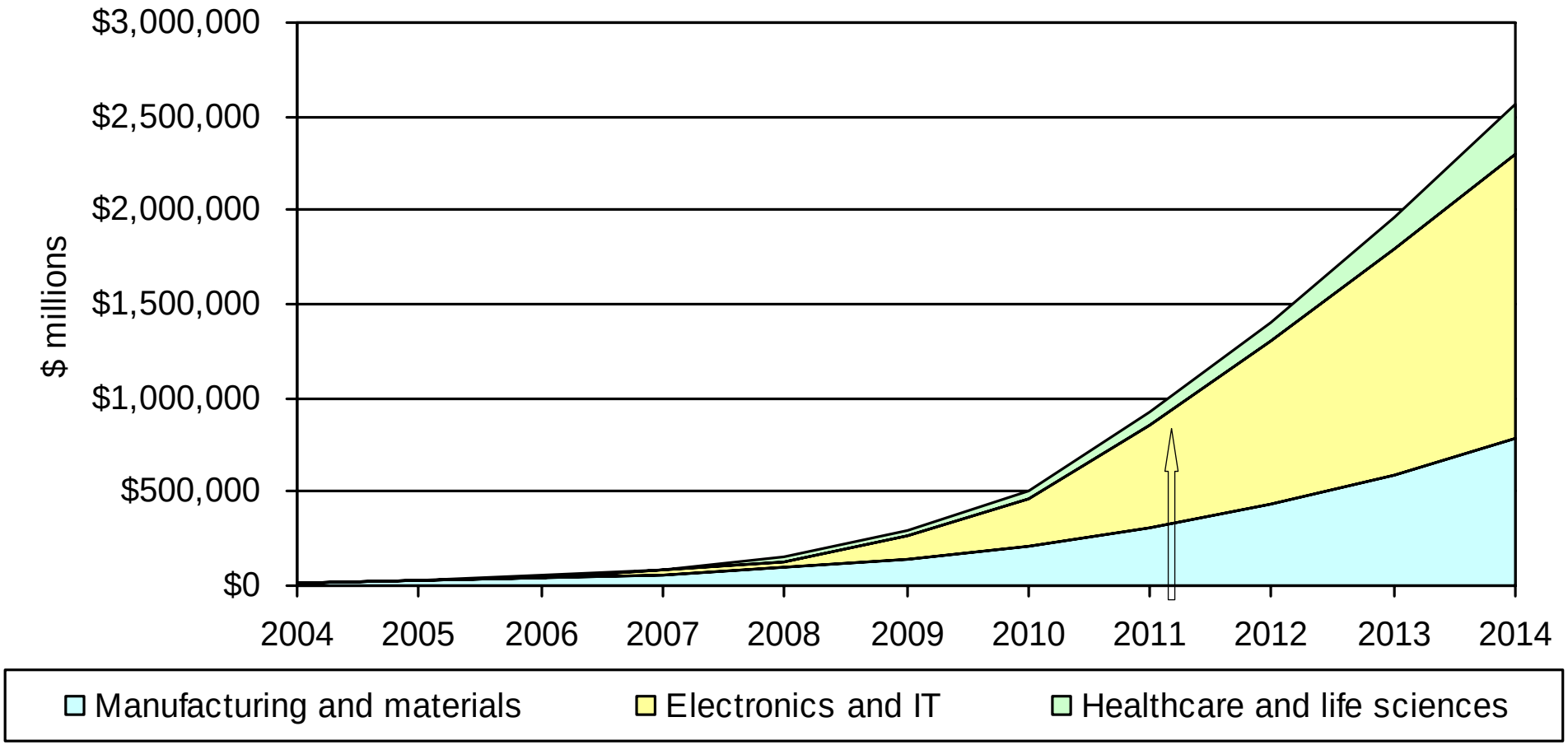
  Materials beyond chemistry: $340B/y
  Pharmaceuticals: $180 B/y
  Aerospace about $70B/y
  Electronics: over $300B/y
  Chemicals (catalysts): $100B/y
  Tools ~ $22 B/y

  Est. in 2000 (NSF) : about $40B for catalysts, GMR, materials, etc.; + 25%/yr
  Est. in 2002 (DB) : about $116B for materials, pharmaceuticals and chemicals

  Would require worldwide ~ 2 million nanotech workers (all ~7M)
  In U.S.: ~ 0.8 million (all with supporting jobs ~ 2.8 million)

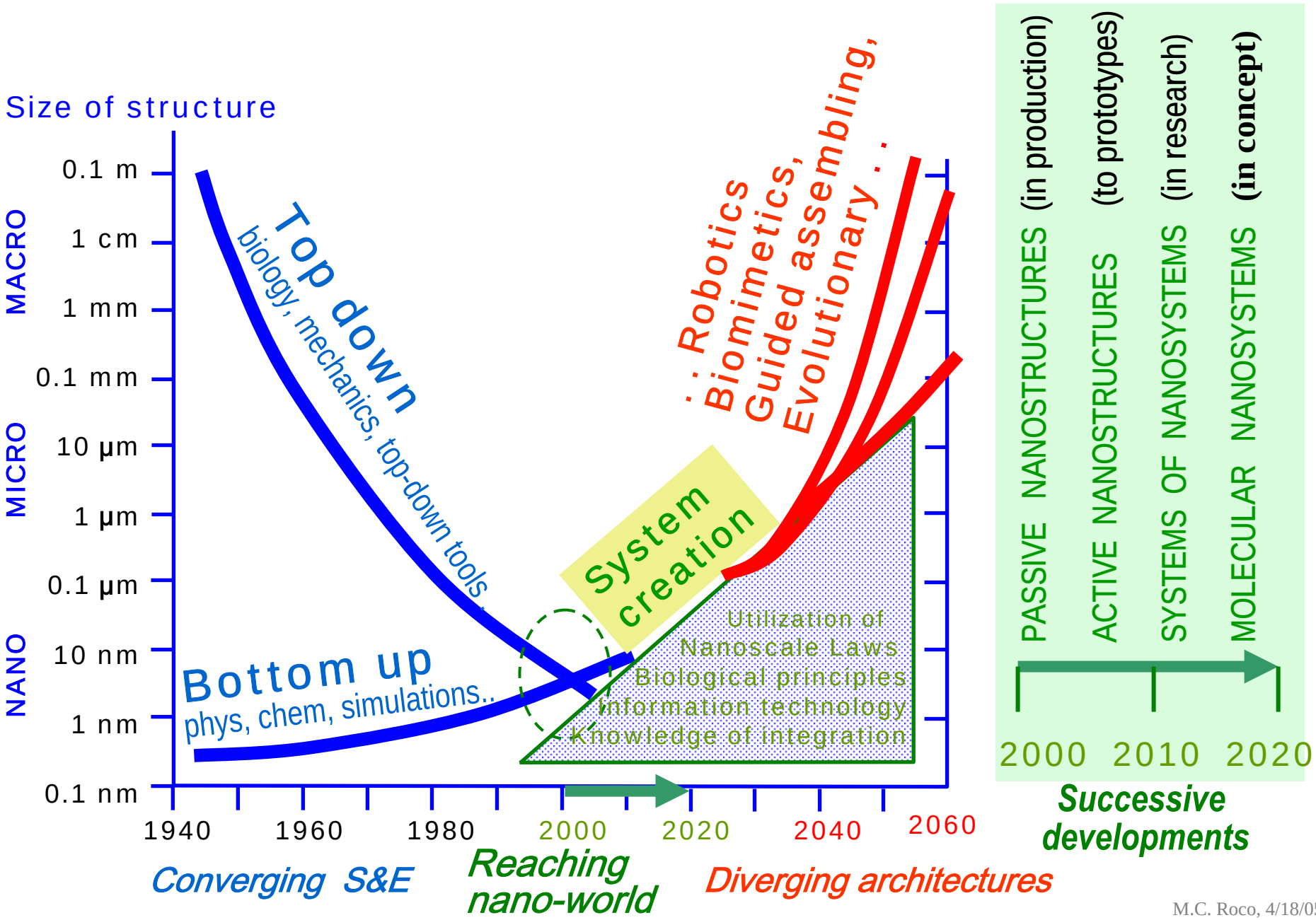
- **Improved healthcare**: extend life-span, its quality, physical capabilities
- **Sustainability**: agriculture, food, water, energy, materials, environment; ex: lighting energy reduction ~ 10% or **$100B/y**

Global forecast, products sold incorporating emerging nanotechnology, 2004 to 2014, 3 sectors

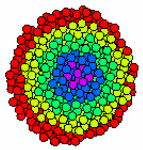


Source: October 2004 Lux Research Report “Sizing Nanotechnology’s Value Chain”

Reaching nano-world and system creation



Timeline for beginning of industrial prototyping and nanotechnology commercialization: Four Generations



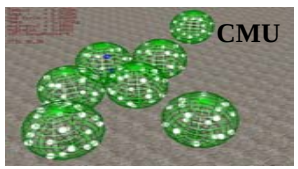
1st: Passive nanostructures (1st generation products)

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

~ 2000

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

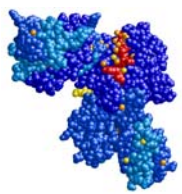
~ 2005



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

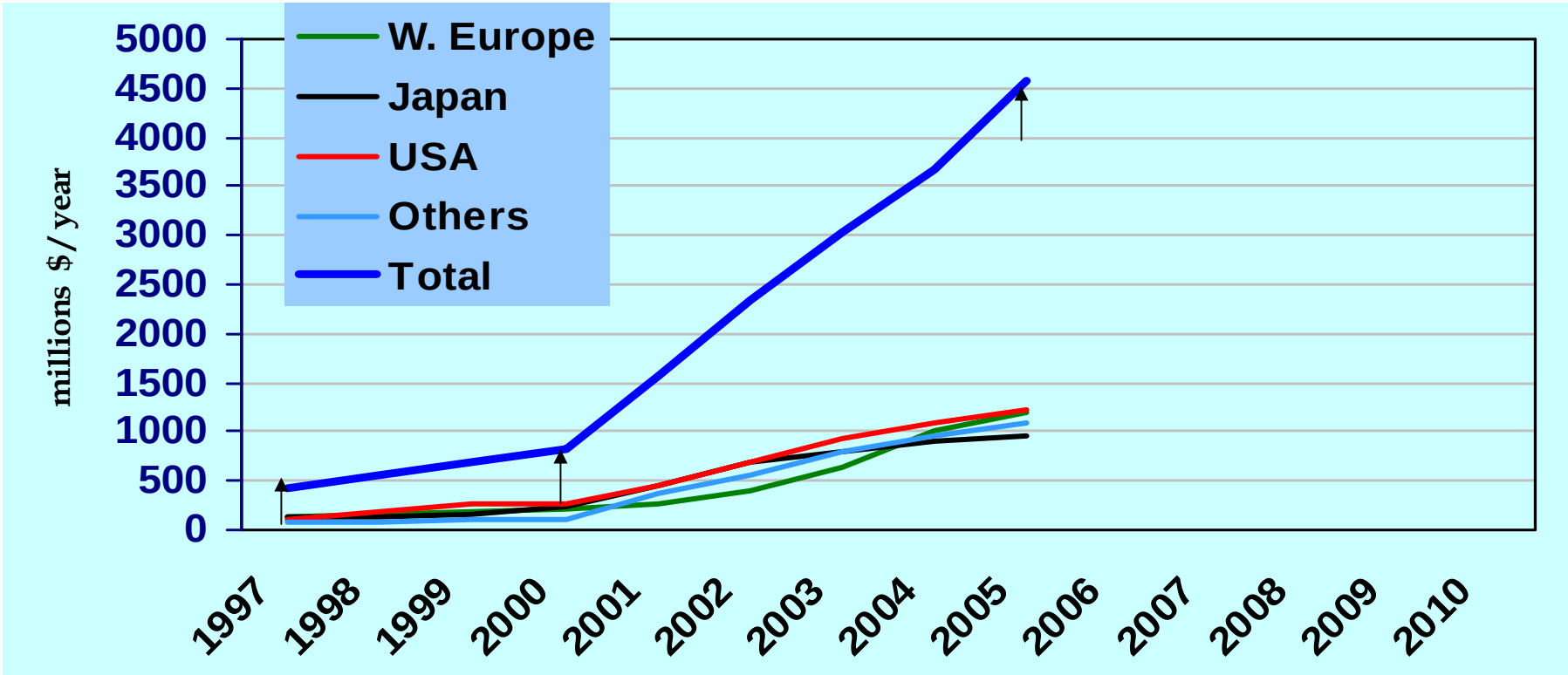
~ 2015-2020

R&D

AIChE Journal, 2004, Vol. 50 (5)

Context – Nanotechnology in the World

Past government investments 1997-2005 (est. NSF)



Seed funding (1991 -)

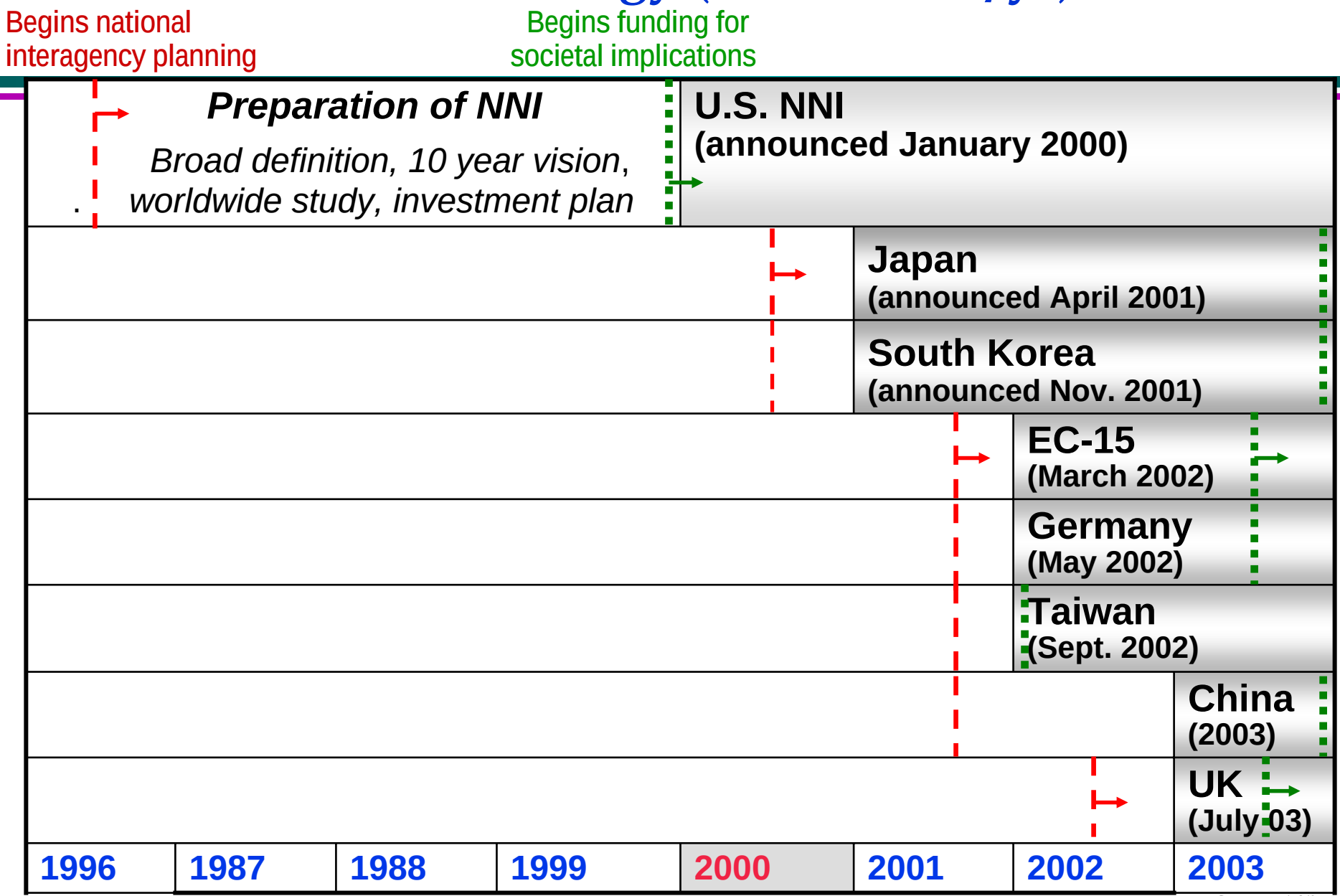
NNI Preparation (vision / benchmark)

1st Strategic Plan (passive nanostructures)

2nd Strategic Plan (active ns. & systems)

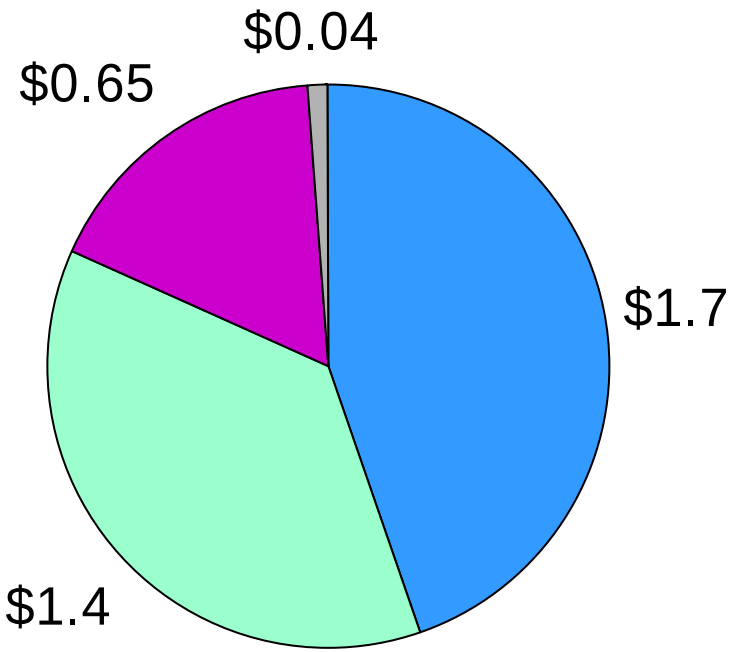
Total government expenditure in FY 2004 – about $3.7 billion

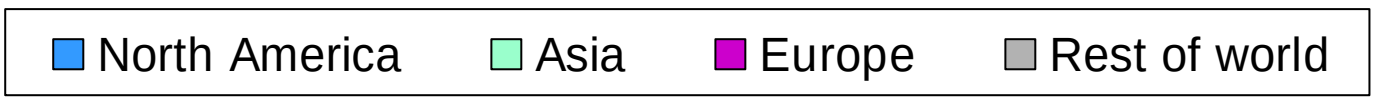
Comprehensive national programs on nanoscience and nanotechnology (over $100M/yr)



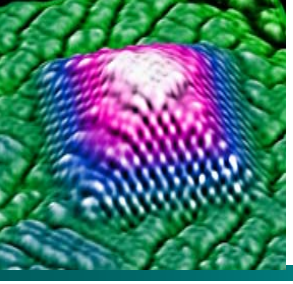
Established corporations spending - > $3.8 billion globally on nanotechnology R&D in 2004

Corporate Nanotechnology Spending ($ billion)





Source: Lux Research reference study “The Nanotech Report 2004;” based on published spending figures, national statistics, Lux Research analysis

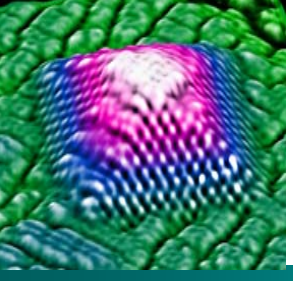


NATIONAL NANOTECHNOLOGY INITIATIVE - *from vision to the investment strategy*

- Timeline (Preparing NNI) -

- March 1991 — "Nanoparticle Synthesis and Processing" (NSF program)
- Nov. 1996 — Nanotechnology Group (bottom-up)
- March 1998 — Functional Nanostructures; Partnership in nanotechnology (NSF in collaboration with other agencies)
- Sept. 1998 — NSTC establishes Interagency Working Group of Nanoscience and Engineering (IWGN)

- March 1999 — OSTP/CT presentation on NNI, Indian Treaty Room
- May-Sept. 1999 — Congress hearings; Three publications NSTC/IWGN; Nanotechnology R&D planning in six agencies; IWGN planning for NNI
- Oct. – Dec. 1999 — OMB review – NNI the only new topic recommended; PCAST – Letter to the President supporting NNI; OSTP and WH Approval
- Jan. 2000 — NNI announced by the President in Jan 2000



NATIONAL NANOTECHNOLOGY INITIATIVE – *from vision to the investment strategy*

- Timeline FY 2001-2005 -

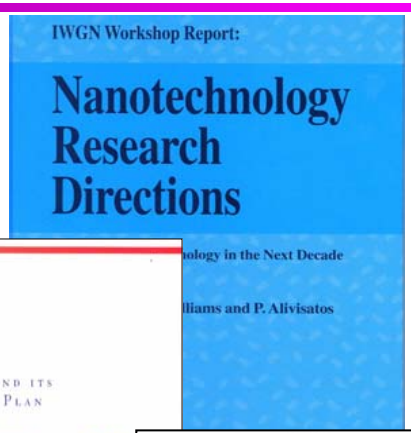
- Feb.–Dec. 2000 - WH, Congress review and approve FY 2001 NNI
  6 agencies (NSF, DOD, DOE, NIH, NASA, NIST)
  Concerns about applicability; "Societal Implications" workshop
- FY 2001 14 agencies (+ EPA, DOT, DOTr, DOS, DOC-TA, DOJ, USDA, IC); $490M
  NSET signs MOU to establish NNCO ; White Hose support to NNI
  International reaction: programs in > 30 countries (now > 60)
  20 states and regional alliances begin to invest (now > 22)
- FY 2002 16 agencies (+FDA, NRC) ; $737M
  Outcomes: R&D, Education, Patents, Industry growth; EHS aspects
- FY 2003 17 agencies (+ DHS); 2 Bills in Congress for FY2004-2008; $942M
  CBAN established, Research directions workshops
- FY 2004 22 agencies (+ NIOSH, CPSC, ITC, USPTO, DOC-BIS); The Law $1,094M
  Infrastructure development; Strategic Plan II (Dec. 2004)
- FY 2005 23 agencies (+ USDA-FS); New frontiers for nanotechnology $1,231M

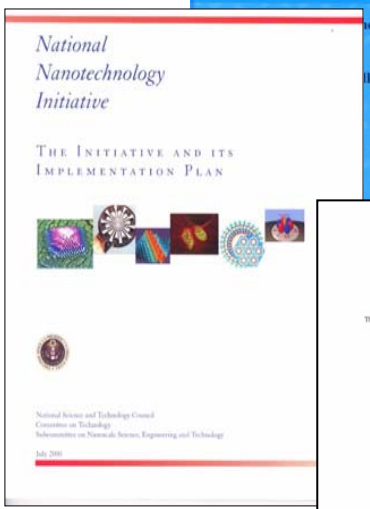
Defining the vision for the *first strategic plan (I)*

National Nanotechnology Initiative

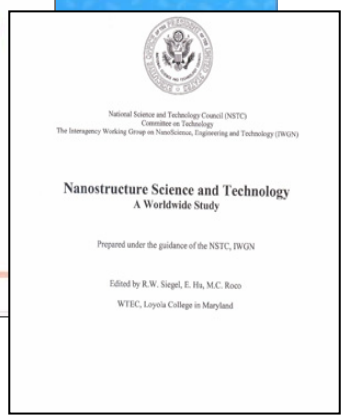
1999-2000

1999:
10-year
vision



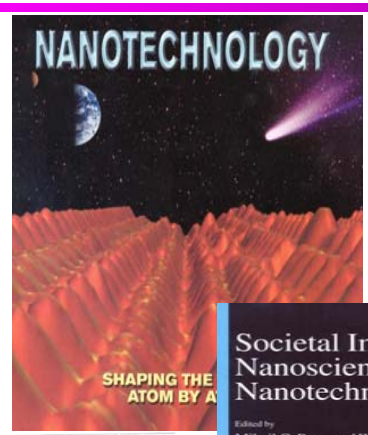


Government
plan



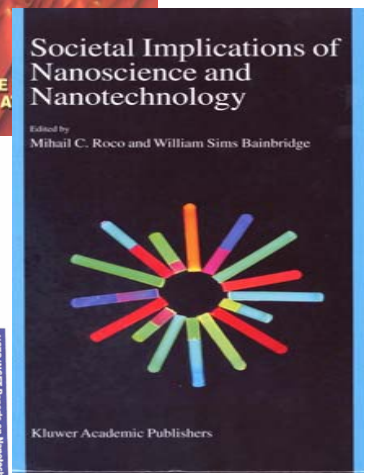
Worldwide
benchmark

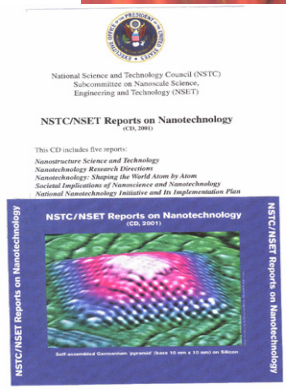
Reports



Brochure for
public

Societal
implications

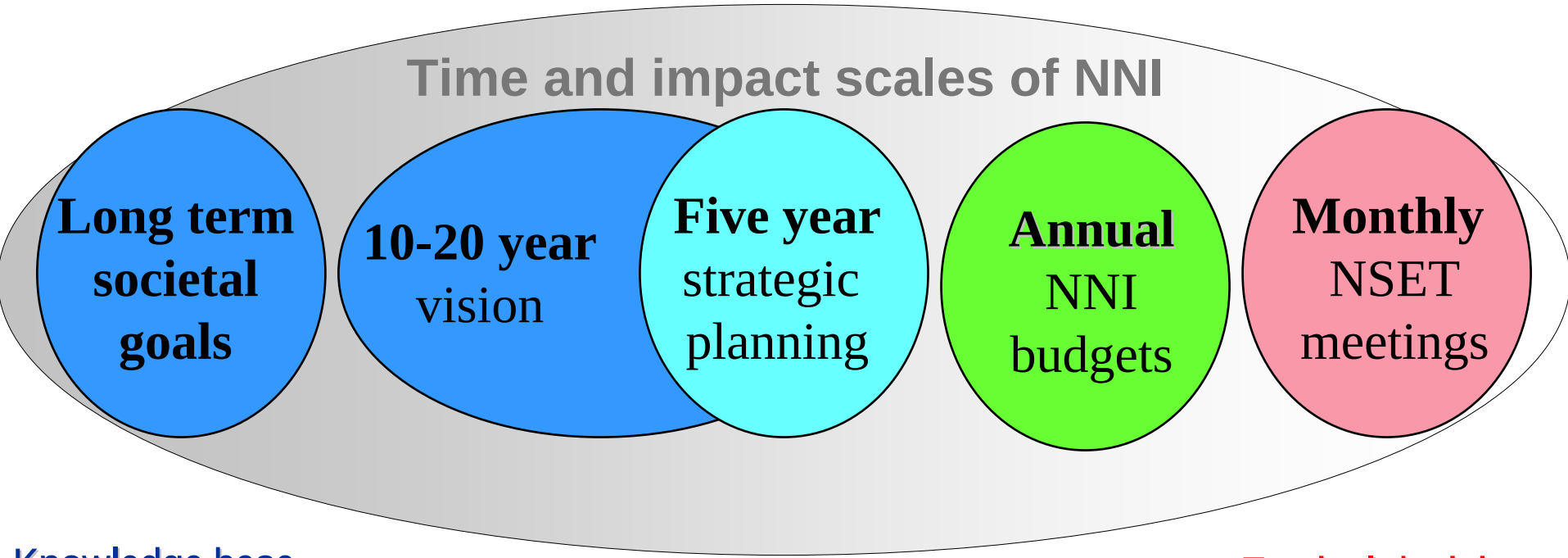




Focus on Knowledge Creation (same principles, phenomena, tools, architectures) to support innovation in various areas of relevance

Planning with Feedback: after each 5 years, 1 year, 1 month;
and various levels: national / NSET, agency (23), R&D program

The long-term vision drives NNI



Knowledge base
Economy
Quality of life
Responsible NT
World context

1999 Research Directions I
2004 Research Directions II
10 topical reports in 03-04
Evaluation PCAST, NRC

Annual budgets
FY 2001, .. , 2005
EOP evaluation,
OMB, GPRA, COV

Tactical decisions
Programs
Partnerships
Safety issues

NNI: Key Investment Strategies

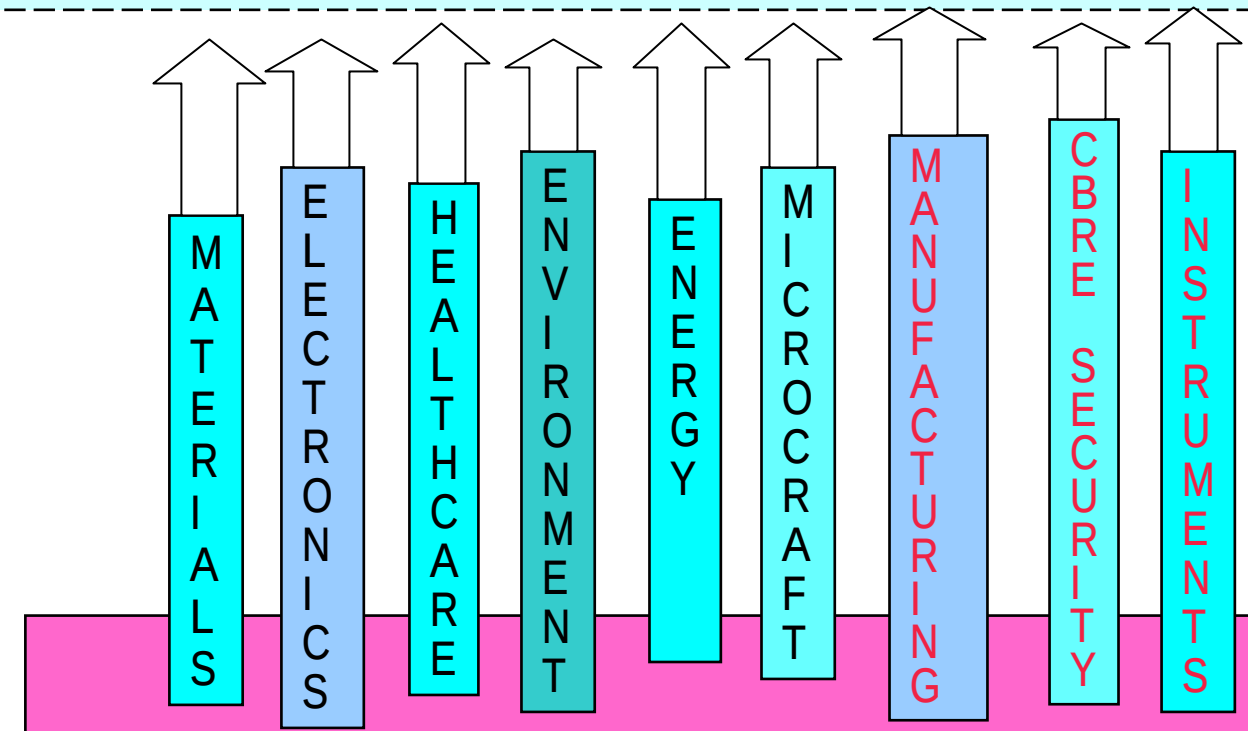
- Focus on interdisciplinary fundamental research ('horizontal') + transition to technological innovation ("vertical')
- Address broad humanity goals and other societal aspects
- Long-term planning, part of coherent S&T evolution
- Prepare the nanotechnology workforce
- Policy of inclusion and partnerships
  Interdisciplinary, Interagency collaboration
- Transforming strategy; "bio-inspired" approach;
  consider the full architecture and interactions

NNI as part of the U.S. Federal R&D ~ 0.25% (2000) to 1% (2005)

U.S. NNI as part of world nanotech investment ~ 1/4 (2005)

Interdisciplinary "horizontal" knowledge creation vs. "vertical" transition from basic concepts to Grand Challenges

Revolutionary Technologies and Products



Converging Technologies

Grand Challenges

Infrastructure

Workforce

Partnerships

NNI Vision: a future in which the ability to understand and systematically control matter on the nanoscale leads to a revolution in technology and industry

- **Changing the foundation of understanding, control, manufacturing and medicine from the macro and micro domains to the nanoscale, where all fundamental material properties and functions can be efficiently established and changed**
- **General purpose technology that will affect almost all sectors of the society. It will disrupt - structural changes - markets, industrial organizations and business models (ex: 50% of new products in advanced industrial areas will use NS&E by 2015)**

NNI as part of the U.S. Federal R&D ~ 0.25% (2000) to 1% (2005)

U.S. NNI as part of world nanotech investment ~ 1/4 (2005)

NATIONAL NANOTECHNOLOGY INITIATIVE

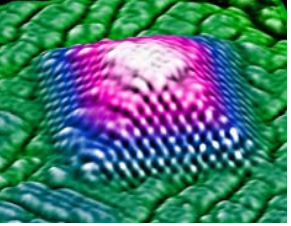
First NNI strategic plan (2001-2005): R&D funding by Agency

Fiscal year (all in million $)	***2000*** Actual	***2001*** Enact/Actual	***2002*** Enact/Actual	***2003*** Enact/Actual	2004 Req./Actual	2005 Req/Est.
National Science Foundation	97	150 /150	199 /204	221 /221	249 /256	305/338
Department of Defense	70	110 /125	180 /224	243 /322	222 /291	276/257
Department of Energy	58	93 /88	91.1 /89	133 /134	197 /202	211/210
Health and Human Services	32	39 /39.6	40.8 /59	65 /78	70 /106	89/145
NASA	5	20 /22	35 /35	33 /36	31 /47	35/45
NIST	8	10 /33.4	37.6 /77	66 /64	62 /77	53/75
EPA	-	/5.8	5 /6	5 /5	5 /5	5/5
Homeland Security (TSA)	-		2 /2	2 /1	2 /1	1/1
Department of Agriculture	-	/1.5	1.5 /0	1 /1	10 /2	5/3
Department of Justice	-	/1.4	1.4 /1	1.4 /1	1.4 /2	1/2
Congressionally-directed to DOD		25	40	80	103	150
TOTAL	270	422 /490	600 /737	770 /942	849 /1092	982/1231
Average annual rate: 38%		+82%	+50%	+28%	+16%	+ 13%

- Industry, state and local organizations: about 2 times NNI budget in 2004
- 2004 NNI budget: 65% to academia; 25% - R&D labs; 10% - industry (7% SBIR)

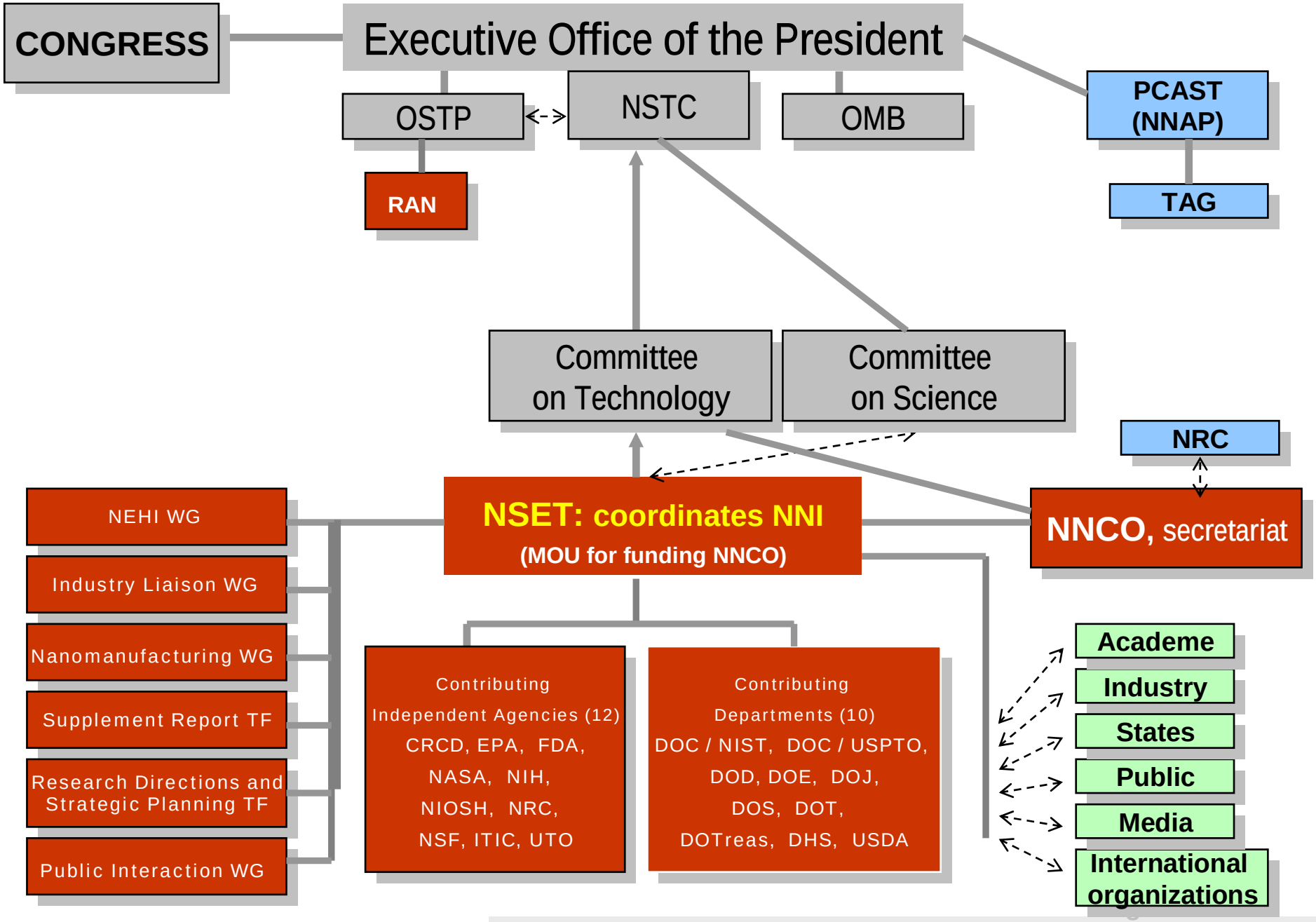
2001-2005: Elements of NNI

- **Fundamental Research**
  Provides sustained support to individual investigators and small groups doing fundamental, innovative research
- **Grand Challenges**
  for research on major, long-term objectives
- **Centers and Networks of Excellence**
  for interdisciplinary research, networking, industry partnerships
- **Research Infrastructure**
  metrology, instrumentation, modeling/simulation, user facilities
- **Societal Implications and Workforce Education and Training**
  for a new generation of skilled workers; the impact of nanotechnology on society: legal, ethical, social, economic
  (* these budgets do not include education and training through research grants)



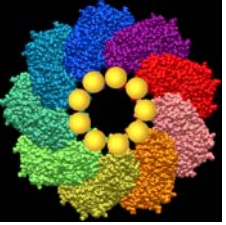
NSET Mission

- The CT/NSET Subcommittee mission:
  - Coordinates, plans, and implements the National Nanotechnology Initiative (about $1B/year)
  - Promotes a balanced investment across all agencies to address the critical elements supporting nanotechnology development
  - Promotes interagency coordination and collaboration
  - Exchanges information with academia, industry, States, & other
  - Requirements of the 21st Century Nanotechnology R&D Act (Public Law 108-153)
- To accomplish the vision - Working Groups (WGs) in key areas:
  - Nanotechnology Environmental and Health Implications
  - Industry Liaison
  - Nanomanufacturing



Organization chart of the NNI

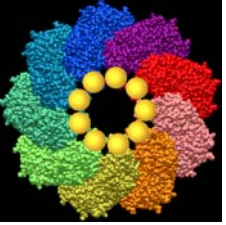
Grey: supervising organizations; Red: organizations implementing NNI; Blue: organizations evaluating NNI; Dash lines: infromational links



Accomplishments (1)

- Developed foundational knowledge for control of matter at the nanoscale:
  over 2500 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 gov. investments, the U.S. accounts for ~ 50% of highly cited papers, ~ 60% of USPTO patents[2], and ~70% of startups[3] in nanotechnology worldwide.
  Small Times reported ~ 1645 US nanotech companies in March 2005;
  In 2004, roughly half of companies were small businesses,
  and NNI SBIR/STTR investment was ~$70 million
- Infrastructure:
  over 35 new large nanotechnology research centers, networks and user facilities; about 6,300 users in 2 academic-based networks

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



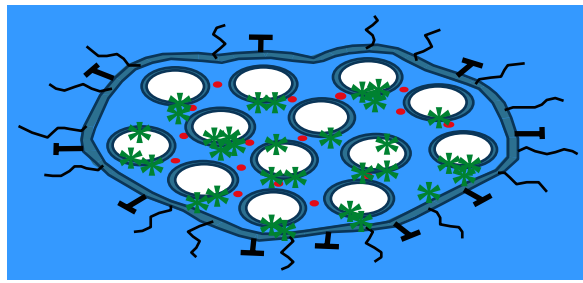
Accomplishments (2)

- Partnerships: with industry (Consultative Boards for Advancing Nanotechnology - CBAN), regional alliances (22), international (over 25 countries), numerous professional societies
- Societal implications and applications - from the beginning, about 10% of 2004 NNI; addresses environmental and health, safety, and other societal and educational concerns; NSET SC leadership thru NEHI WG
- Nanotechnology education and outreach - impacting over 10,000 graduate students and teachers in 2004; expanded to undergraduate and high schools, and outreach; create national networks for formal and informal education
- Leadership: The U.S. NNI has catalyzed global activities in nanotechnology and served as a model for other programs.

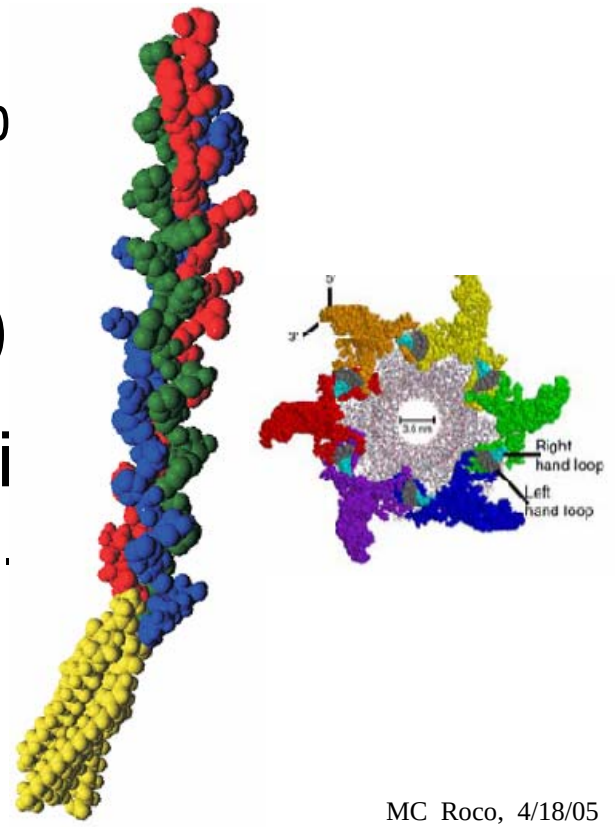
Example:

Synthesis and control of nanomachines

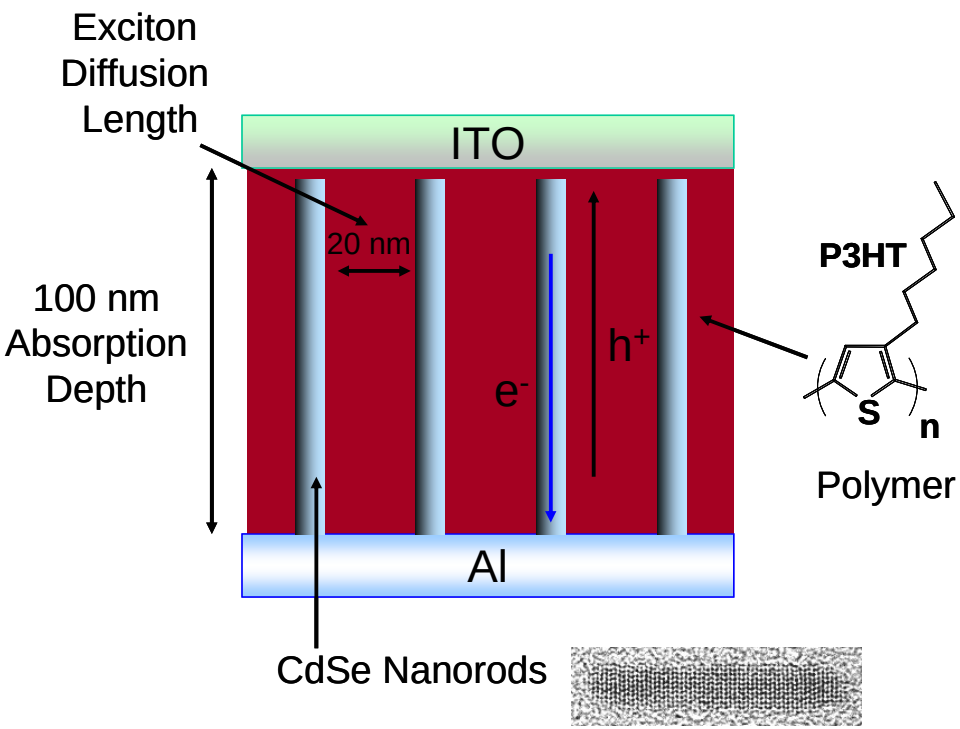
(examples NSE in 2004, www.nseresearch.org - 300 projects)



- **Self-assembly processing** of nanoscale bio-materials and devices for micromachines components (UCSB)
- Chemistry to synthesize components of **nano machines to work on surfaces** and b activated by external electromagnetic fields (UCB)
- **Light driven molecular motors** (U. Nevada)
- **Combinatorial engineering of nanomachi** with application to membranes and filters (U. Penn.
- **Nanoengineering surfaces** for probing viral adhesion (UC Davis)



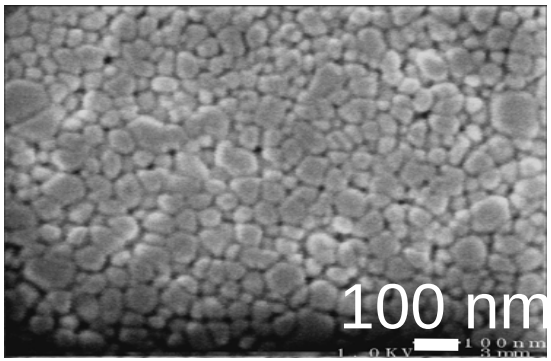
Energy: Schematic design of the nanorod-polymer solar cell

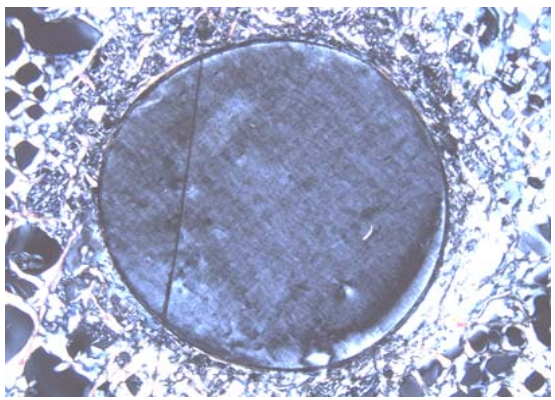


transmission electron micrograph of a CdSe nanorod at the bottom

(courtesy P. Alivisatos, Univ. California, Berkeley; and Nanosys, Inc.).

Angstrom Medica's nanostructured calcium phosphate technology for bone-based orthopedic implants





NanOss™ Calcium Phosphate Nanocrystals

$Ca_{10}(PO_4)_6(OH)_2$ *and* $Ca_3(PO_4)_2$

Composition and morphology of bone
Enhanced bioactivity and strength

Bone bonding in 2 weeks and osteointegration in 4 weeks because the nanostructure closely match that found in human bone

Angstrom Medica received SBIR in 2003 (NSF-0232733) and 2004 (NSF-0349884)

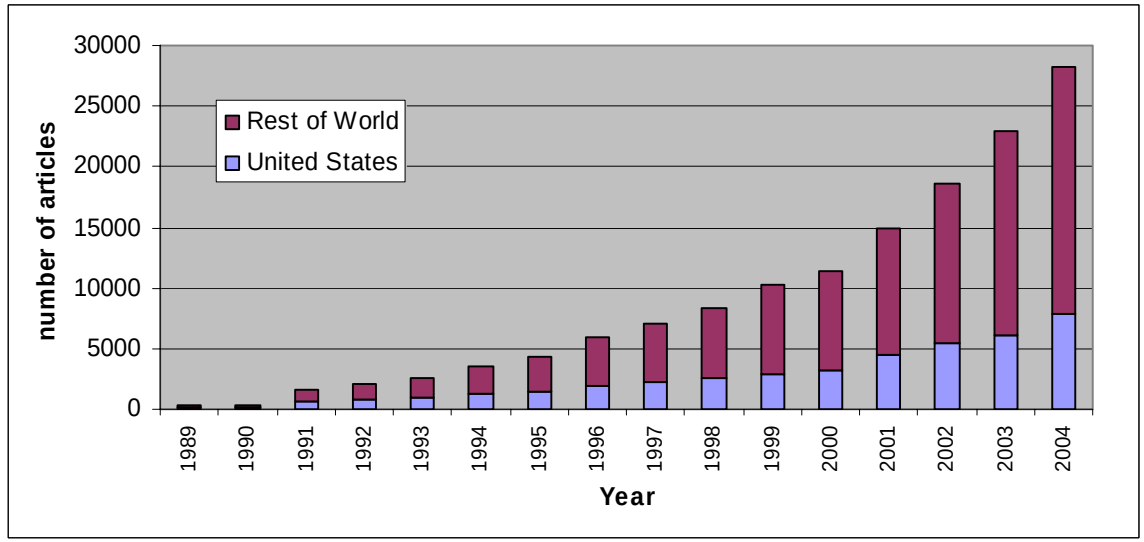
The product received "marketing clearance" from FDA in 2005

Exponential growth; About half of the highly cited papers in key journals originate in U.S.

("nano*" keyword search, after NNI Supplement Budget Report, 2006)

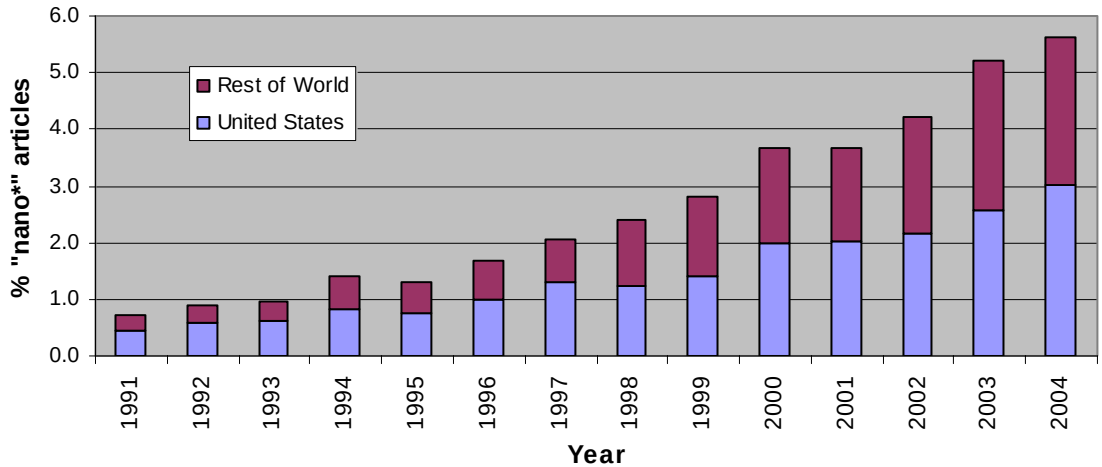
ISI Web of Science Database with 5400 professional journals

- U.S. about 30% for all journal articles in 2004



- U.S. about 50% in high-impact articles (UCLA NanoBank)

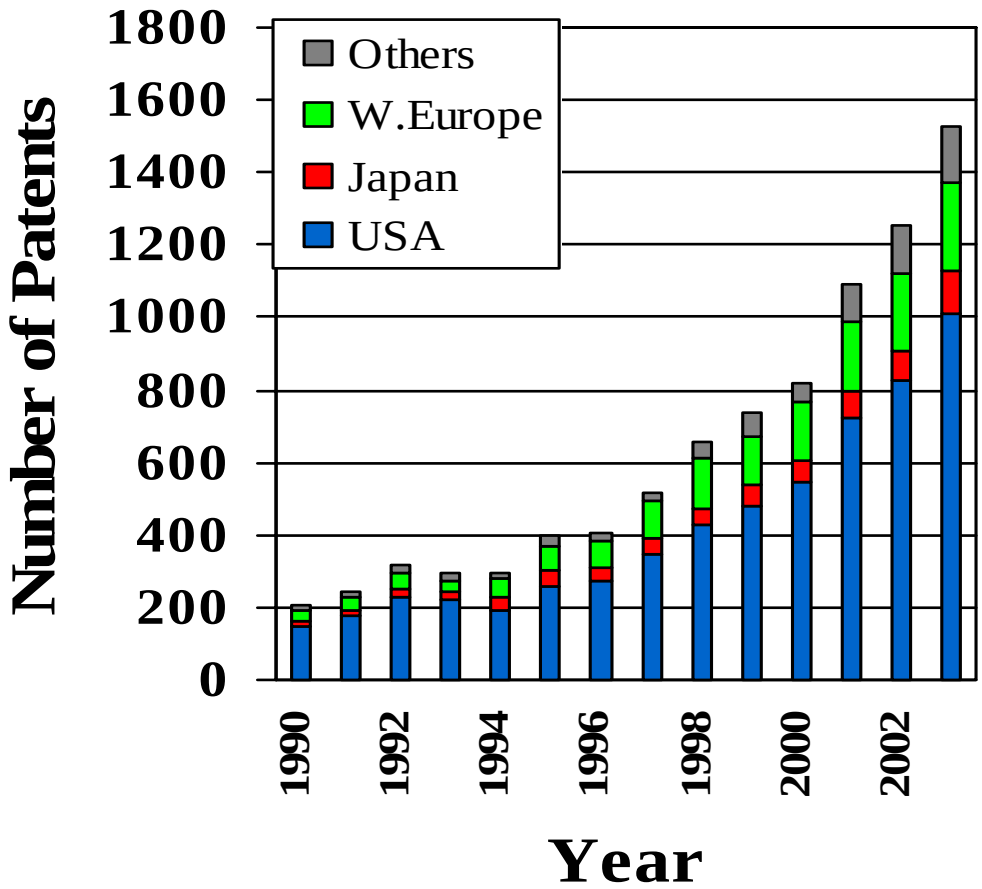
  Ex: recent survey on Nature, Science, and Physics Review Letters



US has about 61% of world NT Patents (USPTO database)

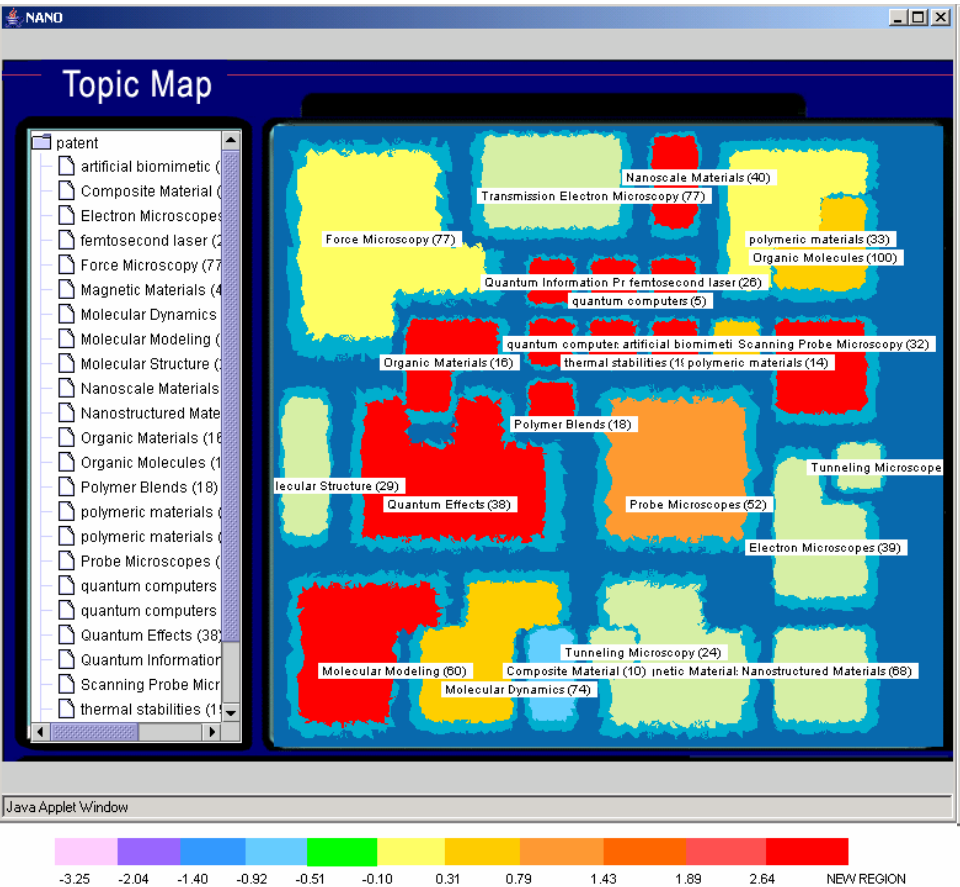
using “Title-claims”and “Full-text” search for nanotechnology by keywords
(using intelligent search engine, after J. Nanoparticle Research, 2004, Vol. 6, Issue 4)

Using “Title-claims” search: nanotechnology claims

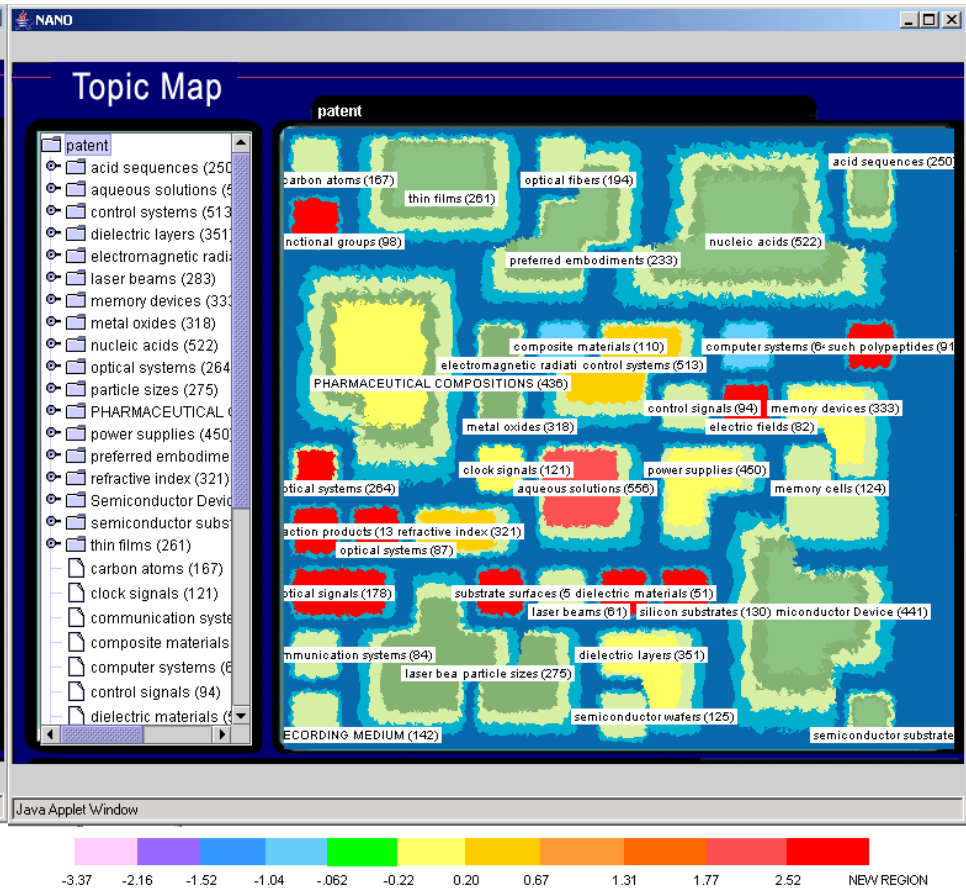


NSE content map analysis
grant – patent topic association

NSE Grant Content Map (2001-2002)



NSE Patent Content Map (2001-2002)



Region color indicates the relative growth rate (red – highest rate)*

(source: NSF sponsored research; J. Nanoparticle Research, 2005, Issue 3)

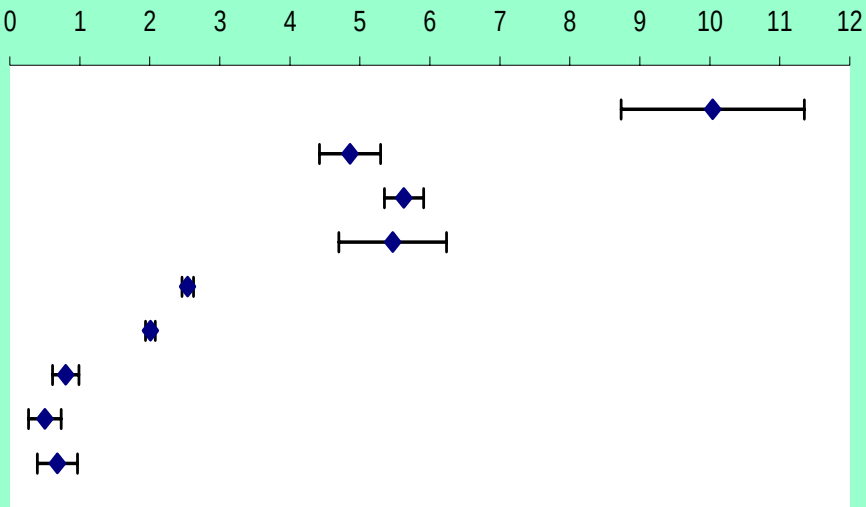
Number of citations of Nanoscale Science and Engineering patents

(analysis NSF sponsored research and USPTO patents)

Source	DF	SS	MS	F	P
Group	8	210748	26344	192.43	0.000
Error	2.00E+05	31210767	137		
Total	2.00E+05	31421515			

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

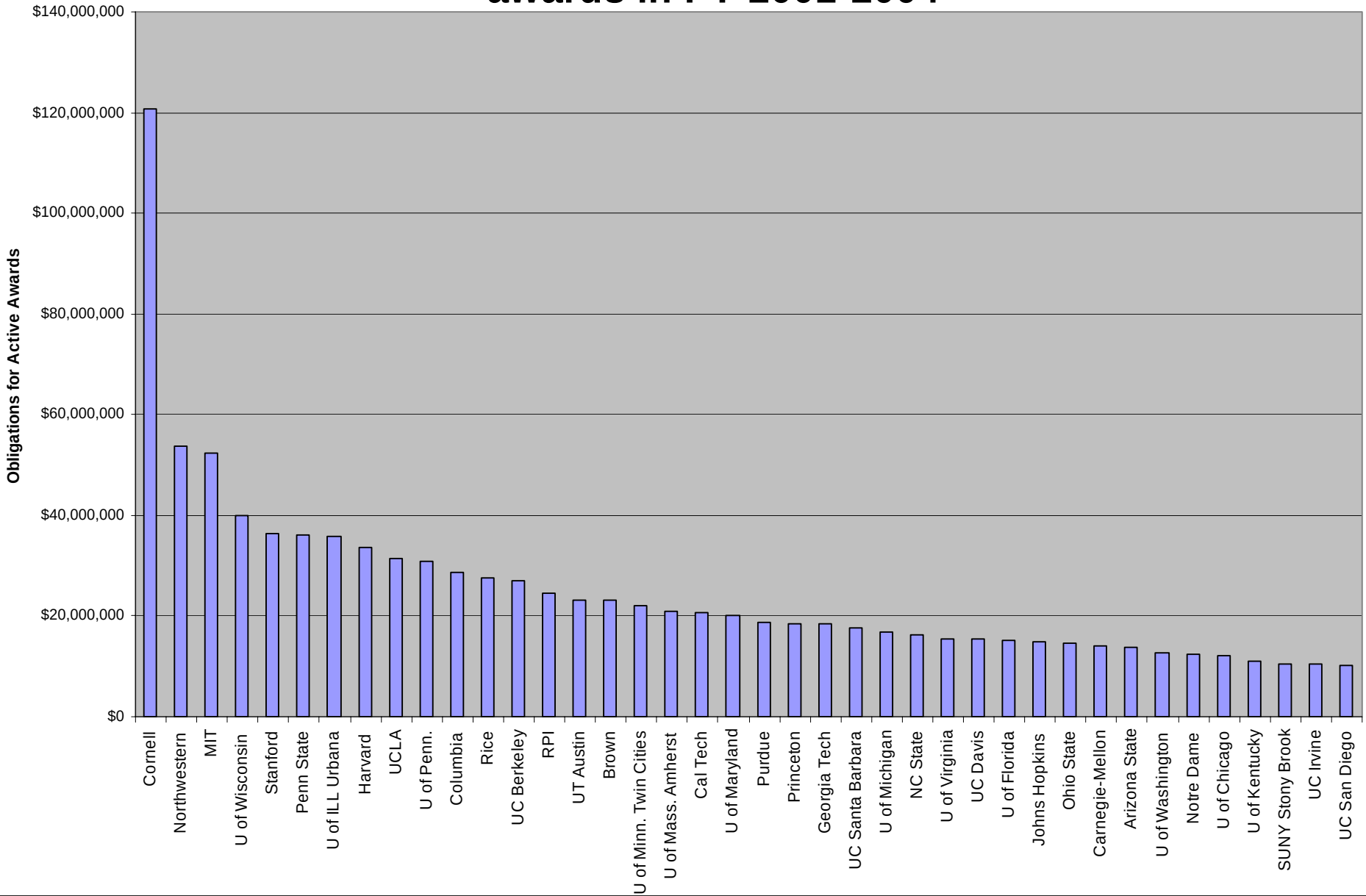


Pooled StDev = 11.70

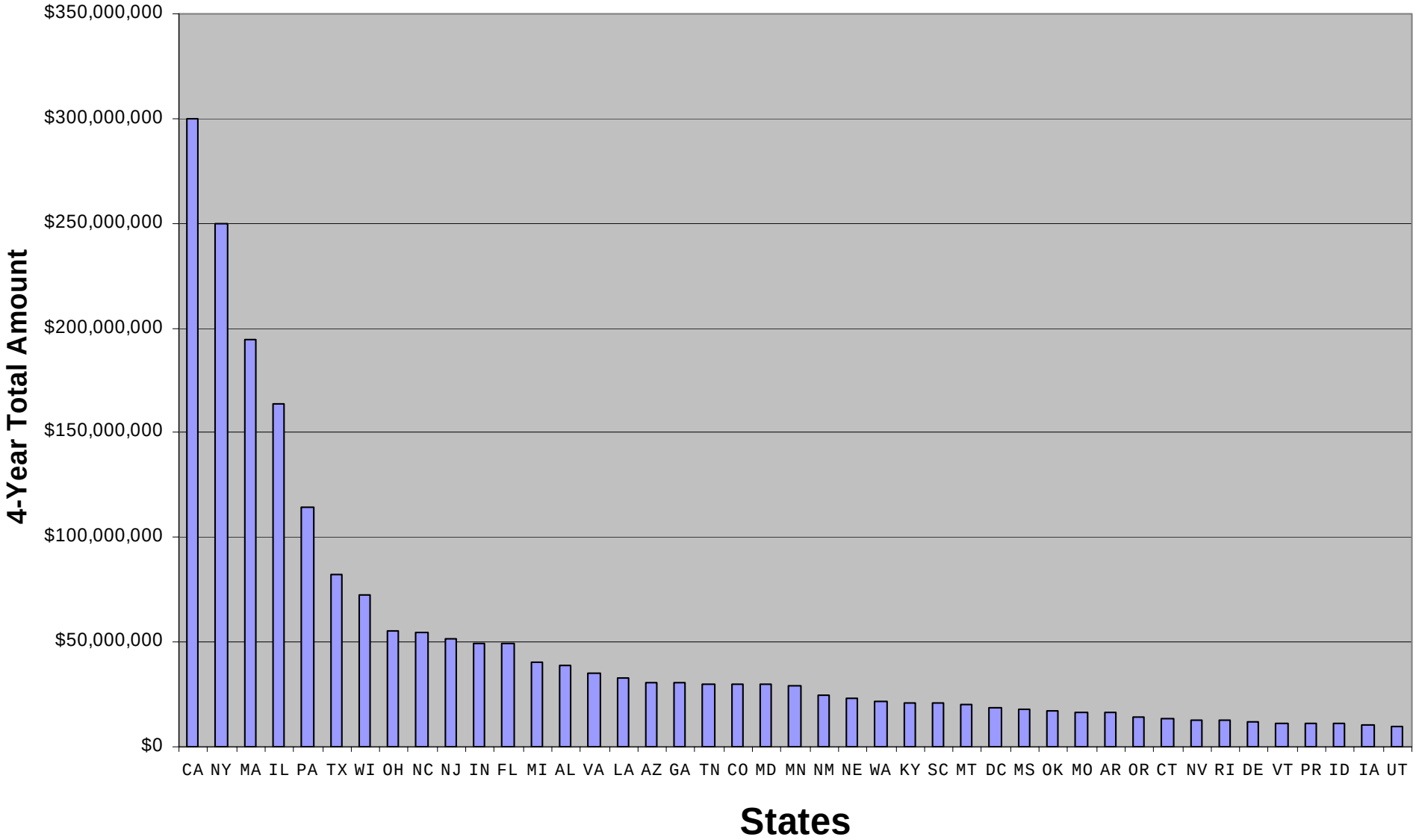
NSF Principal Investigator's patents had significantly higher number of cites measure than most other comparison groups. It shows the relevance of fundamental research for nanotechnology development.

(from J. Nanoparticle Research, 2005, Issue 3)

40 Universities with more than $10 million in active NSF awards in FY 2001-2004

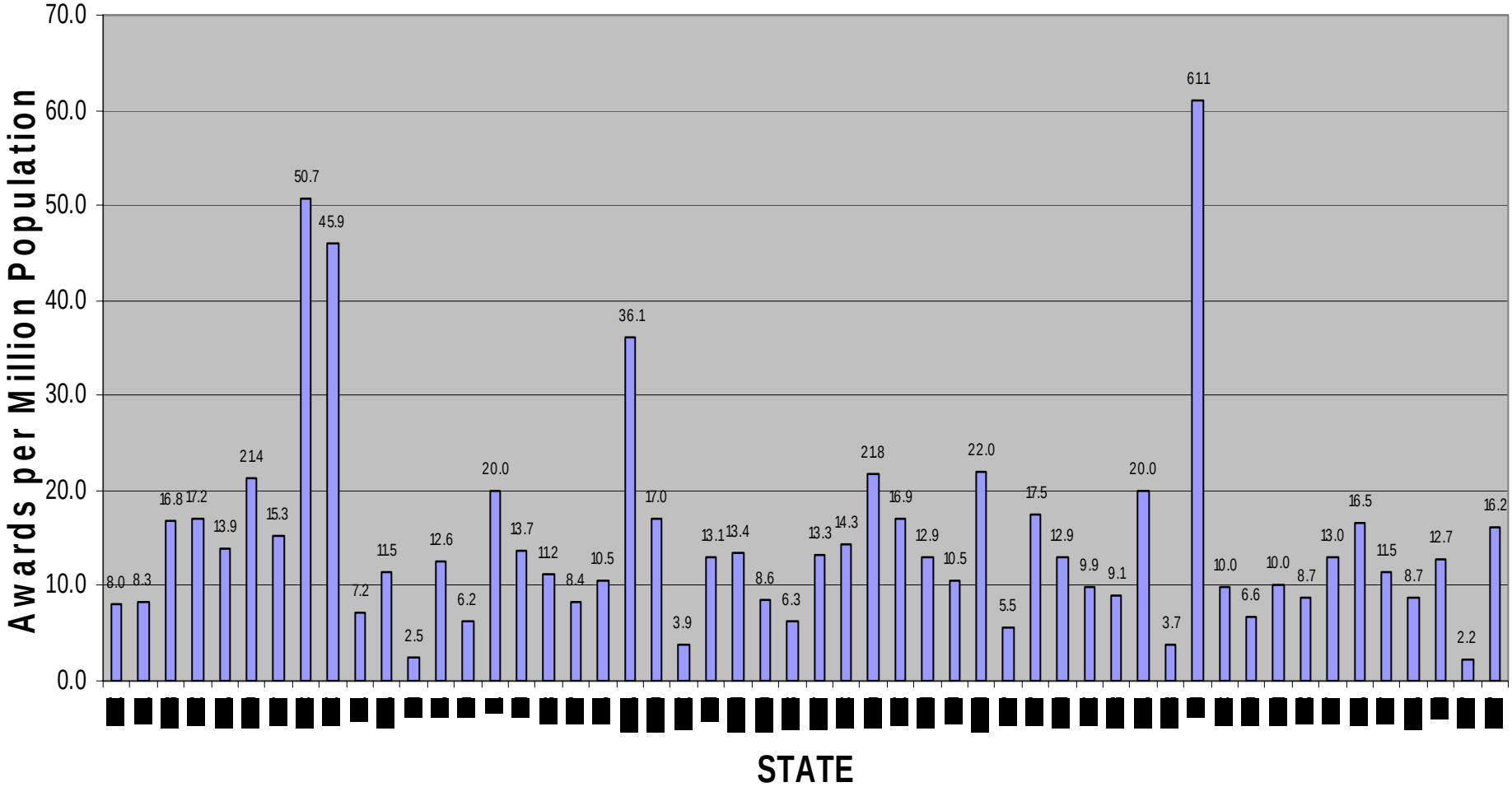


States (US) Awarded $10 Million or More by NSF for NEW Research Grants in FY 2001 - 2004

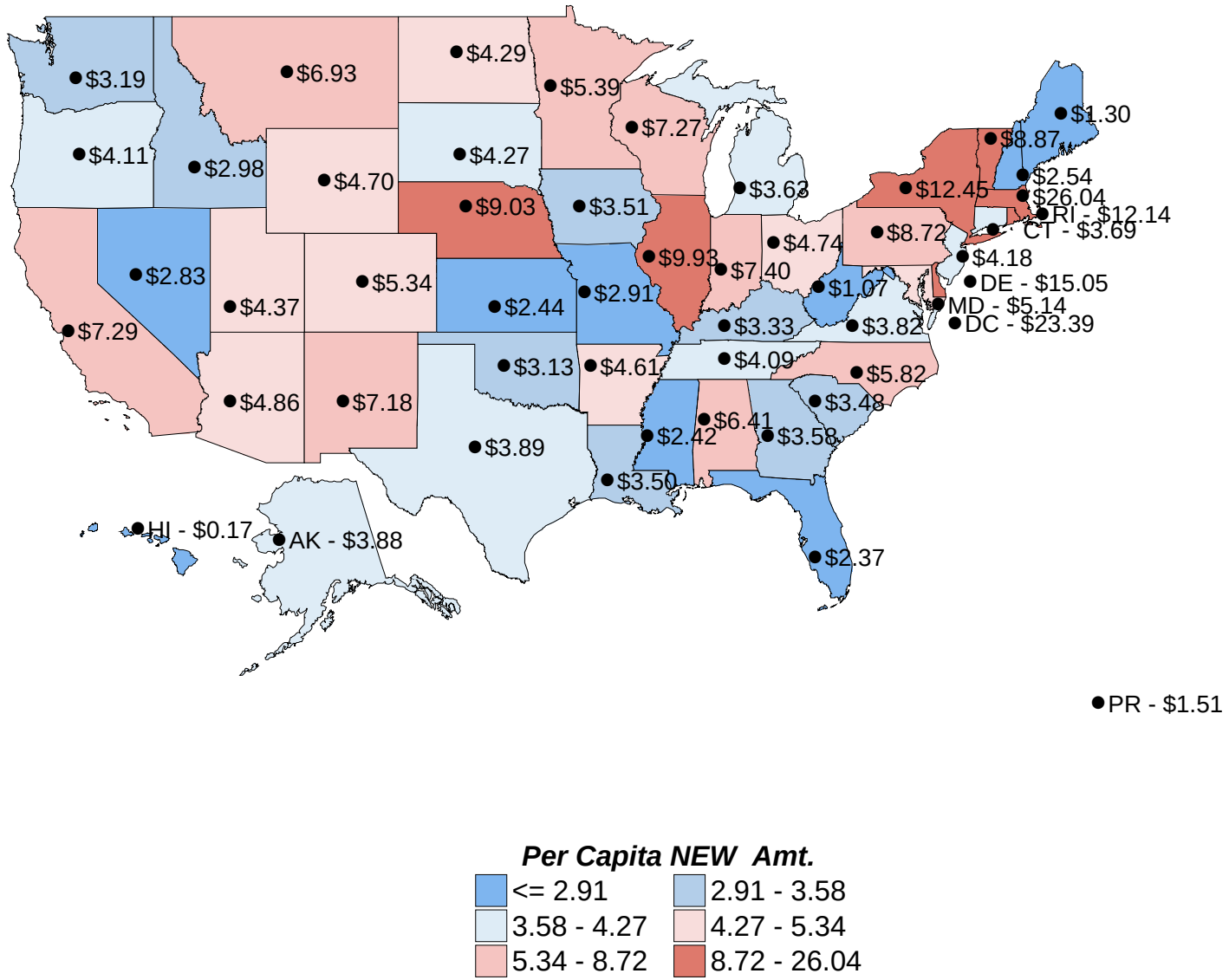


MC Roco, 4/18/05

Number of NEW NNI Awards per Million Population by State
NSF, FY 2001-2004

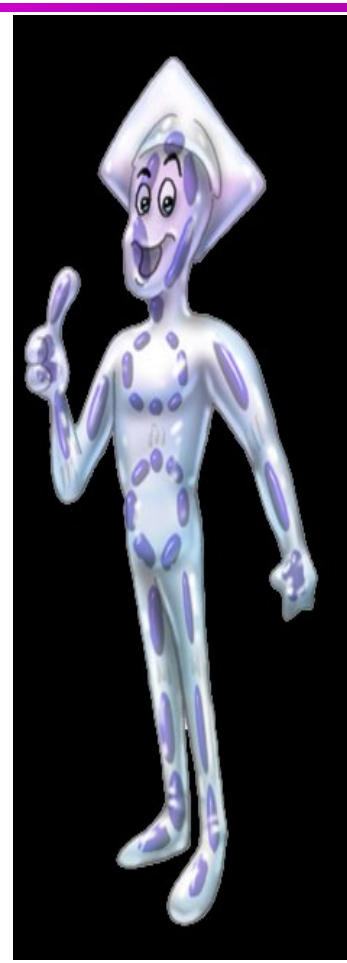


Per Capita NEW NNI Award Amount by State
NSF, FY 2001- 2004



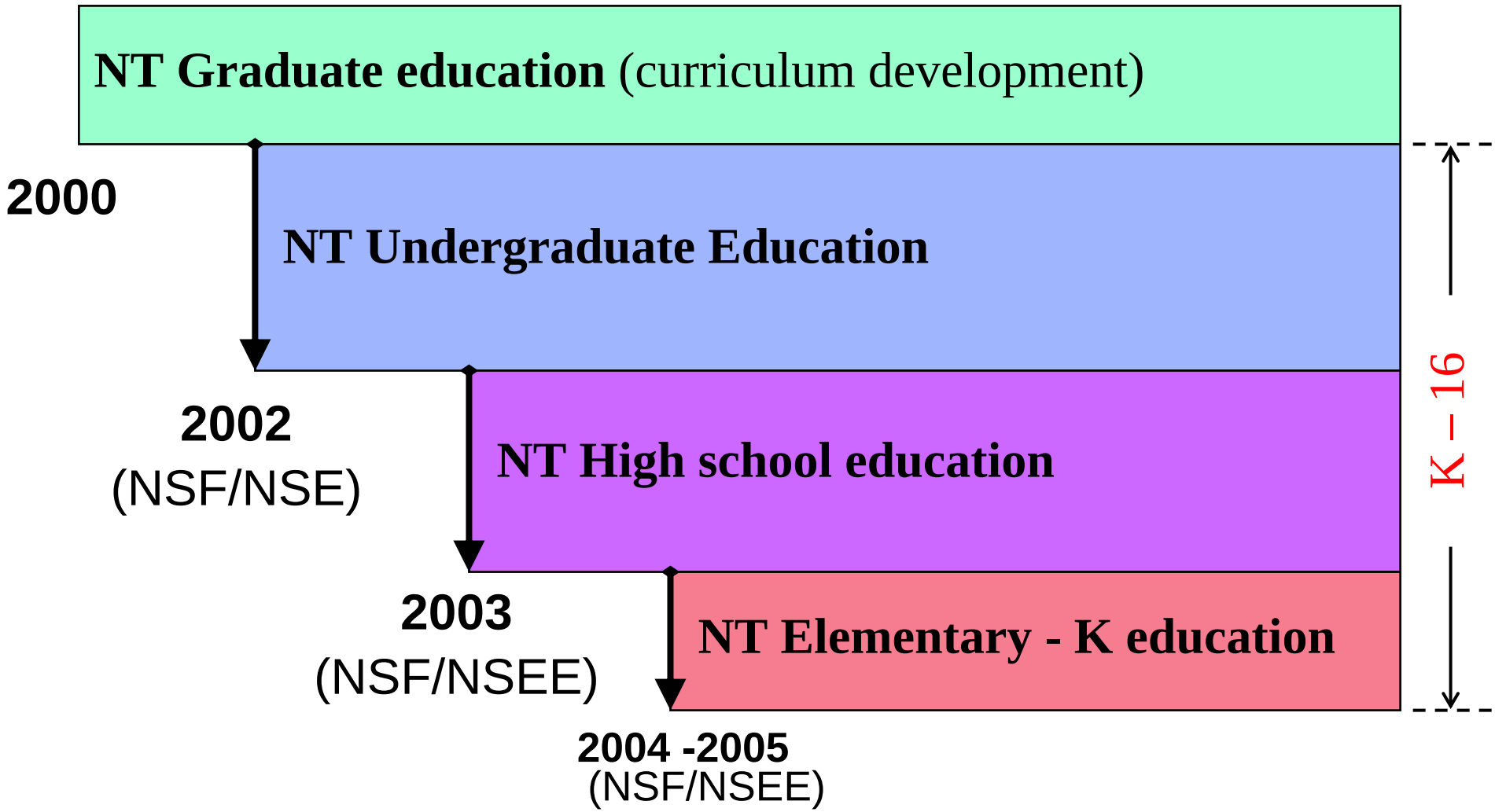
MC. Roco, 4/18/05

Objectives for nanotechnology education



- Fundamental understanding from the nanoscale:
  moving the foundation of learning from "microscale" to "nanoscale"
- Sharing similar concepts in various disciplines and relevance areas:
  unifying concepts earlier in education
- **"Reversing the pyramid of learning"**: learning first unifying concepts of matter/ biology/ information systems, and then averaging techniques specific to each discipline
- **Combine "depth" with "breadth"**
- **Broader accessibility and motivation to S&T**
- **Engineering has an increased role** because of its interdisciplinary, integrative, system approach and transforming characteristics. Nanotechnology deals with systems.

Introducing earlier nanotechnology education
(NSF: Nanoscale Science and Engineering Education)

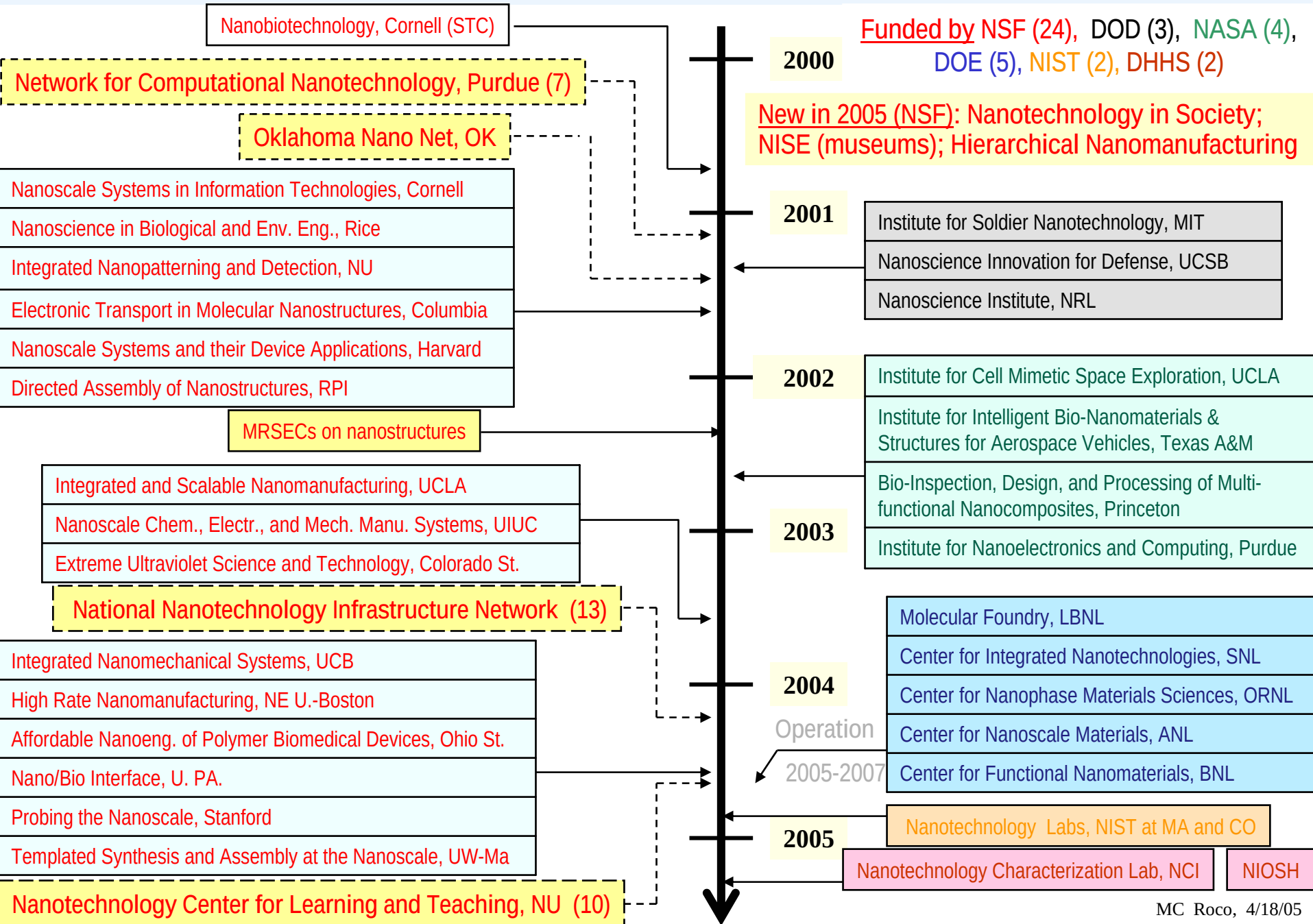


Nanotechnology education: What to do in the future?

- **Developing coherent, longitudinal program** with proper bridges between K-12, UG, G, postdoctoral, and continuing education, and encouraging earlier nanotechnology education
- **Targeting systemic changes K-16**
- Priority to unifying S&E and broad relevance courses
- Partnering for cross-disciplinarity, cross-relevance, and sharing resources (such as facilities and expertise, remote)
- Enabling the teachers
  - Training activities periodical available (ex: RET, at centers)
  - Create educational materials (modules, hand-on-kits, course notes)
  - Access to experimental facilities and specialized museums
- International education opportunities Young researchers to Japan and EU; PASI - Latin America, NSF-E.C.

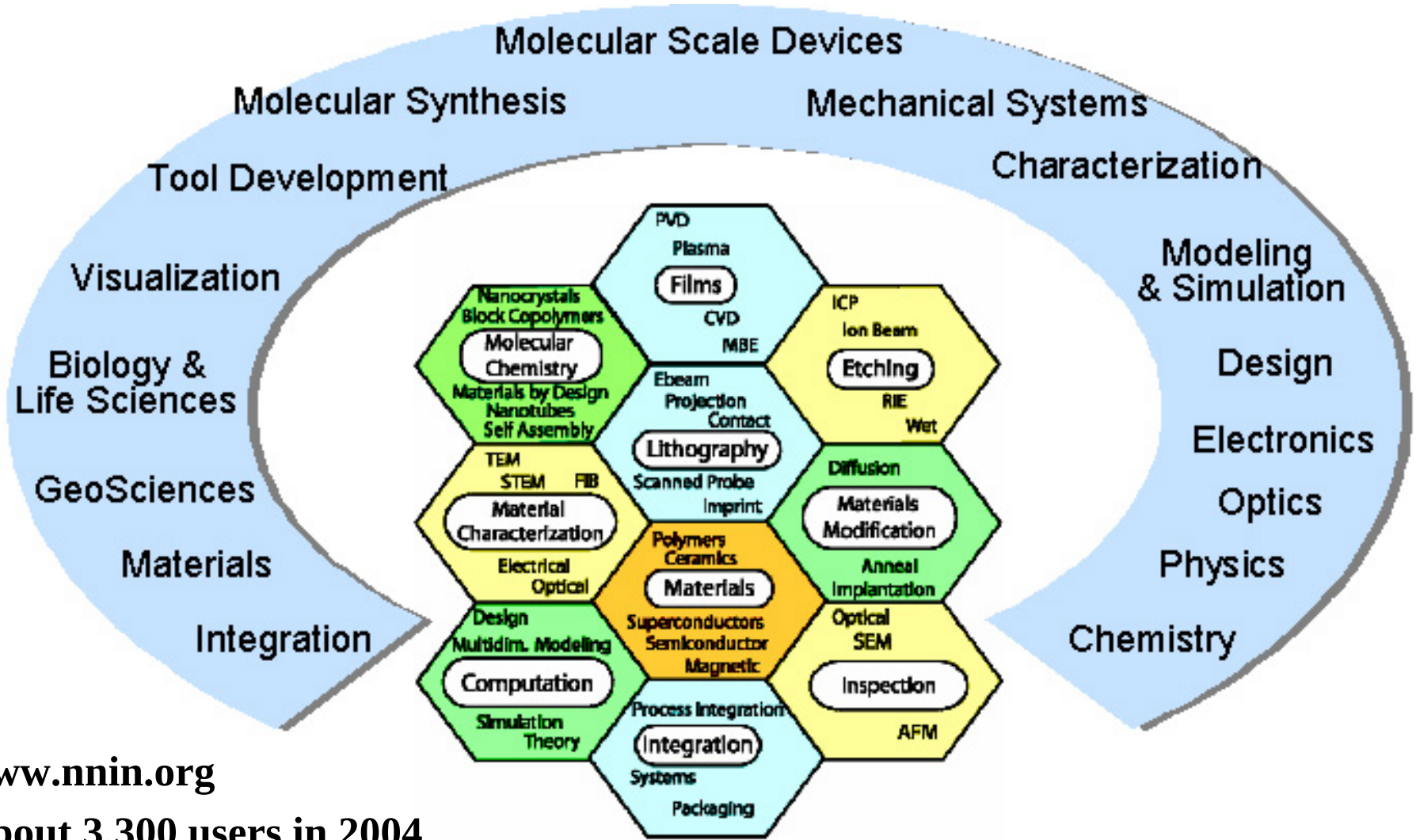
See Appendix B. NNI Activities in Education and Training

Infrastructure 2001-2005: 40 R&D Centers, Networks and User Facilities



MC Roco, 4/18/05

NSF NNIN Scope and Activities
(13 nodes, lead Cornell University)

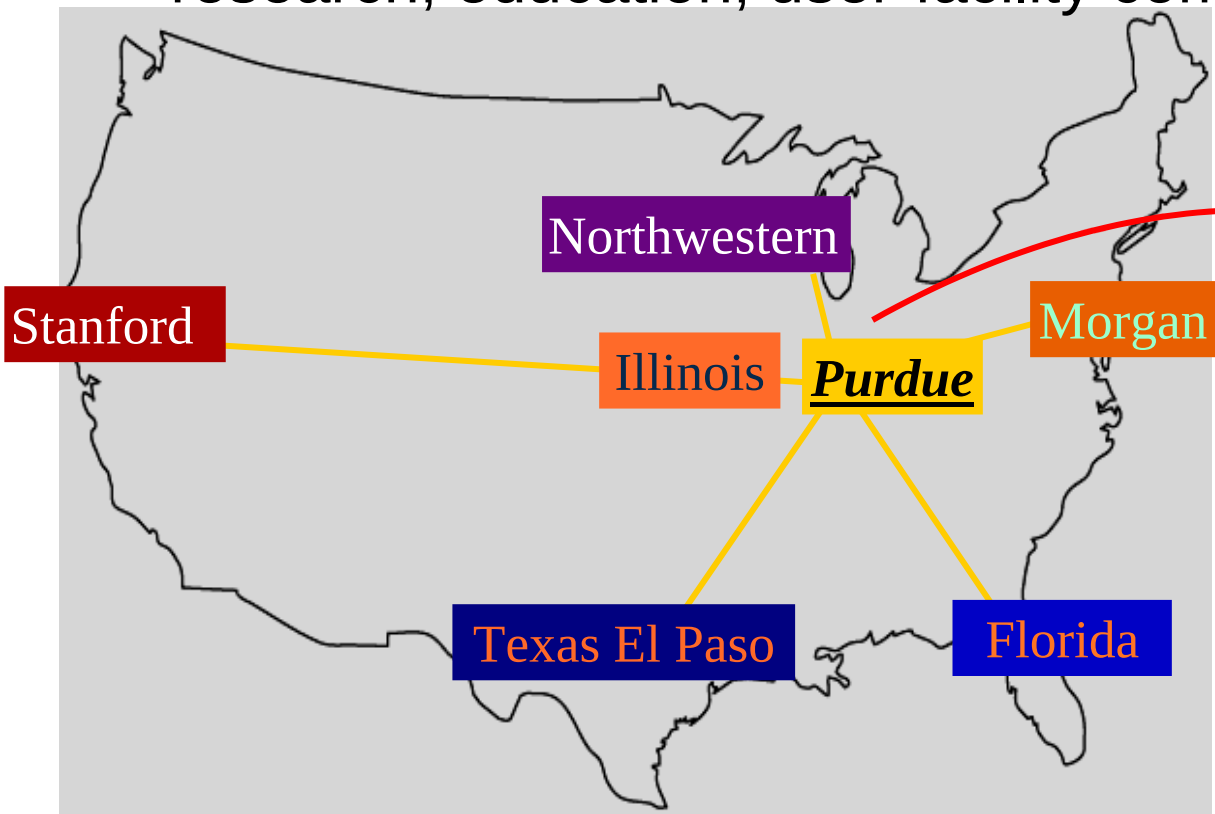


www.nnin.org

About 3,300 users in 2004

Network for Computational Nanotechnology (7 nodes, lead Purdue University)

Multi-scale, multi-disciplinary from “atoms to systems” research, education, user-facility components



www.nanohub.purdue.edu ; About 3,000 users in FY 2004

DOE Nanoscale Science Research Centers

Summer ‘03

Center For Nanophase Materials Sciences at ORNL

Spring ‘05

Center For Functional Nanomaterials at BNL

Spring ‘04

Molecular Foundry at LBNL

Spring ‘04

Center for Nanoscale Materials at Argonne

Spring ‘04

Center for Integrated Nanotechnologies

NSET: Support Transition of Fundamental Discoveries into Innovative Technology

- **Grand challenges (2001-2005) for technology base**

  Ex: nanomanufacturing – new NSF program $22M in FY 02-,
  2 centers established in FY 03, 1 in FY04, 1 in FY 05

- **Infrastructure for instrumentation, tools, laboratories**

  Ex.: 33 centers and networks by 5 agencies; NSF/DMR instrumentation program, NNIN, NIST metrology and standards

- **Prepare the workforce at all levels**

  Ex: Technological, Community Colleges and UE in PA (PFI award)

- **Various mechanisms for interaction with industry**

  Ex.: Fund collaborations with industrial partners (GOALI, centers);
  Provide the NNI results to industry; Provide user facilities;
  Assistance for instrumentation, standards, manufacturing;
  Direct technology transfer and funding industrial projects:
  SBIR/STTR all agencies

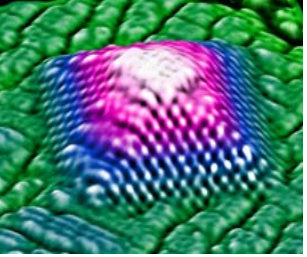
SBIR/STTR funding FY 2003-2004
(estimation)

	2001		2002		2003	
	Total Funding	**Total Projects**	**Total Funding**	**Total Projects**	**Total Funding**	**Total Projects**
DOD	20.9	104	32.2	157	32.2	144
DOE	4.5	34	1.0	2	5.8	30
NASA	5.5	31	12.8	48	2.4	28
HHS (NIH)	6.4	32	8.1	19	14.1	43
NSF	9.4	51	8.1	62	14.0	84
DOT	0.3	2	0	0	N/A	N/A
EPA	0.3	4	0.3	4	0.5	6
USDA	0.1	1	0.5	4	0	0
DOC	0.1	1	0.5	4	0.2	3
Totals	47.5	260	63.5	300	69.2	338

Funding - in million $

About 7% of the NNI R&D budget in FY 2003

About 3.5% of funding for all SBIR/STTR topics, all agencies



Planning for the future: expanding the frontiers of nanotechnology

Workshops for receiving input from the community (examples):

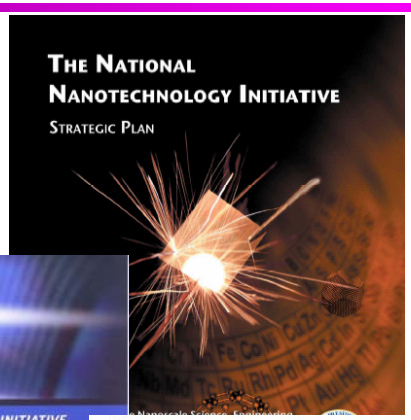
- Nanostructured materials "by design" - Workshops on 10/02, 06/03
- Catalysts that function at the nanoscale - Workshop on 06/03
- Nanoelectronics, optoelectronics and magnetics - Workshops 11/02, Fall 03
- CBRE protection and detection (revised in 2002) - Workshop 05/02
- Advanced healthcare, therapeutics, diagnostics - Workshops 06/00
- Nano-biology and medicine – Workshop Fall 03
- Environmental improvement - Workshops 06/02, 08/02, Spring 03
- Efficient energy conversion and storage - Workshops 10/02, 01/03
- Microcraft space exploration and industrialization - Workshop Fall 03
- Manufacturing processes - Workshops 01/02, 05/02
- Agriculture and food systems – Workshop 11/02
- Societal implications (II) - Workshop 12/03

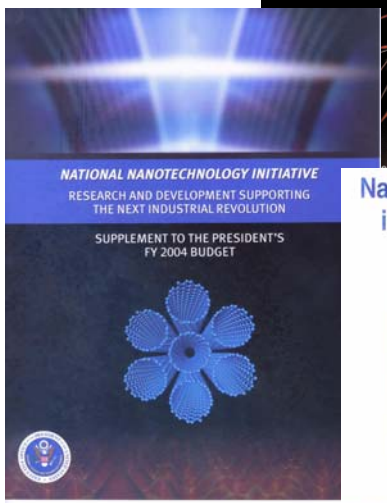
Defining the vision for the second strategic plan (II)

National Nanotechnology Initiative

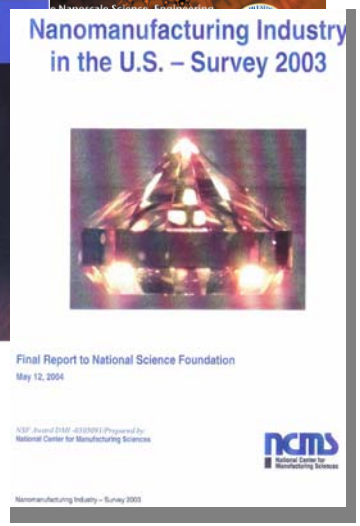
2004

2004:
10-year
vision/plan



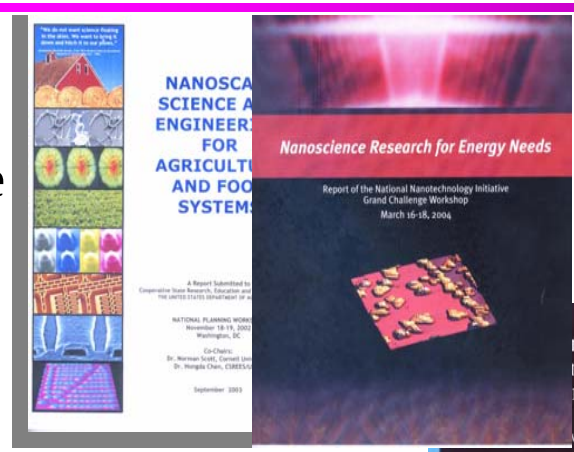


Government
Plan (annual)



Survey
manufacturing

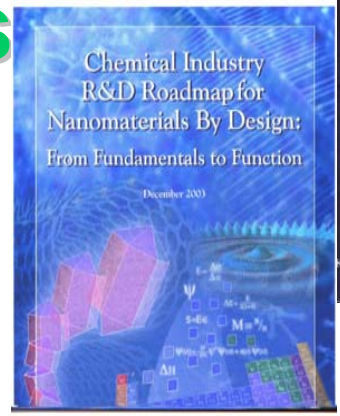
Agriculture
and Food



Energy

Societal
Implications
2004

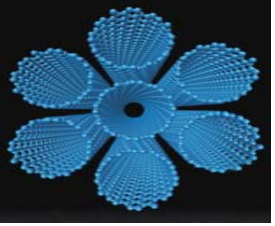
Reports



Other topical reports
on www.nano.gov

Dec. 2004: Update 10 year vision, and develop strategic plan

See Appendix C. List of NNI reports since 2001

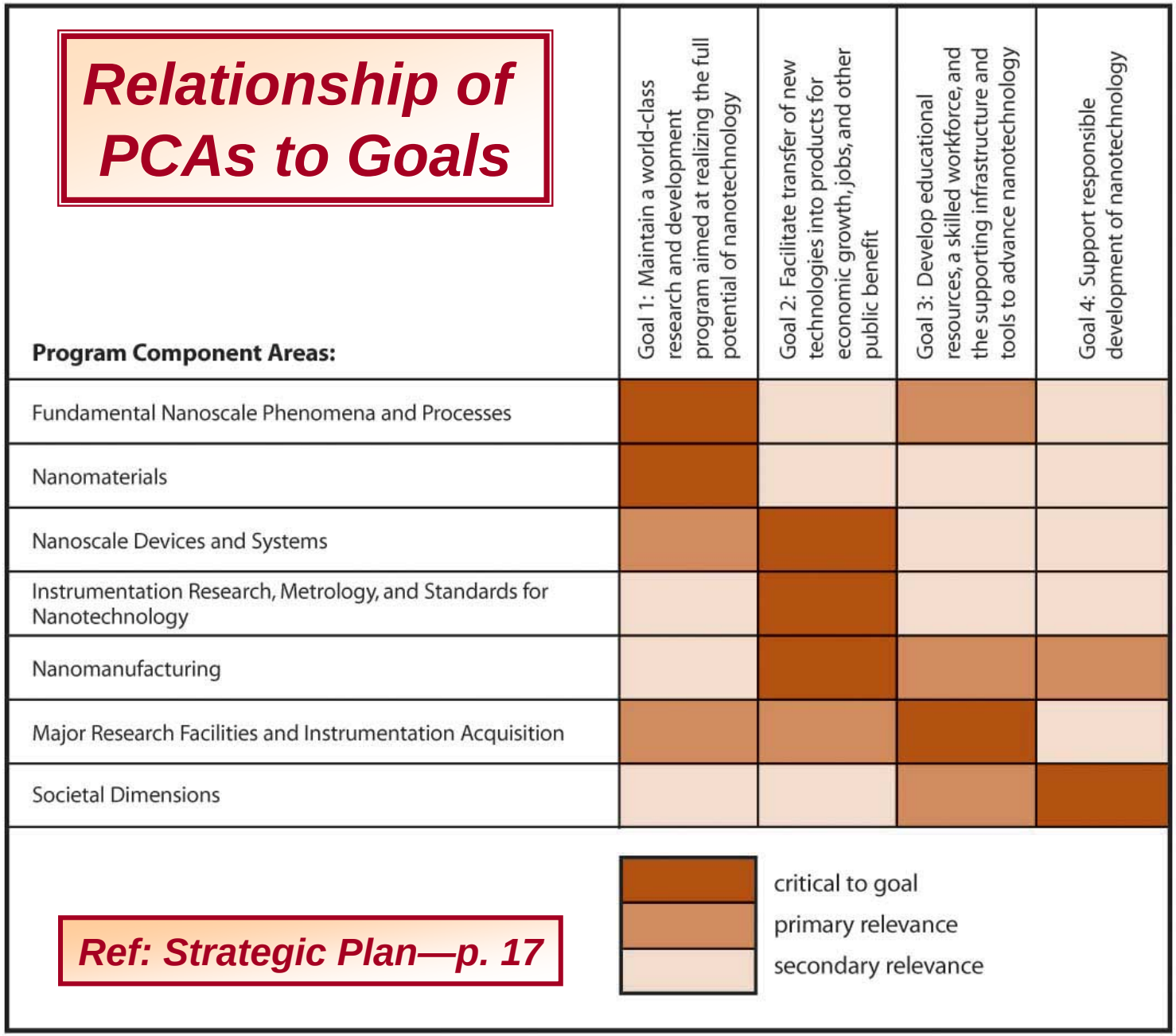


Second NNI strategic plan (2006-2010): Goals / Activities

Four main goals *(including areas of new focus for next 5 years)*

- Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology
  (Support R&D for active nanostructures and nanosystems)
- Facilitate transfer of the new technologies into products for commercial and public benefit *(Increase funding for technological innovation and multidisciplinary R&D platforms)*
- Develop educational resources, a skilled workforce, and the supporting infrastructure and tools needed to advance nanotechnology
  (Access to research facilities and educational opportunities in nanoscale science and engineering for half of the undergraduate and graduate students by 2010)
- Support responsible development of nanotechnology thru societal, environmental and health implications R&D, and interaction with the public
  (Address sustainability and life cycle of products)

Relationship of PCAs to Goals



Ref: Strategic Plan—p. 17

Relationship between PCAs and NNI Agency Missions

● Primary
□ Secondary
Agencies w/ nano R&D $$

	Fundamental Nanoscale Phenomena and Processes	Nanomaterials	Nanoscale Devices and Systems	Instrumentation Research, Metrology, and Standards for Nanotechnology	Nanomanufacturing	Major Research Facilities and Instrumentation Acquisition	Societal Dimensions
CPSC	□	□	●	●			●
DHS	●		●	●		□	
DOC (BIS)	□	●	●	●	□		
DOC (NIST)	□	□	□	●	●	□	□
DOC (TA)	□	□	□	□	●	□	●
DOC (USPTO)		●	●	●	●		
DOD	□	●	●	□	●	□	□
DOE	●	●	□	□	□	●	□
DOJ			●				
DOS							●
DOT	●	□	●		●		
DOTreas		●	●				
EPA	□	●	●	□	●		●
HHS (FDA)		□	●				●
HHS (NIH)	●	□	●	□	□		□
HHS (NIOSH)		□			□		●
IC	□	●	●		□		□
ITC		●	●		●		●
NASA	□	●	●		□	□	
NRC			●				
NSF	●	●	□	□	●	●	●
USDA	□	●	●		□		●

Ref: Strategic Plan – p. 18

Requested FY 2006 NNI Investment by Program Component Areas - each with specific research targets

2006 Planned Agency Investments by Program Component Area (In $ millions)								
	Fundamental Nanoscale Phenomena and Processes	Nano-materials	Nanoscale Devices and Systems	Instrumentation Research, Metrology, and Standards for Nanotechnology	Nano-manufacturing	Major Research Facilities and Instrumentation Acquisition	Societal Dimensions	NNI Total**
NSF	95	75	54	12	24	24	60	344
DOD	35	83	99	3	2	6	2	230
DOE	48	33	5	11	0	109	1	207
HHS (NIH)	46	17	67	6	0	1	8	144
DOC (NIST)	5	1	2	39	19	8	1	75
NASA	4	17	10	0	1	0	0	32
USDA	1	2	3	0	1	0	1	11
EPA	> 0.5	0	> 0.5	0	0	0	4	5
HHS (NIOSH)	0	0	0	0	0	0	3	3
DOJ	0	0	0	0	0	0	2	2
DHS	0	0	1	0	0	0	0	1
TOTAL	234	228	241	71	47	148	82	1054

See Appendix A. Goals and activities of key NNI agencies

After 3 years of NNI:
New R&D potential targets for 2015 (ex.)

2004 **2015**

Nanoscale visualization and simulation of 3D/m domains

= Micro domains with nano space and time resolutions

Transistor beyond/integrated CMOS under 10 nm

New catalysts for chemical manufacturing

No suffering and death from cancer when treated

Control of nanoparticles in air, soils and waters

MC. Roco, 4/18/05

After 3 years of NNI:
New R&D potential targets for 2015 (2)

2004 **2015**

Advanced materials and manu.: ½ from molecular level

Pharmaceuticals synthesis and delivery: ½ based on nano

Converging technologies from the nanoscale

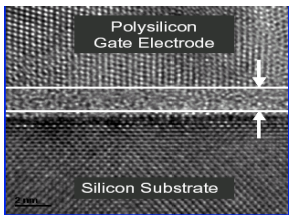
Including: artificial organs, manufacturing multidisciplinary platforms, etc.

Life-cycle biocompatible/sustainable development

Education: nanoscale instead of microscale-based

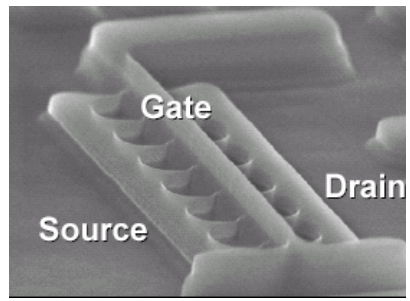
Challenge 2015: Transistor beyond/integrated CMOS under 10 nm

- In the 70s, 80s and 90s
  Geometrical scaling was the major driver
- In the 2003 - 2012 period (industry target)
  Use of novel physical phenomena to extend performance by equivalent scaling are the major drivers. Examples (2004):



1.2 nm gate oxide is ~5 Silicon atom layers thick

"Strained Silicon" - Separating the Silicon Atoms for Faster Electron Flow



Tri-gate Transistor

In addition, to explore beyond CMOS:

- New carriers instead of electron charge
- Integrate CMOS with other nanodevices
- New system architectures
- Integration with applications

Challenge 2015: To simulate engineering problems from basic principles at the nanoscale

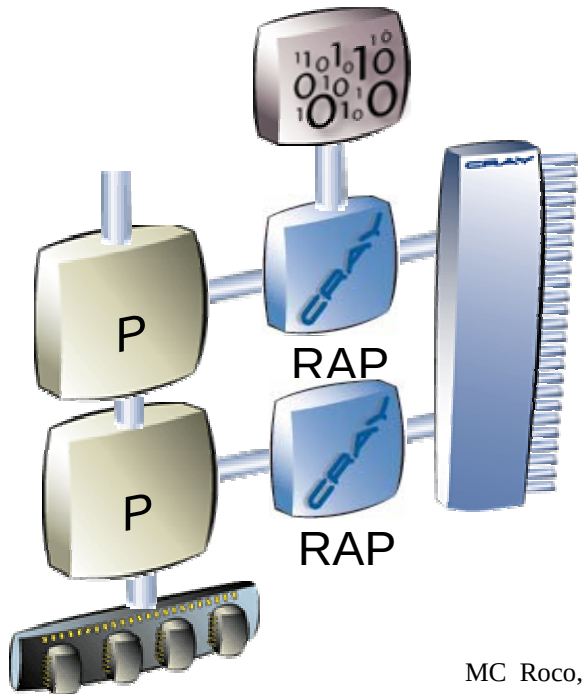
Using nanotechnology to build the highest speed processors

Capability 2004 (Cray X1):
50+ TFLOPS (fastest computer in the world)

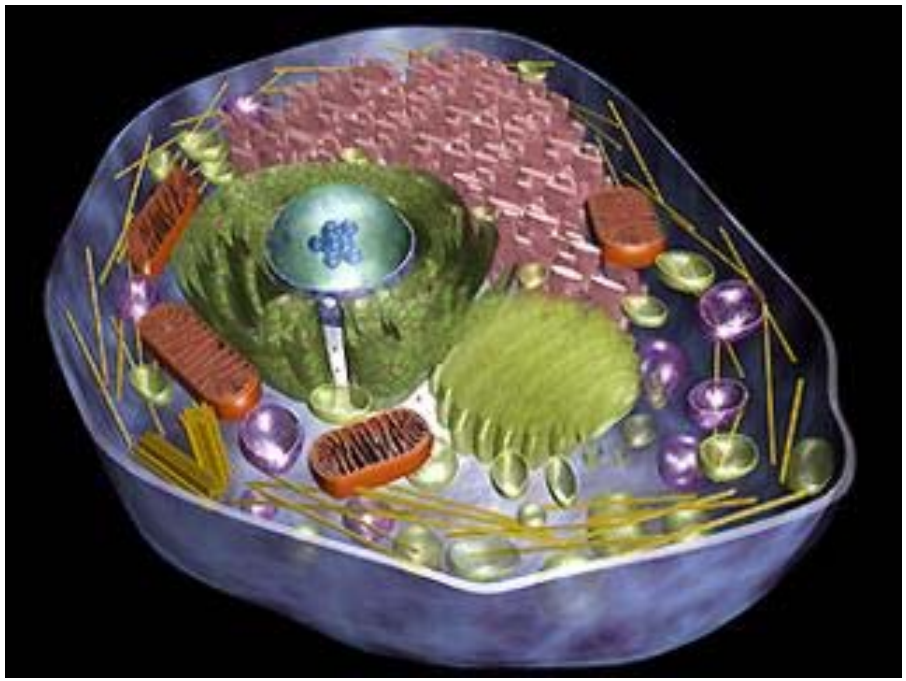
~ 2010 (Cray Cascade):
DARPA – NSF – DOE acad. support
1,000+ TFLOPS

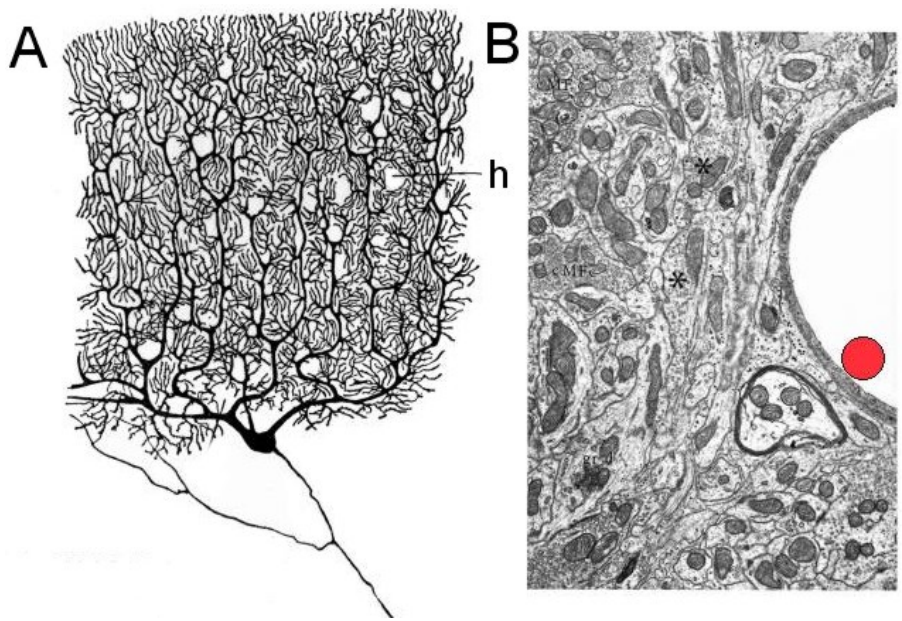
~ 2015 (Cray target):
10-100,000 TFLOPS

Using fast computers and reconfigurable computing for nanoscale S&E "application acceleration" (for 100x potential speeedup)



Challenge 2015: Specify the state of a cell and of nervous system from the nanoscale





R. Llinas, 2003

The Cell

– basic nanosystem of life

The brain

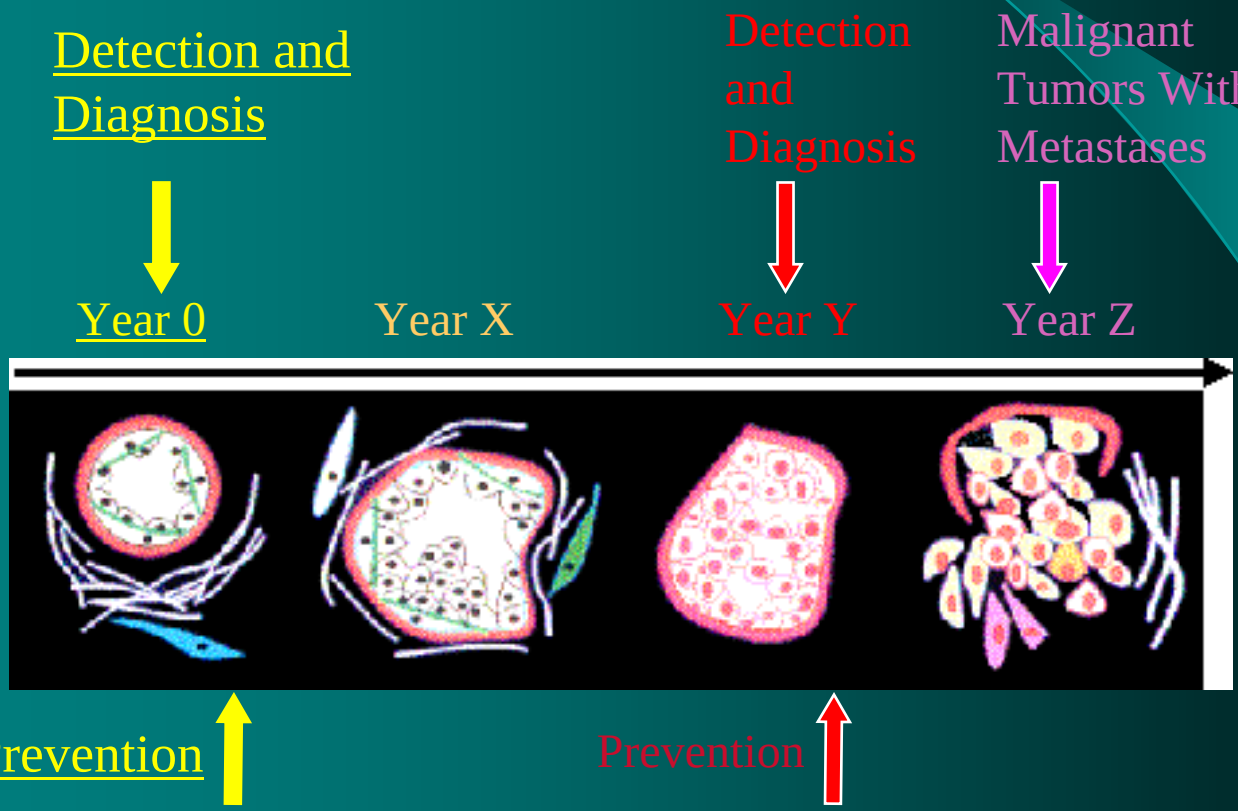
– complex system based on nanoscale processes

Measure and simulate, 3 dimensional, highly parallel, . . .

Challenge 2015: To Eliminate Suffering and Death Due to Cancer

"A Vision Not a Dream!" by using nanotechnology, A v. *Eschenbach, NCI*

Where We Want To Be ← Where We Are



Cancer results from accumulation of multiple genetic changes in a cells.

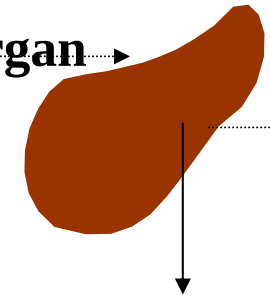
Nanotechnology will allow earlier detection and prevention (Year 0)

Examples of levels for intervention of nanobiotechnology *in human life extension*

Human

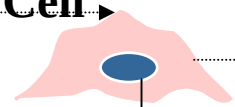
- Joint replacement
- Non-invasive and invasive diagnostics for rapid patient monitoring
- Cognitive-assist devices
- Targeted cancer therapies

Organ



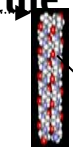
- Artificial organs
- Sensors for in vivo monitoring
- Localized drug delivery
- Neural stimulation
- Cardiac therapies

Cell



- Improved cell-material interactions
- Scaffolds for tissue eng.
- Genetic therapies
- Cell ageing
- Stem cell therapies

Molecule



- Localized drug delivery
- Gene therapy devices
- Self-assembly structures
- Fast diagnostic techniques

(NBIC Report, 2002)

NNI agencies and collaborations

- Interagency NSET:
  - Coordination in R&D planning
  - R&D investment (ex: fund complementary fields of research that are critical for the advancement of the nanotechnology)
  - Develop a balanced infrastructure (ex: portfolio of programs, development of new specific tools, instrumentation, simulation infrastructure, standards for nanoscale)
  - Correlate funding activities for centers and networks of excellence; cost-share high cost R&D activities; develop a broad workforce trained in the many aspects necessary to nanotechnology
  - Address related aspects of EHS issues
  - Avoid unnecessary duplication of efforts; others.
- The coordination also addresses NNI management issues, interaction with nanotechnology regional alliances, and international activities. NNCO - office of NSET for this purpose, and several NSET working groups provide support for partnerships.

NNI agencies and collaborations - Illustrations for FY 2006 -

- Nanomanufacturing (main partners NSF, DOD and NIST)

  NSF's Center for Hierarchical Nanomanufacturing will become fully operational in 2006, as will the complementary DOD MURI, and the NIST N^3F. NSET will also coordinate its activities in this area with the NSTC Interagency Working Group on Manufacturing Research and Development.

- Environmental, Health, and Safety (EHS) Research

  EPA, NSF, NIOSH, and USDA plan an expanded joint extramural research program The National Toxicology Program's initiative; NIOSH's "recommended practices" for safe handling of nanomaterials; NEHI monthly meetings

- Industry Liaison in Support of Technology Transfer and Commercialization

  The NSET Subcommittee will expand its activities to reach out to U.S. industry NSF's "Silicon Nanoelectronics and Beyond" activity DOD will place a new emphasis in 2006 on moving research innovations into applications in support of the DOD mission. NSET's informal working group on industry liaison will help to coordinate this interagency thrust.

- Standards Development

  Partner: American National Standards Institute's Nanotechnology Standards Panel (ANSI-NSP)

- Infrastructure Development

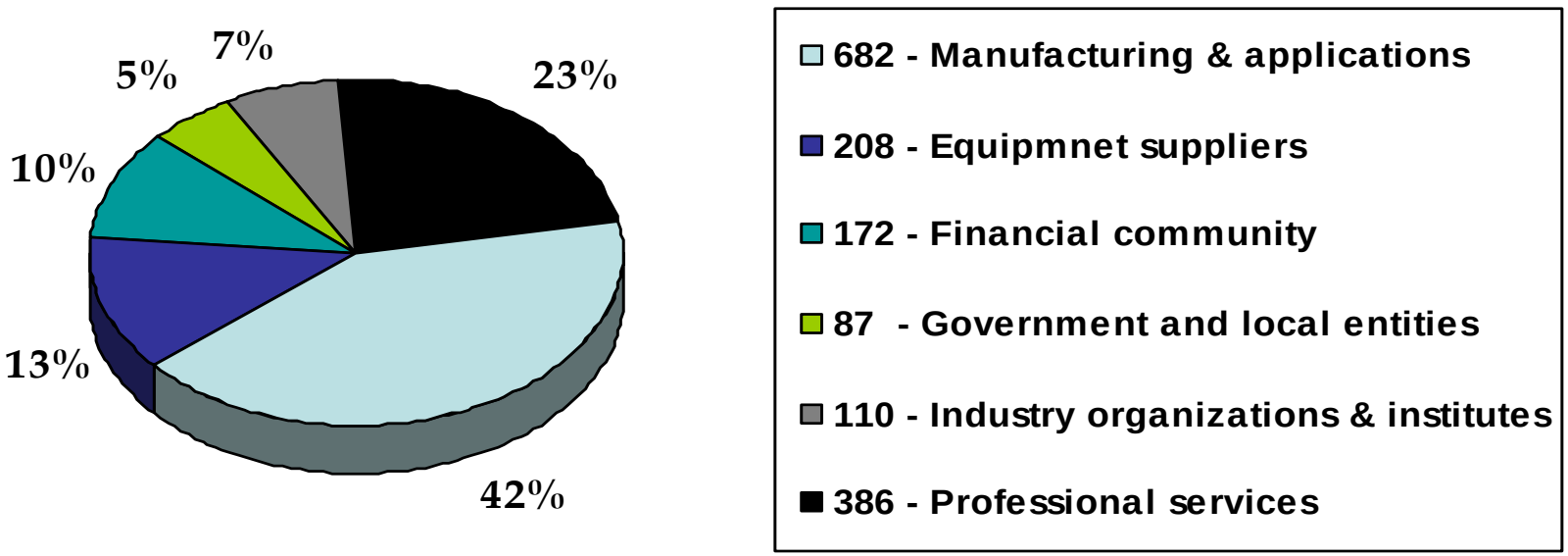
  Among R&D centers (NSECs, NNIN and NCN, centers and network with DOD, NASA and DOE);

  Modeling and simulation and nanoelectronics (DOD, NASA and NSF).

Industry surveys (1)

- **Companies working in nanotechnology**
  (Survey by Small Times in 2004, based on individual contacts and direct verification; partial NNI support)

  - In March 2004: 775 nanotech companies
    (475 products in 215 companies; 23,000 new jobs in small companies)
  - In March 2005: 1455 nanotech companies



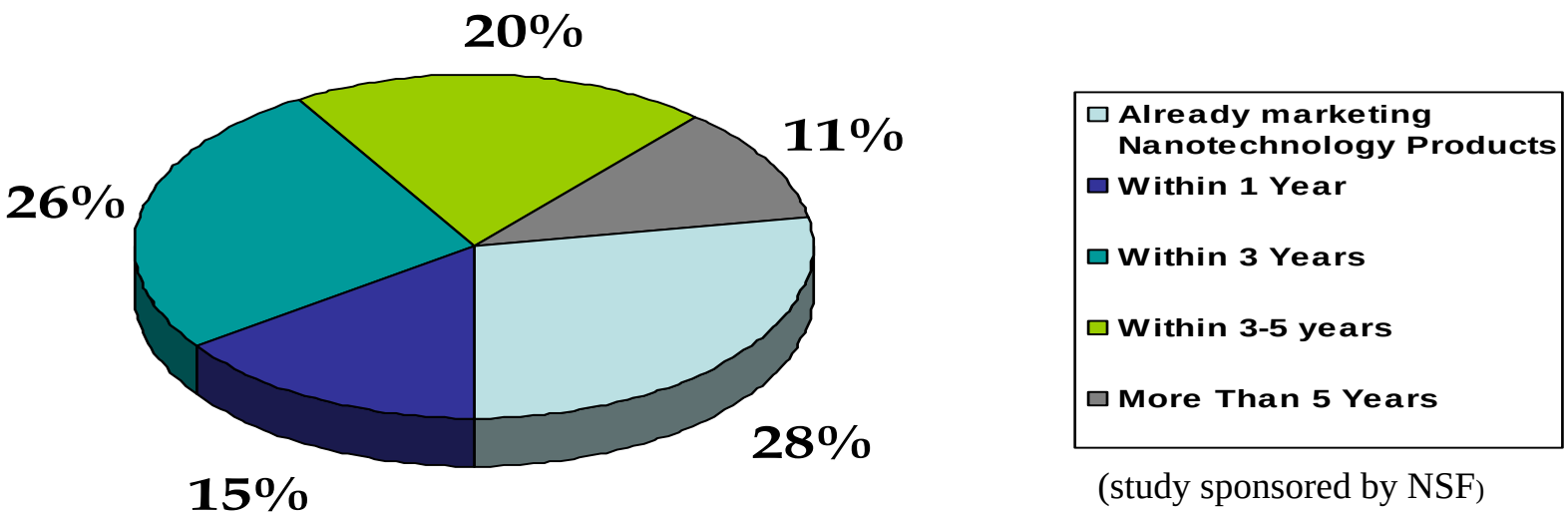
Industry surveys (2)

-19 of the 30 Dow Jones companies have launched nano initiatives; All Fortune 500 companies in emerging materials / electronics / pharmaceuticals

- Timeline for commercialization

Survey by National Center for Manufacturing Sciences:

81 manufacturing companies: 89% expect products in < 5 years



(study sponsored by NSF)

NNI-Industry Consultative Boards for Advancing Nanotech (1)

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-Biotechnology (BIO lead), 10/2004-**
  - Collaborative activities in key R&D areas
  - 2 working groups, R&D collaboration and EHS; joint funding

NNI-Industry Consultative Boards for Advancing Nanotech (2)

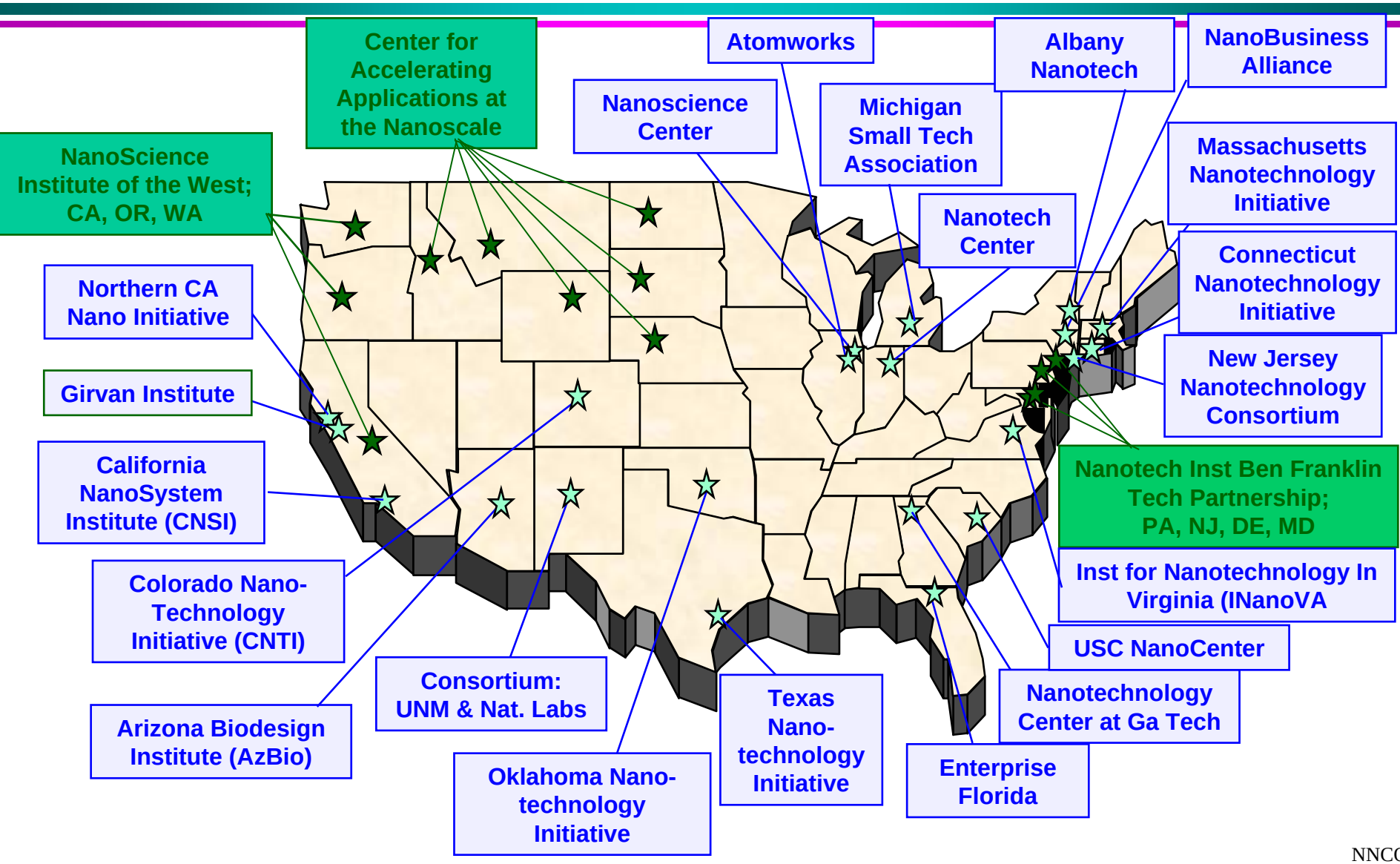
Key for development of nanotechnology, Reciprocal gains

In development

- **NNI - Pharmaceuticals (Phrma lead), 4/2004-**
  - **Joint road map for nanomaterials R&D**
  - **2 working groups, including on EHS**
  - **Use of NNI R&D results, and identify R&D opportunities**
- **NNI – Forestry and paper products (FS lead), 10/2004-**
  - **Workshop / roadmap for R&D**
  - **2 working groups (nanotech in industry, EHS)**
  - **Exchange information, use NNI results, support new topics**
- **NNI - Automotive Industry, 3/2005-**

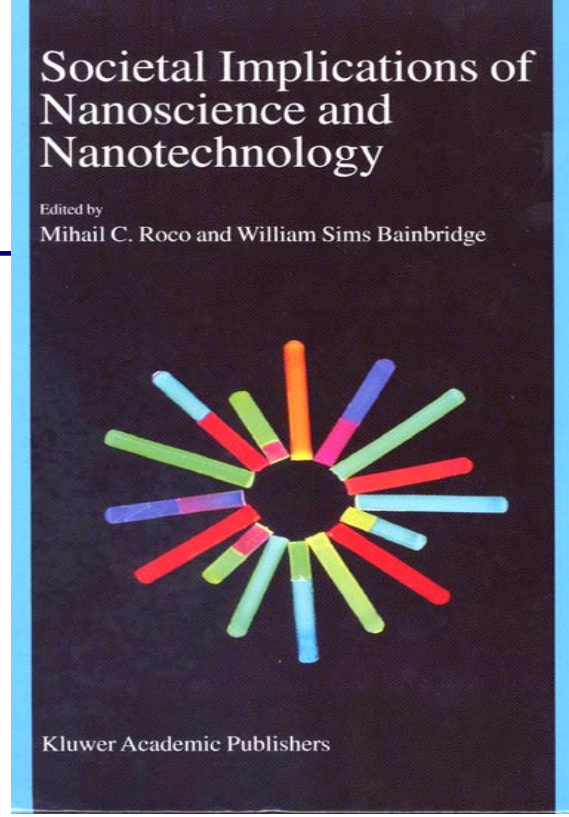
Other contacts: industry sectors such as aeronautics, plastics, food products, energy-related

Sampling of Current Regional, State, & Local Initiatives in Nanotechnology



NNCO

Societal Implications: Follow-up of the September 2000 report



- Make support for social, ethical, and economic research studies a priority:
  (a) New theme in the NSF program solicitations;
  (b) Centers with societal implications programs;
  (c) Initiative on the impact of technology, NBIC, HSD
- NNCO – communicate with the public and address Environmental, Health and and Safety issues, and unexpected consequences

http://nano.gov

- NSET's Nanostructures Environmental and Health Issues working group has been established in 8/2003, 12 agencies
- Workshop with EC (2001); Links to Europe, Americas, Asia; International Dialogue (26 countries, NSF-sponsored)

Key issues in long term

- Respect human right to: access to knowledge and welfare; human integrity, dignity, health and safety
- Balanced and equitable R&D nanotechnology investment
- Environment protection and improvement (water, air, soil) Sustainable development, life-cycle of products, global effects (weather), eliminate pollution at the source
- Economic, legal, ethical, moral, regulatory, social and international (developed-developing countries) aspects Interacting with the public and organizations
- Adaptive/corrective approach for a complex system

Immediate and continuing issues:

- *EHS in research laboratories and industrial units*
- *Harmonizing nomenclatures, norms and standards*
- *Primary data and methodology for risk analysis*

NNI activities
for Environmental, Health and other Societal Implications

A. Align R&D investment with societal implications

B. Evaluate and implement regulatory standards

C. Coordinated measures for EHS and ELES

D. Periodical meeting for grantees, setting research targets, and interaction with industry and the public

E. International collaboration (International Dialog for Responsible R&D of Nanotechnology)

(Details in Environmental Science and Technology, ACS, March 2005, Overview)

A. NNI coordination for R&D investments

- NSF research grants on environmental and societal implications
  All basic R&D areas, transport of nanoparticles; Programs since 2000
- NIH research on effects of nanoscale materials in the body
- EPA research grants on environmental implications of manufactured nanomaterials
- National Toxicology Program (NIEHS, NCTR, NIOSH)
  Project to study toxicity of nanotubes, quantum dots, and titanium dioxide
- NIST development of standards and measurements for nanoscale particles
- FDA and USPTO training and specialized activities
- USDA and DOE support fate and transport studies
- DOD supports exposure studies
- Solicitations (SI): NSF (ENV, SI), EPA-NSF-NIOSH, USDA, NIH

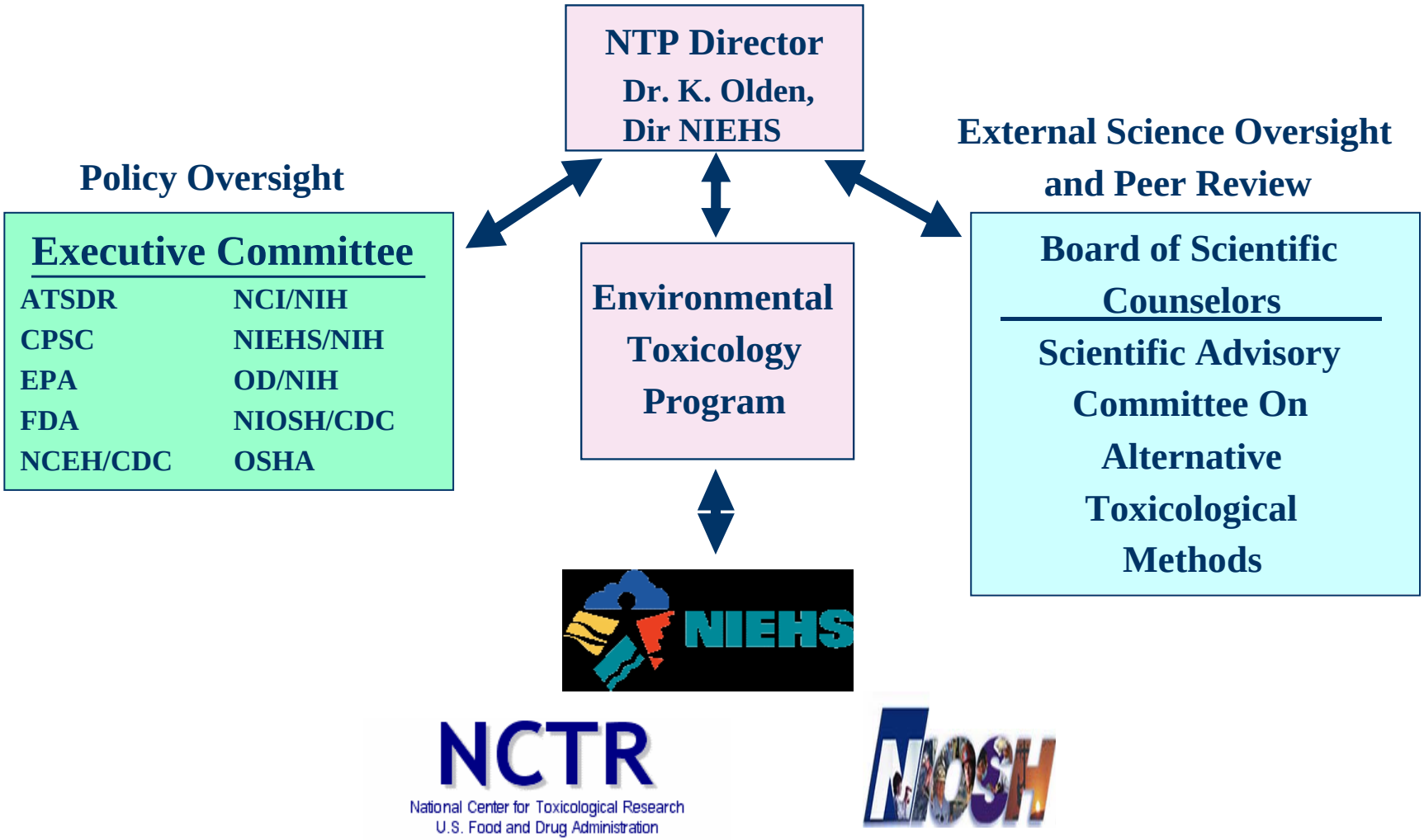
NSF environmental centers and interdisciplinary groups with research and education at the nanoscale

Center (details on www.nsf.gov/home/crssprgm/nano/nni01_03_env.htm)	**Institution**
Fundamental Studies of Nanoparticles Formation in Air Pollution	Worcester Polytechnic Institute ($2.7M)
Center for Advanced Materials for Water Purification	University of Illinois at Urbana ($20.1M)
Center for Environmentally Responsible Solvents and Processes	University of North Carolina at Chapel Hill ($25.0M)
Nanoscience in Biological and Environmental Engineering (estimated 50% in environment)	Rice University ($11.8M)
Environmental Molecular Science Institute	Univ. of Notre Dame ($5M)
NIRT: Investigating Nano-carbon Particles in the Atmosphere: Formation and Transformation	University of Utah ($1.7M)
NIRT: Nanoscale Processes in the Environment - Atmospheric Nanoparticles	Harvard University ($1.6M)
Center for Advanced Computational Environment	SUNY Buffalo ($5.5M)
NIRT: Nanoscale Sensing Device for Measuring the Supply of Iron to Phytoplankton in Marine Systems	University of Maine ($0.9M)

NNI projects supporting toxicity research (examples)

Project	Agency, Institution
National Toxicology Program ($0.5M in FY 2004 to $5M in FY 2008)	NIH/NIEHS, FDA/NCTR, NIOSH
Particle characterization for health and safety ($1.7M in FY 2004 rto $2.3M in FY 2005)	NIOSH
Nanotechnology Characterization Laboratory ($5M/yr, part of $144M/yr NCI for FYs 2004-2008)	National Cancer Institute
Multidisciplinary University Research on Nanoparticle Toxicity	Department of Defense supported center
Molecular function at the Nano-Bio Interface (component on nanostructures and cell behavior)	NSF/NSEC U. Pennsylvania
Nanomanufacturing Center for Enabling Tools (component on safe manufacturing)	NSF/NSEC Northeastern University
Size Dependent Neural Translocation of Nanoparticles	NSF/SGER, Rochester University
Reverse Engineering Cellular Pathways from Human Cells Exposed to Nanomaterials	NSF/SGER

National Toxicology Program organization



Nanotechnology Characterization Laboratory (NCI) Concept of Operations

For comparison and characterization of nanomaterials intended for cancer detection, diagnostics, and therapeutics in humans.

Sources of Nanomaterials

- Cancer Centers of Nanotech Excellence (CCNEs)
- Academia
- NNI
- Small Business
- NCI, NIH, NSF
- DoD, DoE
- Unconventional Innovative Program (UIP)

NIST

Physical Characterization

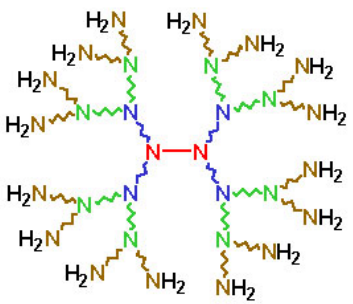
In Vitro

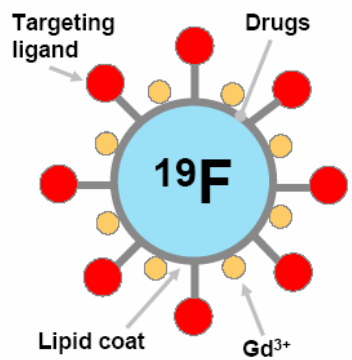
NCL

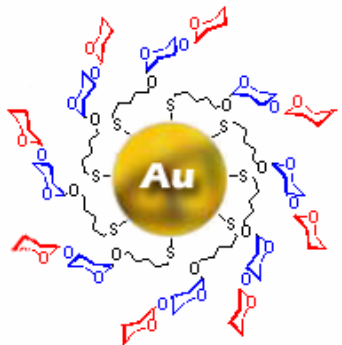
In Vivo

- Detection
- Diagnostics
- Therapeutics

Candidate Nanoparticles







NNI projects supporting social implications (examples (1))

Project	Agency, Institution
Nanotechnology and its Publics	**NSF,** **Pennsylvania St. U.**
Public Information, and Deliberation in Nanoscience and Nanotechnology Policy (SGER)	**Interagency,** **North Carolina St. U.**
Social and Ethical Research and Education in Agrifood Nanotechnology (NIRT)	**NSF,** **Michigan St. U.**
From Laboratory to Society: Developing an Informed Approach to NSE (NIRT)	**NSF,** **U. of South Carolina**
Social and ethical dimensions of nanotechnology	**NSF,** **U. Of Virginia**
Ethics and belief inside the development of nanotechnology (CAREER)	**NSF,** **U. Of Virginia**
All centers, NNIN and NCN have a societal implications components	**NSF, DOE, DOD and NIH** **All nano centers and networks**

NNI projects supporting social implications (examples (2))

Project	Agency, Institution
Citizen Learning, Deliberation, and Reasoning in Internet-Mediated Technology Policy Forums	**NSF, North Carolina State University**
Public Information, and Deliberation in Nanoscience and Nanotechnology Policy (SGER)	**Interagency, North Carolina State University**
An Integrated Approach to Teaching Nanotechnology and Society (NUE)	**University of Wisconsin**
Nanotechnology: Content and Context (NUE)	**Rice University**
Undergraduate Exploration of Nanoscience, Applications and Societal Implications (NUE)	**NSF, Michigan Technological U.**
Assessing the Implications of Emerging Technologies (IGERT)	**NSF, MIT**
Nanoparticle Science and Engineering (IGERT)	**NSF, University of Minnesota**

Four NSF centers with national outreach fully or partially dedicated to societal dimensions

- **Center for Nanotechnology in Society**
  (2005 -)
- **Nanotechnology Center Learning and Teaching**
  (2004 -)
- **Center for Nanotechnology Informal Science Education**
  (2005 -)
- **Center for Hierarchical Nanomanufacturing**
  (2005 -)

B. Regulatory and Research Topics for EHS

Source/ Inventory

Emission

air

NSF, EPA, USDA, DOE

plants

water

soil layers

sediment

Fate, transport & transformation

Personal Protection Equipment

NIOSH, OSHA & DOD

NIOSH, EPA, FDA, DOE

Exposure Events

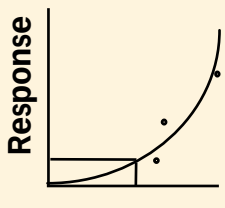
FDA & EPA

Uptake

NIH, EPA & DOE

Biokinetics

Toxicology



NIEHS, NCTR, NTP

All Agencies

Risk Characterization & Communication

All Agencies

Risk Mitigation

Modified after schematic
Mark Alper, LBNL

C. Current NNI coordinated measures for EHS

- Develop statement on "Best practices" for research laboratories and industry units (NIOSH, NSF, DOE, NASA, DOD), and identify gaps
- Map of EHS responsibilities and contacts in each NNI agency
- Establish response approach to an unexpected event or an emergency
- Identify protective equipment suitable for nanoparticles and other nanostructured materials (OSHA, NIOSH, other agencies)
- Support development of instrumentation and metrology (NSF, NIST)
- Develop a unified, explicit nomenclature (agencies, ANSI)
- Develop standards for nanotechnology (NIST, ANSI, IEEE, ASME)
- Collaborative activities with industry (SRC, CCR, Phrma, IRI)
- Identify research and educational needs (Fundamental, GCs)

NSET Group: "Nanomaterials Environmental and Health Implications"

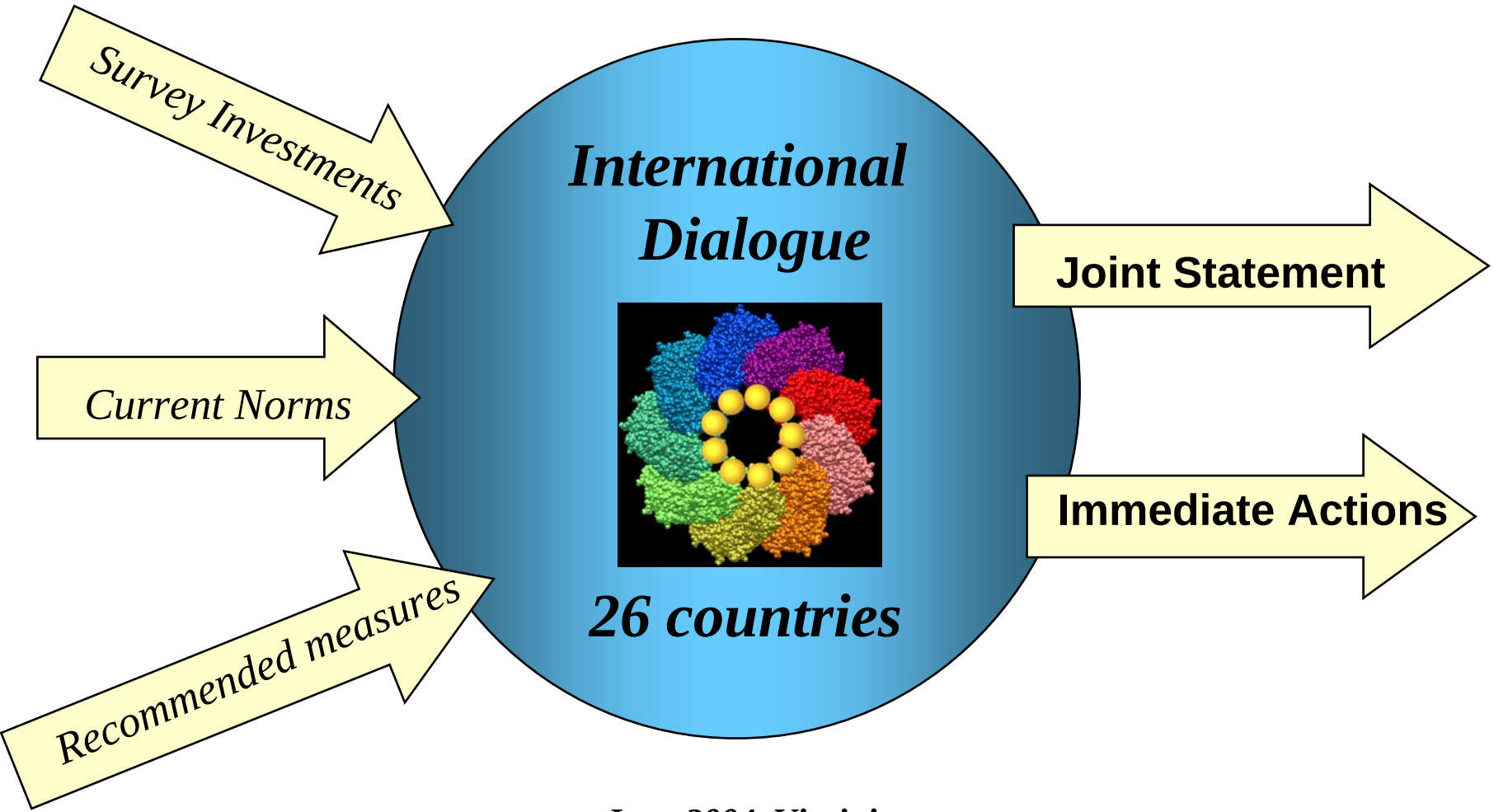
OSTP Group: "Risk Assessment of Nanotechnology" task force

D. NNI workshops on nano-environmental research

examples

- NSF, 9/2000: "Societal Implications of Nanoscience and Nanotechnology"
- NSF, 6/2002: "Nanoparticles and the environment" (grantees meeting, book)
- EPA, 11/2003: "Nanotechnology and the environment applications and implications" (grantees meeting, brochure)
- ACS, 3/2003: "Symposium on nanotechnology implications in the environment", New Orleans
- NNI, 5/2003: "Vision for environmental implications and improvement" ***(interagency, report)***
- NSET/NNCO, 8/2003: Review of Federal Regulations (report)
- NNI, 9/2003: Interagency : grantees meeting (report);
- Wilson Center, 10/2003: EPA and FDA regulatory functions (report)
- NSET, 12/03 "Societal Implications of Nanoscience and Nanotechnology (II)"

E. International Dialogue on Responsible Nanotechnology R&D



June 2004, Virginia

http://www.nsf.gov/home/crssprgm/nano/dialog.htm

MC. Roco, 4/18/05

International Dialogue on Responsible Nanotechnology R&D

Activities after the June 2004 International Dialogue on Responsible Nanotechnology (Virginia, U.S.)

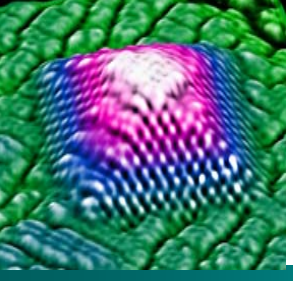
- October 2004/October 2005 - Occupational Safety Group
- November 2004 – OECD group on nanotechnology
- December 2004 – Meridian study for developing countries begins (next meeting in March 2005)
- December 2004 - International collaboration for nomenclature and standards has been initiated
- February 2005 – N-S Dialogue on Nanotechnology (UNIDO)
- May 2005 – Nano-world, MRS (Materials, Education)
- Spring 2005 – International Agreement? (host: EC)

NNI challenges

- Coherent long-term (5-10 year) programs: new priorities – how to handle budget constrains; support interdisciplinary research and education, flexible infrastructure, and broad societal implications; Nano-bio - in infancy
- Horizontal versus vertical S&T development: increasing technological innovation in the 2nd NNI Strategic Plan
- More responsible and effective in including public, industry and states perspectives
- Collaboration and synergism among agencies; Incentives for agency participation and proper reporting
- Need for bold system-oriented programs, particularly in mission-oriented agencies, focused on topics such as: the new catalyst, new transistor, conditioning the cell
- International collaboration and competition

Appendix A.
Agencies with major NNI investment

- NSF
- DOD
- DOE
- NIH
- NASA
- NIST
- EPA
- NIOSH
- USDA
- FDA
- USPTO

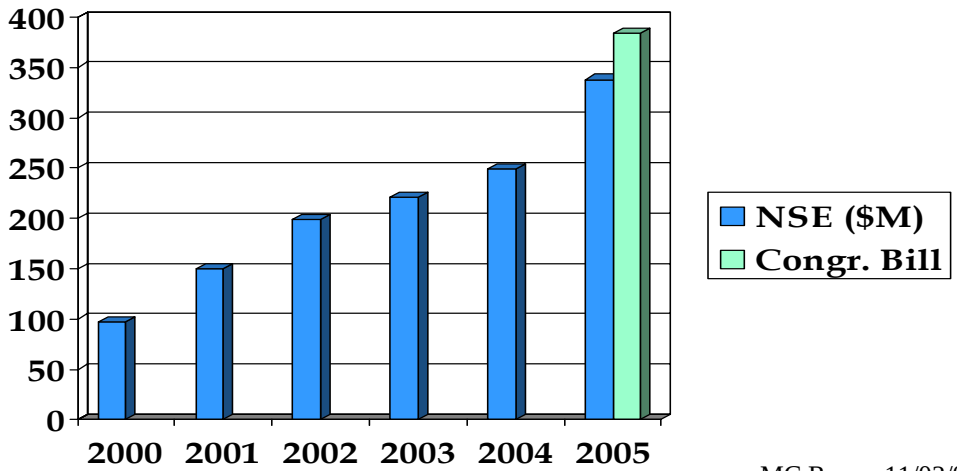


NSF - a pioneer at the international level in Nanoscale Science and Engineering

FY 2005: ~ **1/4 of Federal** and **1/12 of World Investment**

- **Eight themes**: Biotechnology, Novel nanostructures and phenomena, Device and system architecture, Beyond CMOS, Environmental Processes, Multiscale modeling, Nanomanufacturing; Societal implications and Improving human performance
- **Establishing the infrastructure**: over 2,500 active projects; 25 large centers, 2 user facilities (NNIN, NCN), multidisciplinary teams
- **Training and education** - 10,000 students and teachers

Fiscal Year		NSF	Law 03
	2000	$97M	
	2001	$150M	
	2002	$199M	
	2003	$221M	
	2004	$254M	
C. Plan	2005	$338M	$384M



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

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National Science Foundation
WHERE DISCOVERIES BEGIN

SEARCH
NSF Web Site

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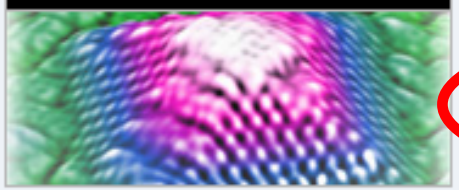
NNI



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

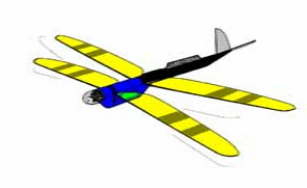
NSF Announcement 05-543: Nanoscale Science and Engineering Education (NSEE)
"Preparation workshop: Public Engagement in Nanoscale Science and Engineering"(PDF, 776KB)

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

DOD STRATEGIC RESEARCH AREA
NANOSCIENCE (NNI Plan)

DOD SCIENCE-DRIVEN OPPORTUNITIES WITH MAJOR IMPACT



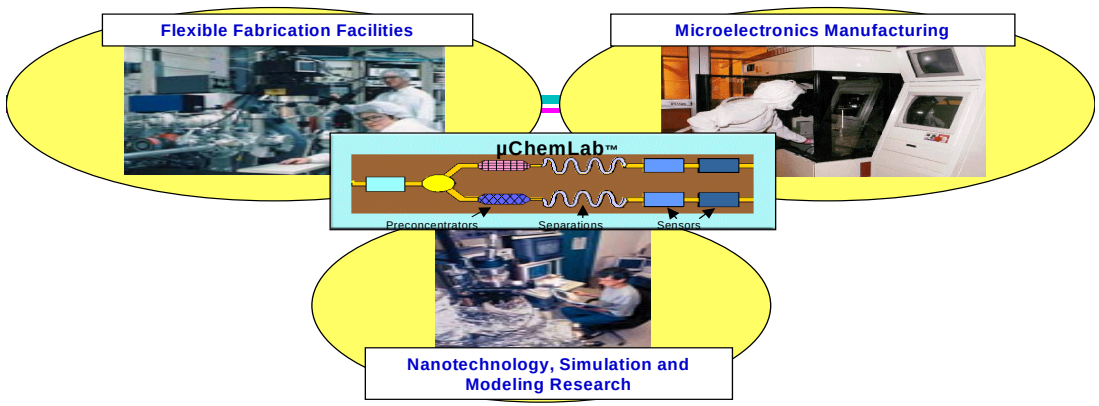
- **NANOELECTRONICS/PHOTONICS/MAGNETICS**
  - Network Centric Warfare
  - Information Warfare
  - Uninhabited Combat Vehicles
  - Automation/Robotics for Reduced Manning
  - Effective training through virtual reality
  - Digital signal processing and LPI

- **NANOMATERIALS "BY DESIGN"**
  - High Performance, Affordable Materials
  - Multifunction, Adaptive (Smart) Materials
  - Energetic Materials/Power Sources
  - Nanoengineered Functional Materials (Metamaterials)
  - Reduced Maintenance - halt nanoscale failure initiation

- **BIONANOTECHNOLOGY - WARFIGHTER PROTECTION**
  - Chemical/Biological Agent detection/destruction
  - Human Performance/Health Monitor/Prophylaxis

DOE: Proposed Initiative Focus Areas (NNI Plan)

- Fundamentals for the study of the properties and behavior of nanostructures and nanostructured materials.
- Grand Challenges primarily for the study of novel materials and energy-related
- DOE Nanoscale Science Research Centers (5) – large user facilities
- Research Infrastructure primarily for increasing user support and instrumentation for nanotechnology at the BES user facilities.



Nanotechnology integration at the Sandia National Laboratories

NIH: NANOTECHNOLOGY FOCUS AREAS
(NNI Plan)

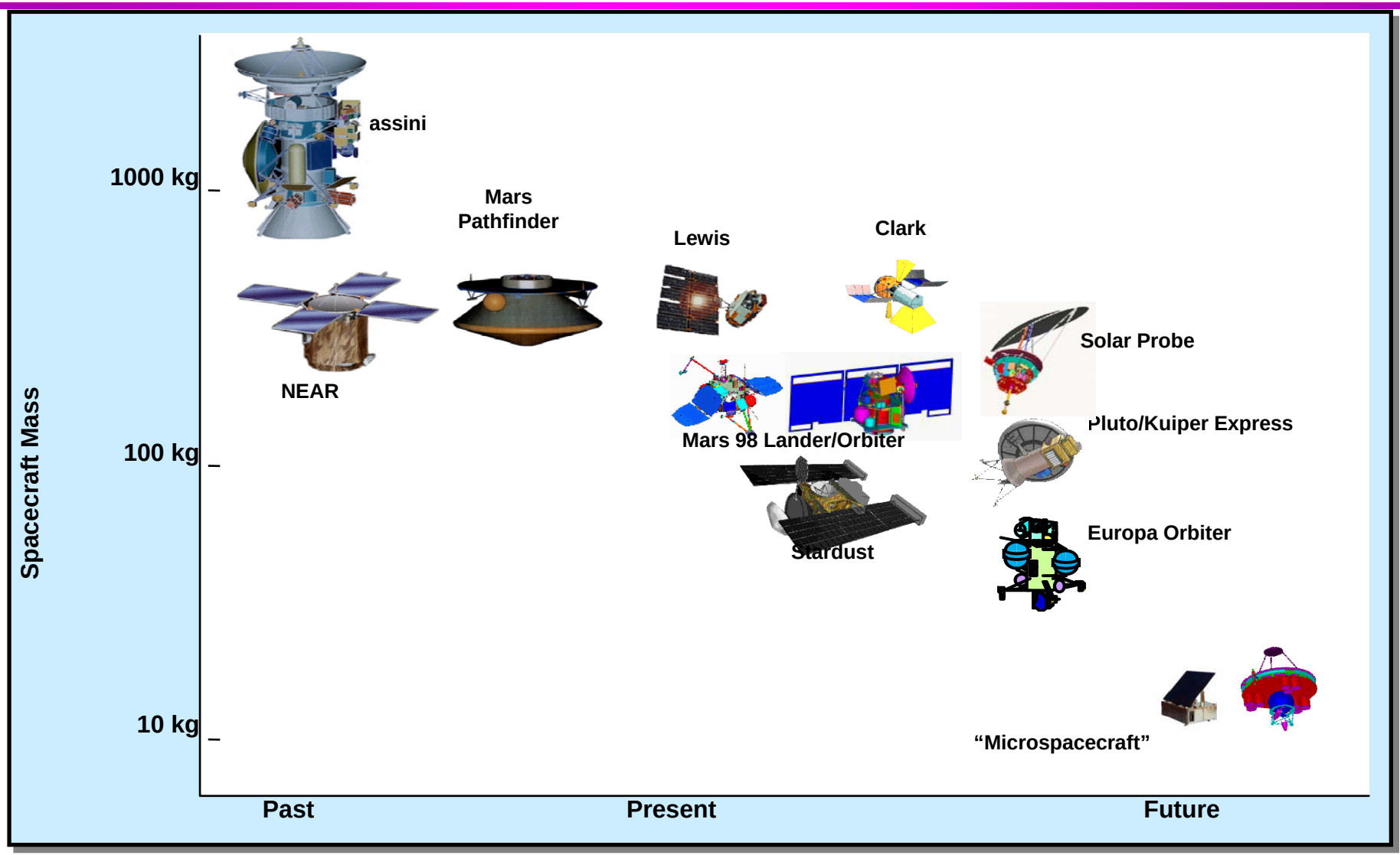
GOALS

- **Early detection of disease: Imaging; Sensors**
- **Novel therapeutic delivery systems: New forms to expand the type of materials that can be used for targeted delivery**
- **Tissue repair and regeneration: Design materials that can interact with the biological environment**
- **Deep insight into biological systems: Understanding of the *design* of biological systems and processes.**

IMPLEMENTATION

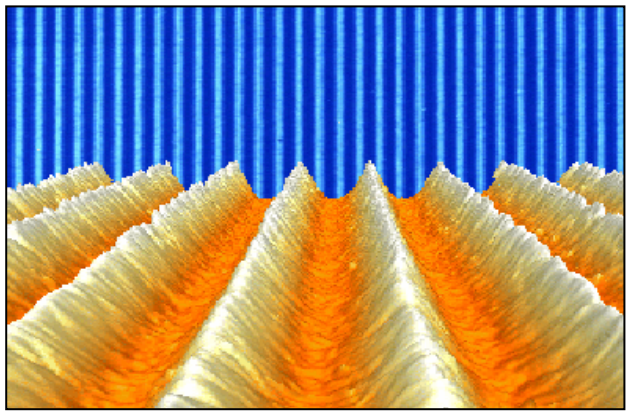
- Investigator-initiated grants
- Trans-NIH nanotechnology opportunities (e.g., BECON)
- NCI Nanotechnology Alliance
- NHLBI Centers
- NIEHS/NTP toxicology studies
- NIH Nanomedicine Roadmap

NASA: Progressive spacecraft miniaturization
(NNI Plan)



NIST: Measurement and Technology Support (NNI Plan)

- Measurements
- Standards and metrology
- Evaluated Data



Atomic scale dimensional standards

- New Test and Measurement Methods
- Support to academic and industrial users

Environmental Protection Agency (NNI Plan)

Goals for R&D program:

- Build and sustain a community of researchers in nanotech and the environment-both applications and implications
- Institutionalize nanotech within EPA's mission
- Advance consideration of the environment and human health in government R&D
- Work with industry to assure environmentally responsible development
- Provide leadership in international activities related to EHS
- Provide education and outreach to the public to promote understanding of nanotechnology with respect to environment and human health.

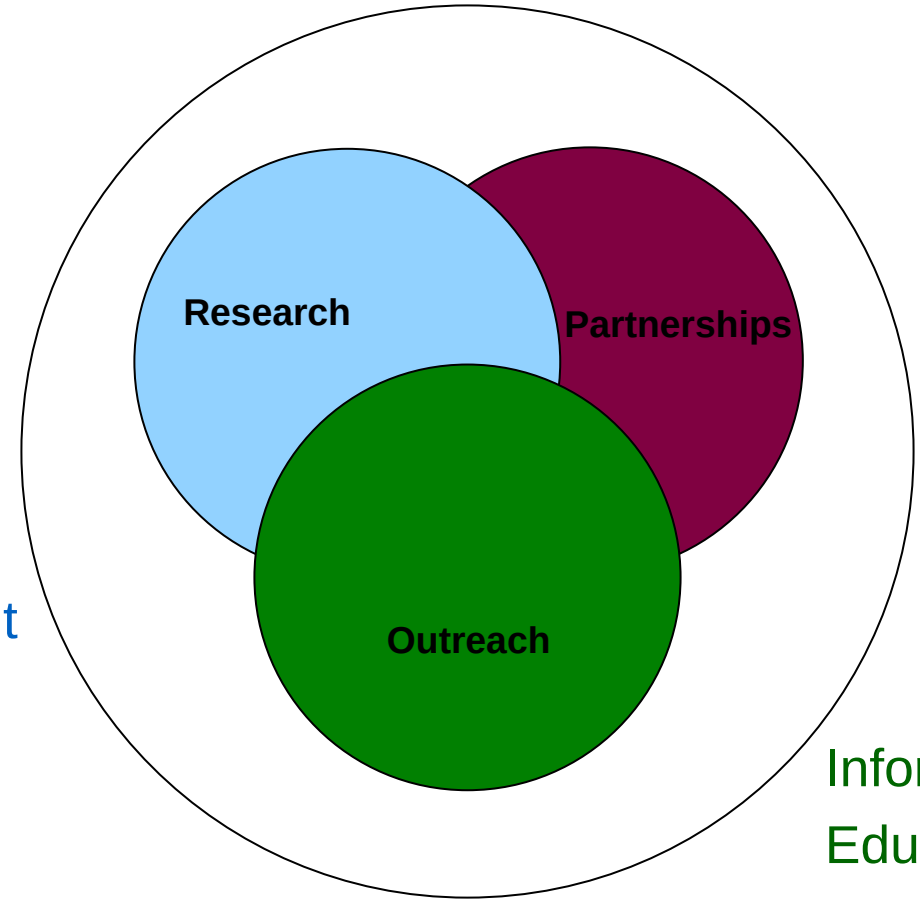
Examples of the successes in nanotechnology and the environment are:

- Nanomaterials to clean up chlorinated organics and heavy metals
- Nano-improved sensors for detecting different bacterial species,algal toxins, heavy metals
- Nanocatalysts that improve air quality, treat wastes, enable more efficient manufacturing

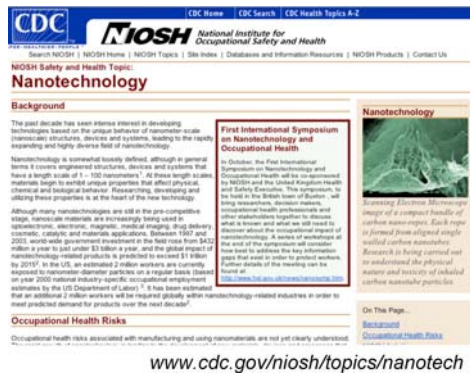
The NIOSH Nanotechnology Initiative

Addressing the implications and applications of nanotechnology in the workplace

Toxicity
Health Effects
Exposure
Measurement
Control
Surveillance
Risk Assessment
Risk Management



Government
Academia
Industry
Workers



www.cdc.gov/niosh/topics/nanotech

Information
Education
Recommendations

Mission: To provide national and world leadership in preventing work-related illness and injury through the responsible development and use of nanotechnology

USDA

- **Cooperative State Research, Education, and Extension Service portfolio**: Research nanoscale phenomena and processes with implications for: improving biological production, processing, and preservation; sensing mechanisms useful to ensure food safety/ biosecurity, improve environmental quality, enhance production and process efficiency, and promote human health through optimal food, and nutrition and diet.

- Major research areas are:

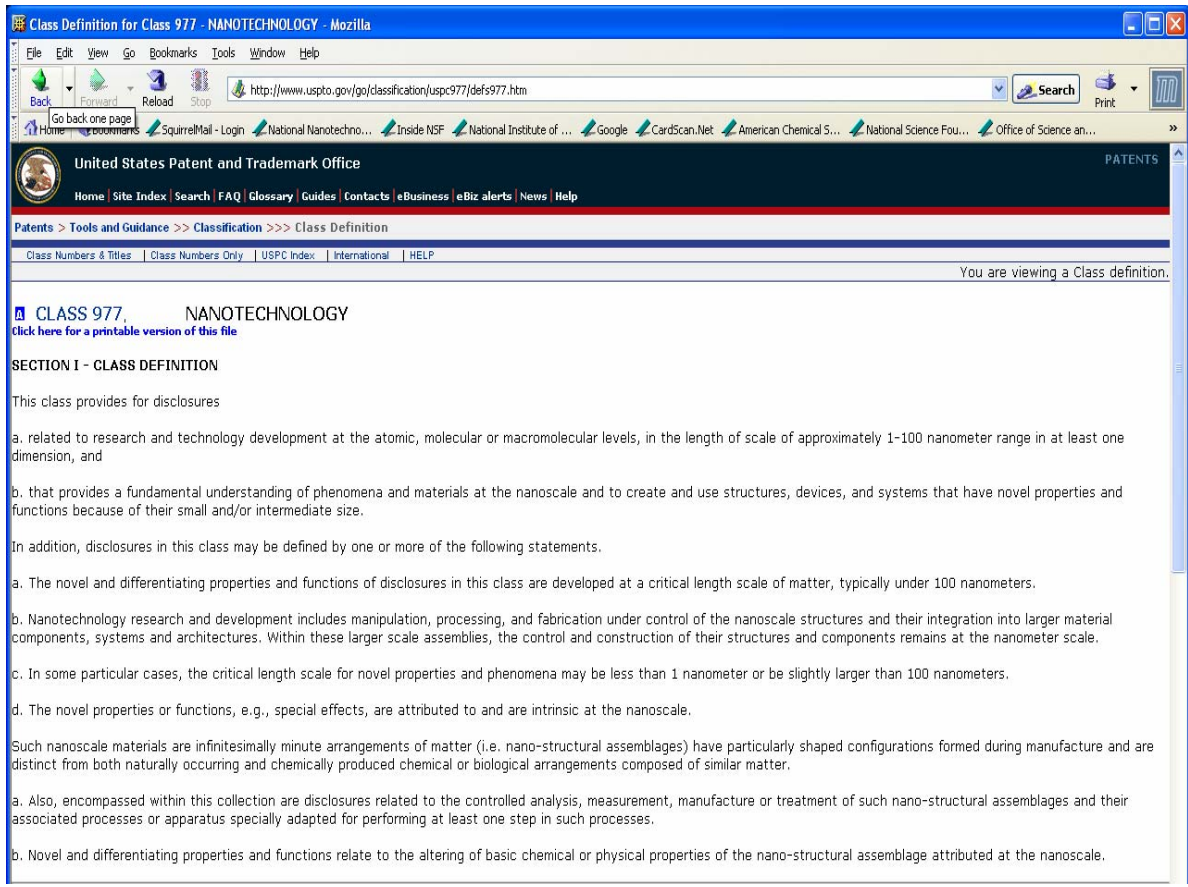
(a) Nanoscale biomaterials of agricultural origins for novel uses;
(b) Nanomaterials that can be used in sensing and detection for food safety and biosecurity, identity preservation and tracking, controlled delivery and release of functional contents;
(c) Novel biocatalysts; and
(d) Nanocomposite materials for various applications (e.g., improved barrier and mechanical properties of packaging materials).

FDA

- Approve nanotechnology products for public use
- Partnering with NIEHS, NIOSH, and CPSC to manage and operate the National Toxicology Program
- Participant on ANSI-NSP
- Nanotechnology topic page on FDA homepage with information on regulation of nanotechnology products
- Training of FDA staff members in nanotechnology

USPTO

- In-depth training in nanotechnology for patent examiners
- Development of new cross-reference digest for nanotechnology
- Ongoing discussions with “Tri-lateral Offices” of European Patent Office and Japan Patent Office



Intelligence Community Activities under NNI

- **Established a community-wide Nanotechnology Program and Technical Working Group**
- **Funding four Post Doc's under the DCI Postdoctoral Research Fellowship Program**
- **Commissioned National Academy of Science study of impact of Nanotechnology on IC**
- **Researching improved performance of Lithium batteries by nanomaterials substitution**
- **Funding a study of unique signatures of nanomaterial microstructures**

Appendix B. NNI Activities in Education and Training

- **Integrated Research and Education - Make Every Lab a Place of Learning** (about 10,000 trained per year)
- **Curriculum development**
  New courses, 10 IGERT, Nanotech Undergrad Education
- **Education and outreach programs**
  from K-12 to G; includes NSEE; science museums
- **International education opportunities**
  young researchers to Japan and Europe; REU sites; attend courses abroad; PASI - Latin America, NSF-E.C.; bi-lateral workshops and exchanges

Nanotechnology university education
- examples of activities -

- Nanotechnology curriculum development (G, UG)
- Integration of research and education
  (ex: IGERT, CRCD, REU, RET)
- Local and long-distance outreach education (G, UG, K-12)
- Technological education
- Education and training in centers and networks
- Modules for individual training
- Public education (non-technical audiences)
- Courses and tutorials offered by professional societies
- International dimension

Examples : IGERT projects

Focus on interdisciplinary fellowships, research and education
Each IGERT (Integrative Graduate Education, Research and Training) provide support for > 12 interdisciplinary graduate fellowships / site.

- **NEAT (Nanophases in the Environment, Agriculture and Technology)**
  University of California -Davis (A. Novrotski)
- **Nanostructural Materials and Devices**
  City University of New York (D.L. Akins)
- **Nanobiotechnology**
  University of Washington (A. Vogel)
- **Nanoparticle Science and Engineering**
  University of Minnesota (U. Kortshagen)
- **11 sites in FY 2002 (4 since 2001, and 4 since 2002)**

Nanotechnology Undergraduate Education (NUE)

New component of the 2003-2005 NSF Nanoscale Science and Engineering program is focused on:

- Introductory undergraduate courses
  development of text, software, laboratory experiments, and web-based resources
- Development and dissemination of teaching modules
  for existing undergraduate courses, particularly during first and second year studies.

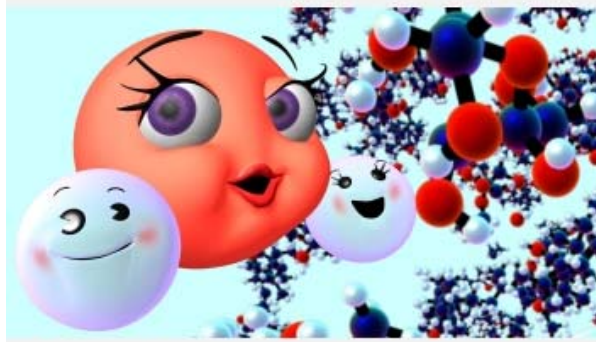
About 90 awards in FY 2003 – FY 2005

Workshop on 9/11-12/02
(www.nanofab.psu.edu/education/nsf-nue-program.htm**)**

K-12 NANOTECHNOLOGY
Education Modules

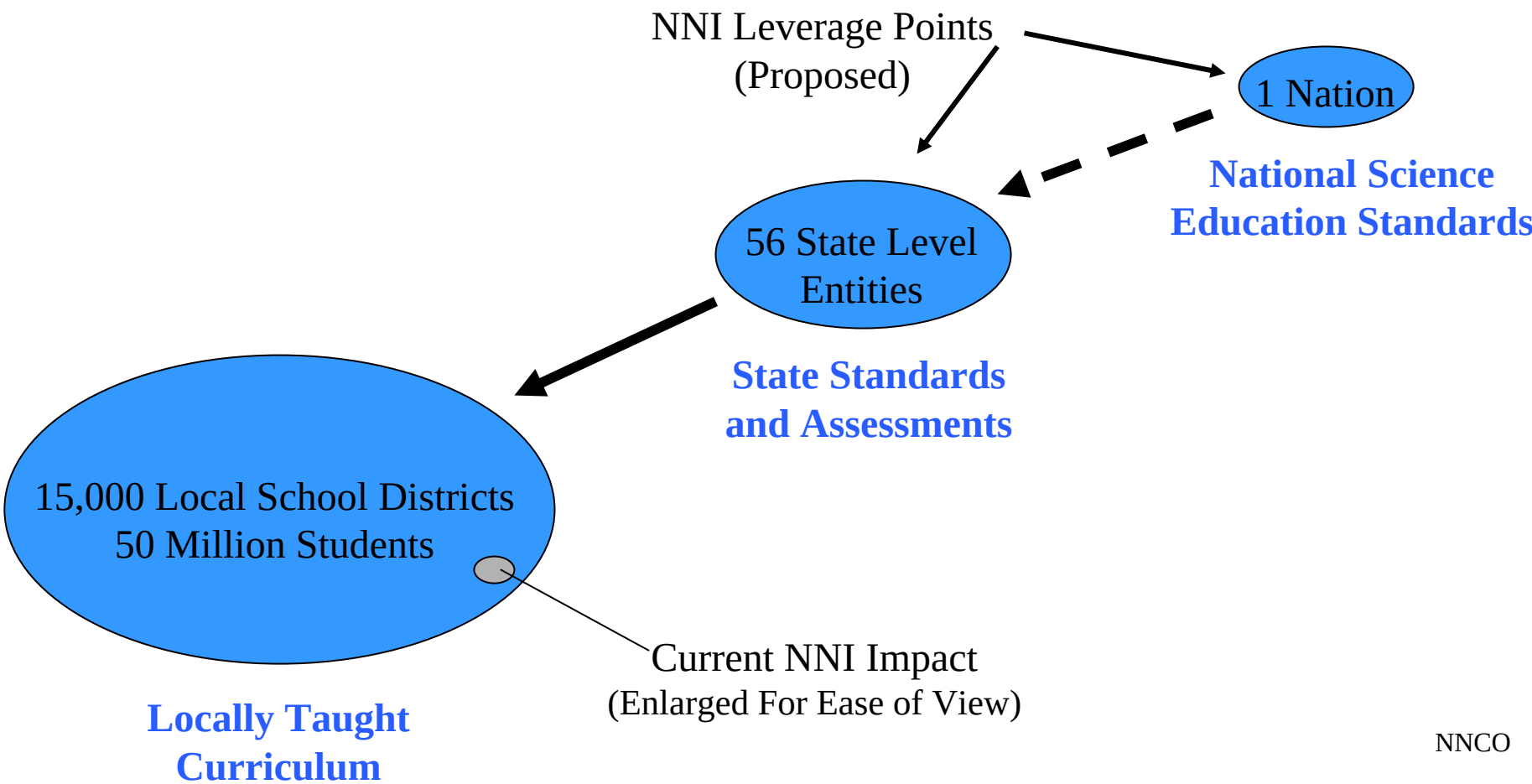
Illustrations

- **University of Wisconsin -**
  Art Ellis: Nanoworld for kids
- **Rice University – James Tour: NanoKids**
- **Cornell University: for nano-biotechnology, and -electronics**
- **Northwestern University, Chicago: manuals, public museum**
- **Harvard University: manuals, museum**
- **UNC Nanomanipulator**
- **Purdue NanoHub**
- **Molecularium, RPI**



- NSF plans to have 10 K-12 education modules in 2005

State K-12 Curriculum Standards and NNI



NATIONAL NANOTECHNOLOGY INITIATIVE

Appendix C. **NNI reports (1)**

A. NSTC Publications

- ***Nanotechnology: Shaping the World Atom by Atom,*** 1999.
  Brochure explaining nanotechnology and its potential for the general public (http://www.wtec.org/loyola/nano/IWGN.Public.Brochure/)
- ***Nanostructure Science and Technology,*** 1999.
  Worldwide study on status and trends (http://www.wtec.org/loyola/nano/)
- ***Nanotechnology Research Directions: IWGN Workshop Report,*** 1999.
  Report of the first NNI Research Directions workshop (http://www.wtec.org/loyola/nano/IWGN.Research.Directions/)
- ***National Nanotechnology Initiative: The Initiative and its Implementation Plan,*** 2000.
  First detailed implementation plan for the NNI (http://nano.gov/html/res/nni2.pdf)
- ***National Nanotechnology Initiative; Research and Development Supporting the Next Industrial Revolution,*** 2003.
  Supplement to President's FY 2004 Budget (http://nano.gov/html/res/fy04-pdf/fy04-main.html)

NATIONAL NANOTECHNOLOGY INITIATIVE

NNI reports (2)

B. Related Agency Publications

- ***Societal Implications of Nanoscience and Nanotechnology, 2001***.
  NSF report on the September 2000 workshop, also Kluwer Acad. Publ. 2001.
- ***Nanoscience and Nanotechnology: Shaping Biomedical Research, 2000***.
  Symposium Report. Bioengineering Consortium, NIH.
- ***Nanoscale Science and Engineering for Agriculture and Food Systems, 2003.***
  Report Submitted to Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture.
- ***Nanotechnology in Heart, Lung, Blood, and Sleep Medicine, Executive Summary, 2003***.
  National Heart Lung and Blood Institute, NIH, NHLBI Working Group:
- ***Going Small for Big Advances: Using Nanotechnology to Advance Cancer Diagnosis, Prevention and Treatment, 2004.*** *National Cancer Institute, NIH.*

C. Previous Outside Reviews of the NNI

- ***Small Wonders, Endless Frontiers: Review of the National Nanotechnology Initiative, 2002.*** *National Research Council. (http://nano.gov/html/res/smallwonder.html)*

NATIONAL NANOTECHNOLOGY INITIATIVE

NNI reports (3)

D. Completed reports with NNI support

- ***Regional Workshop of the National Nanotechnology Initiative, 2001.***
  hosted by the University of California at Los Angeles, CA
- ***NSF-EC Workshop on Nanomanufacturing and Processing, 2002.***
  NSF and EC, San Juan, Puerto Rico, U.S.
- ***Regional Workshop: From the Laboratory to New Commercial Frontiers, 2002.***
  Hosted by Rice University, May 2002, Houston, TX
- ***Nanotechnology Innovation for Chemical, Biological, Radiological, and Explosive (CBRE): Detection and Protection, 2002****. NNI Grand Challenge Workshop, Monterey, CA*
- ***Chemical Industry R&D Roadmap for Nanomaterials By Design: From Fundamentals to Function, 2003.***
  Report of the 2002 Chemical Industry Vision 2020/NNI GC Workshop, Baltimore, MD
- ***Nanoscience Research for Energy Needs, 2004****.*
  Report of the National Nanotechnology Initiative GC Workshop, Alexandria, VA

NATIONAL NANOTECHNOLOGY INITIATIVE

NNI reports (4)

E. Reports in Preparation with NNI support

- ***Buildings for Advanced Technology Workshop, 2003.*** *NIST, Gaithersburg, Maryland.*
- ***Nanoscale Processes for Environmental Improvement, 2003.*** *NNI GC workshop, NSF, Arlington, VA*
- ***Nanomaterials, National Science Foundation, 2003.*** *NNI GC workshop, NSF, Arlington, VA*
- ***Nanotechnology and the Environment: Applications and Implications, 2003.*** *NNI workshop, NSF, Arlington, VA*
- ***Workshop on Regional, State, and Local Initiatives in Nanotechnology, 2003.*** *NNI workshop, Washington, D.C.*
- ***Workshop on Nanobiotechnology, 2003.*** *NNI GC workshop, Arlington, VA*
- ***Societal Implications of Nanoscience and Nanotechnology, 2003.*** *NNI workshop, NSF, Arlington, VA*
- ***Instrumentation and Metrology for Nanotechnology, 2004.*** *NIST, Gaithersburg, MD*
- ***NNI Grand Challenge Workshop on Nano-electronics, -photonics, and -magnetics, 2004.*** *NNI GC workshop, NSF, Arlington, VA*
- ***Nanotechnology for Space Exploration, 2004.*** *NNI GC workshop, Palo Alto, CA*
- ***NNI Research Directions II workshop, 2004.*** *Wash., D.C.*