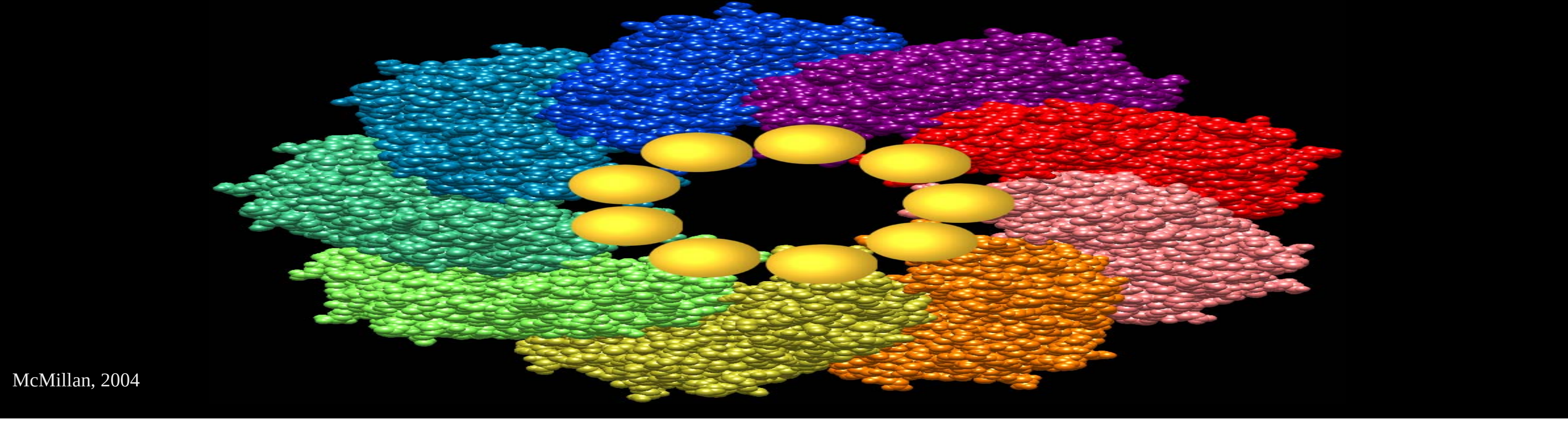


Governance of New Generations of Nanotechnology Products and Processes

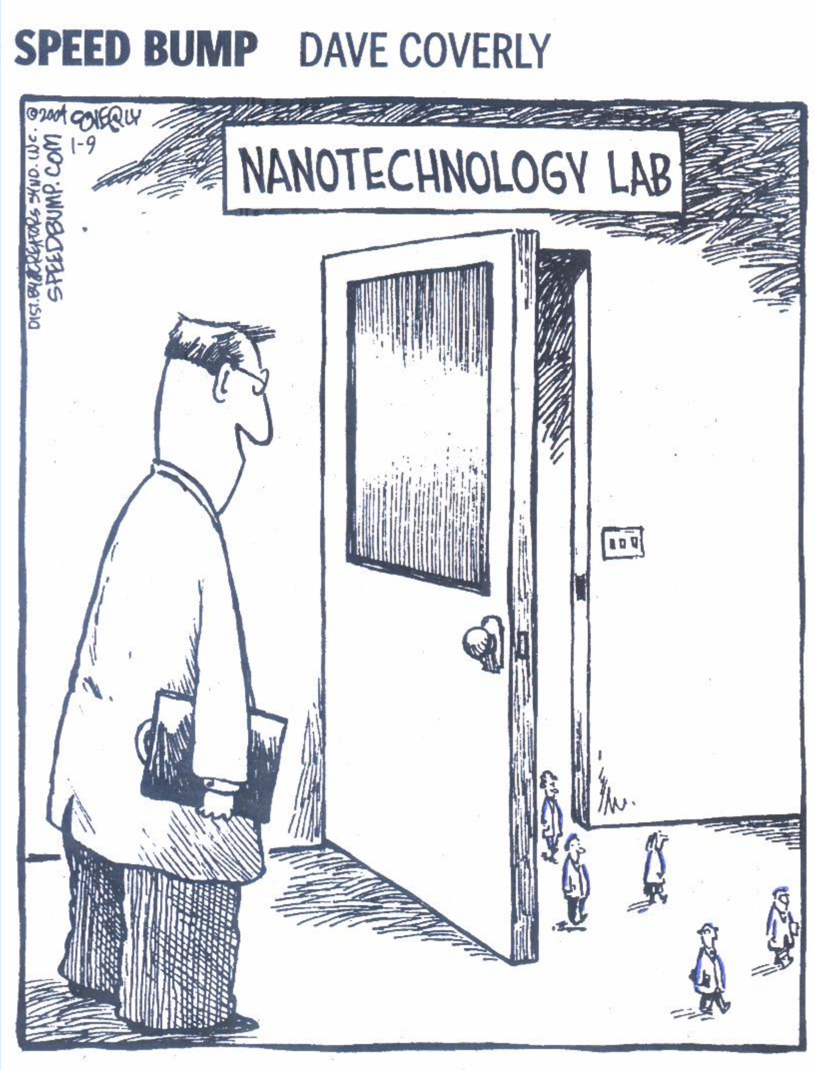
Mihail C. Roco

National Science Foundation and
National Nanotechnology Initiative

EC, Brussels, November 18, 2009

Many perceptions of nanotechnology today

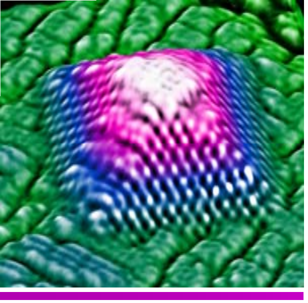
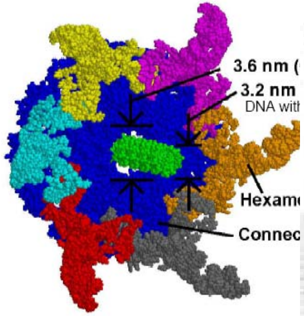
from CAN DO ANYTHING

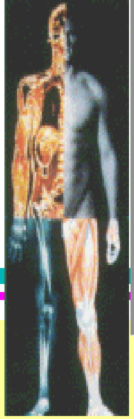
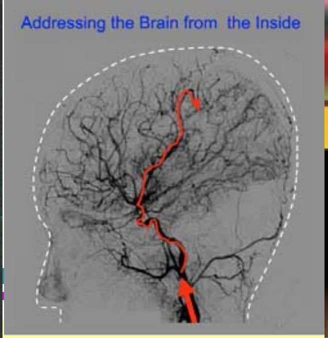


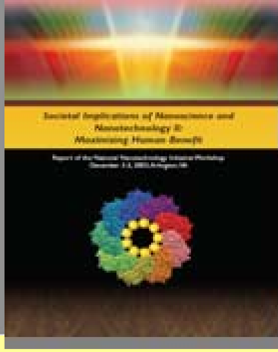
to RISK ANYWHERE

At a nano lunch,
there is a perceived risk

"... nanopizza is taking technology a step too far"



TOPICS

Long view for nanotechnology development

Global progress to date and future opportunities

Increased complexity and dynamics (four generations)
- with increased uncertainty and risk

Corresponding levels of governance (two frameworks)
- with staggered risk management approach (four steps)

Values-driven global governance of nanotechnology

visionary, transformative, responsible, inclusive

Context: Emergence of new technologies - a continuous process

- Knowledge has quasi-exponential growth

  There is an accelerating & non -uniform process of discoveries and innovations leading to emerging technologies

- Need of radically new technologies

  Demographics with limited natural resources

- Particularities in governance of emerging technologies

  - Integration of new tools and separated disciplines, new education skills, partnerships, risk management

  - Need of global governance for development, collaboration and avoiding conflict

More people

9-10 billion by 2050

INCREASED USE OF WATER, FOOD, ENERGY, MATERIALS, AND ENVIRONMENT

NEED OF RADICALLY NEW TECHNOLOGIES

Examples of emerging technologies and corresponding U.S. long-term S&T projects

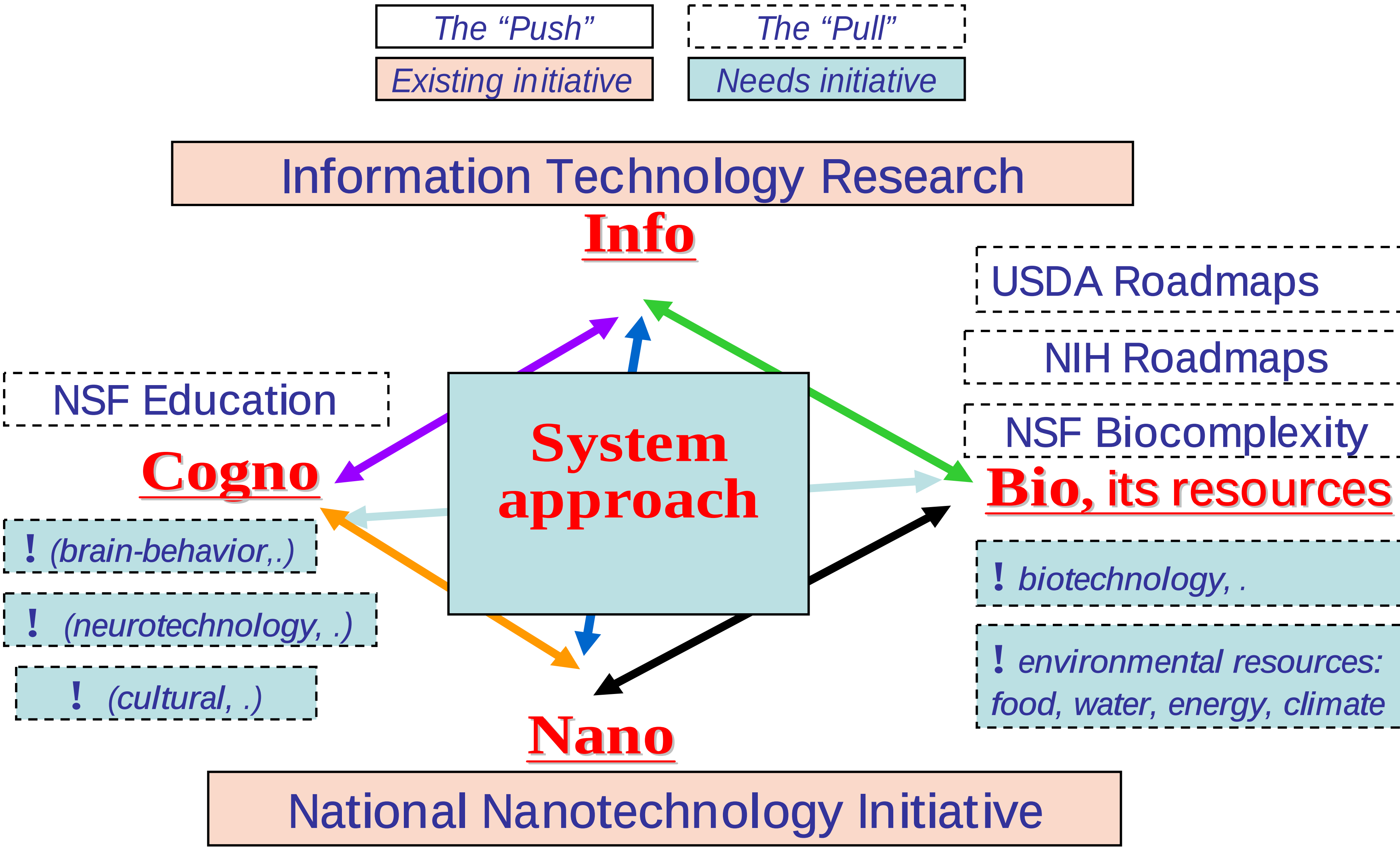
Justified mainly by societal/application factors

- Manhattan Project, WW2 (centralized, goal focused, simultaneous paths)
- Project Apollo (centralized; goal focused)
- AIDS Vaccine Discovery ("big science" model, Gates Foundation driven)
- IT SEMATECH (Roadmap model, industry driven)
- IT Research (top-down born & managed; application driven)

- National Nanotechnology Initiative (bottom-up science opportunity born, for general purpose technology)

Converging New Technologies transforming tools

(overview in 2000 ; ~ 50% relevance in NSF awards in 2010 ; convergence has been better developed than for *large-scale systems*)



Benchmark with experts in over 20 countries in 1997-1999

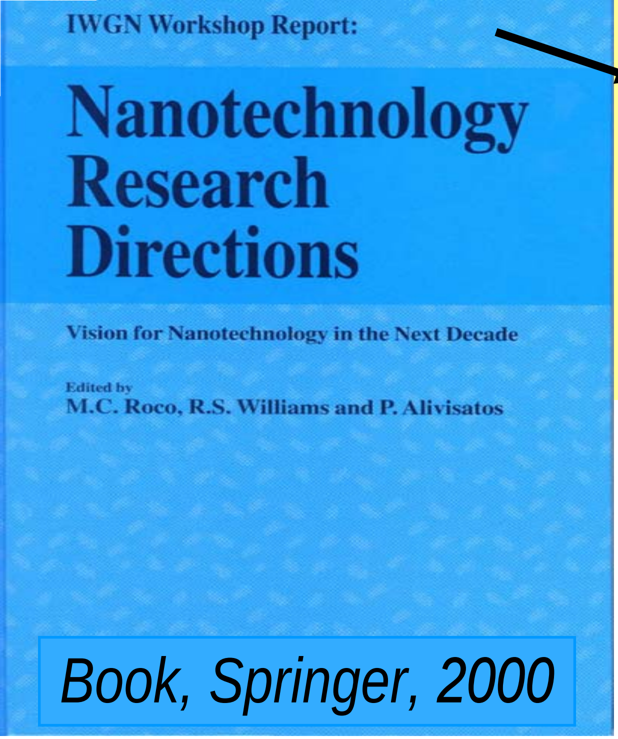
"Nanostructure Science and Technology"

NNI preparatory Report, Springer, 1999

Nanotechnology Definition for the R&D program

Working at the atomic, molecular and supramolecular levels, in the length scale of ~ 1 nm (a small molecule) to ~ 100 nm range, in order to understand, create and use materials, devices and systems with fundamentally new properties and functions because of their small structure

- NNI definition encourages new R&D that were not possible before:
  - ***the ability to control and restructure matter at nanoscale***
  - ***novel phenomena, properties and functions at nanoscale***,
  - ***integration along length scales, systems and applications***



Book, Springer, 2000

"Vision for nanotechnology in the next decade" (2001-2010)

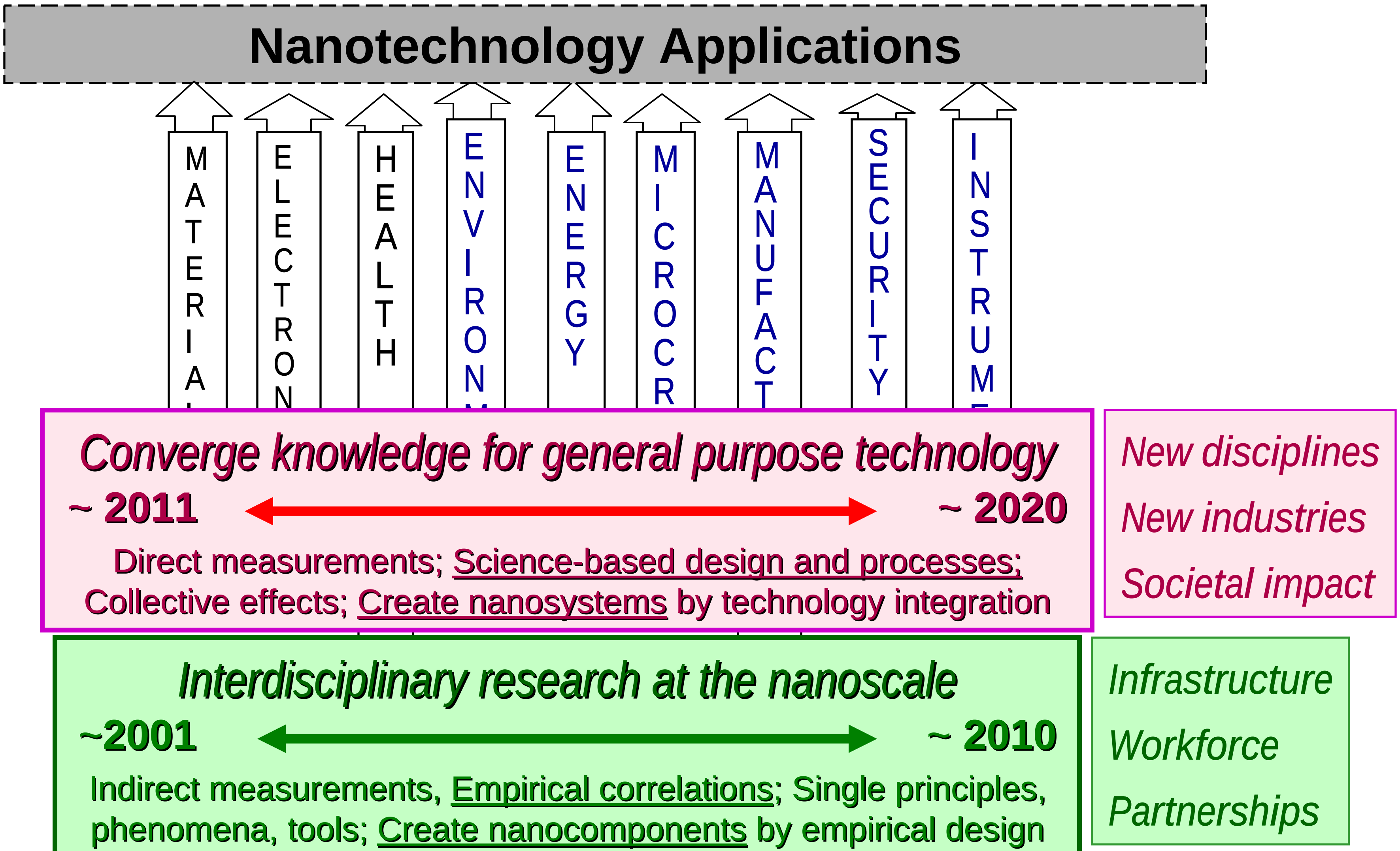
Systematic control of matter on the nanoscale will lead to a revolution in technology and industry

- *Change the foundations from micro to nano in knowledge, industry, medicine, sustainability, ..*
- *Create a general purpose technology (similar IT)*

More important than miniaturization itself:

- Novel properties/ phenomena/ processes/ natural threshold
- Unity and generality of principles
- Most efficient length scale for manufacturing, biomedicine
- Show transition from basic phenomena and components to system applications in 10 areas and 10 scientific targets

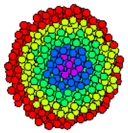
CREATING AN NEW FIELD AND COMMUNITY IN TWO FOUNDATIONAL STEPS (2000~2020)



MC Roco, Nov. 18 2009

Introduction of New Generations of Products and Productive Processes (2000-2020)

Timeline for beginning of industrial prototyping and nanotechnology commercialization



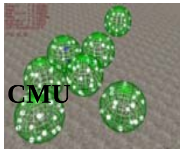
2000

1st: Passive nanostructures (1st generation products)

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

~ 2005

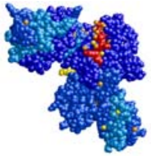
2nd: Active nanostructures Ex: 3D transistors, amplifiers, targeted drugs, actuators, adaptive structures



~ 2010

3rd: Nanosystems

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



15-2020

4th: Molecular nanosystems

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

Converging technologies

Ex: nano-bio-info from nanoscale, cognitive technologies; large complex systems from nanoscale

Increased Complexity, Dynamics, Transdisciplinarity

	R&D →		*Broad Use*
IT	1960	-	2000
BIO	1980	-	2010
NANO	2000	-	2020
NBIC	2010	-	2030

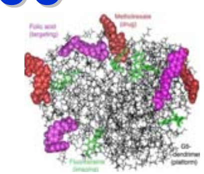
Reference: AIChE Journal, Vol. 50 (5), 2004

Perceived Higher Risks Areas (2000-2020; 2020-)

as a function of nanotechnology generation

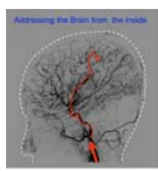
1st: Passive nanostructures *Ex: Cosmetics (pre-market tests), Pharmaceuticals (incomplete tests for inflammatory effects, etc.), Food industry , Consumer products*

~ 2000



2nd: Active nanostructures *Ex: Nano-biotechnology, Neuro-electronic interfaces, NEMS, Precision engineering, Hybrid nanomanufacturing*

~ 2005



3rd: Systems of nanosystems *Ex: Nanorobotics, Regenerative medicine, Brain-machine interface, Eng. agriculture*

~ 2010

?

4th: Molecular nanosystems *Ex: Neuromorphic eng., Complex systems, Human-machine interface*

~ 2015-2020

Converging technologies *Ex: Hybrid nano-bio-info-medical-cognitive application*

~ 2020-

Higher uncertainty & risk

Highest perceived risks in 2009:
- in air - car combustion
- in water - industrial pollution
- in food and cosmetics

MC Roco, Nov. 18, 2009

Examples of 3rd and 4th generation

- Artificial organs using nanoscale control of growth
- Subcellullar intervention for treatment of cancer
- Bioassembly (ex. use of viruses) of engineered nanomaterials and systems
- Evolutionary systems for biochemical processing
- Sensor systems with reactive mechanisms
- Nanoscale robotics on surfaces and 3-D domains
- Simulation based experiments and design of engineered nanosystems from basic principles
- New molecules designed as devices
- Hierarchical selfassembling for micro or macro products

Four generations of products and productive processes *in nanoelectronics*

- First generation - scaling down with nanoscale components with new physics. Ex: passive nanoscale layers in production - since 2003

- Second generation - with device state change during operation. Ex: “Integrated-CMOS” with carbon-nanotubes, single-electron transistors; “directed self-assembly” leading to CMOS scaled to its ultimate limits

- Third generation - "Novel logical switch": Nanosystem solutions based on state variables other than electric charge. Ex: electron-spin, photonic states, graphene-based

- Fourth generation - Molecular and supramolecular components of nanoelectronic systems “by design”; guided assembling nanosystem

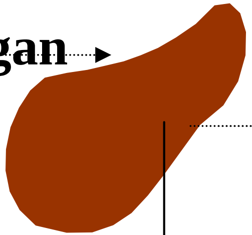
- Converging techn. – integration with applications; hybrid architectures

Examples of levels for intervention of nanobiotechnology

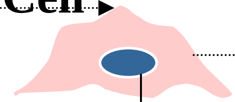
4 generations of products for human life extension

Human

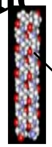
Organ



Cell



Molecule



- **(1st)** Joint replacement
- Non-invasive and invasive diagnostics for rapid patient monitoring
- Cognitive-assist devices
- Targeted cancer therapies

- **(2nd)** Sensors for in vivo monitoring
- Localized drug delivery
- Neural stimulation
- Cardiac therapies
- Artificial organs

- **(3rd)** Improved cell-material interactions
- Scaffolds for tissue eng.
- **(4th)** Genetic therapies
- Cell ageing
- Stem cell therapies

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

(NBIC Report, 2002)

Nanotechnology convergence with bio, info and cogno, and bifurcation of nanosystem architectures: 2010-2020

New nanosystem architectures, more

- Guided assembling
- Nanobio evolutionary
- Molecular design and guided hierarchical selfassembling
- Robotics based
- Reconfigurable sensorial systems
- Biomimetics . . . .

and less defines

- ? New carrier of information instead of electron charge
- ? Manufacturing by nanomachines
- ? Extending use of human potential
- ? Use of virtual reality and intelligent environments
- ? Collective cognitive capabilities . . . .

CT: Expanding Human Cognition and Communication

- **Understanding brain functions; brain-machine-brain interactions; and group communication**
  Ex: unveil the memory, thinking and emotional capacity of the nervous system;
  culture of connectivity
- **Spatial cognition and visual language using converging technologies**
- **Portable IT "personal broker"**
- **Enhanced tools for learning and creativity**
- **Predictive science of societal behavior**
- **Improving cognition**

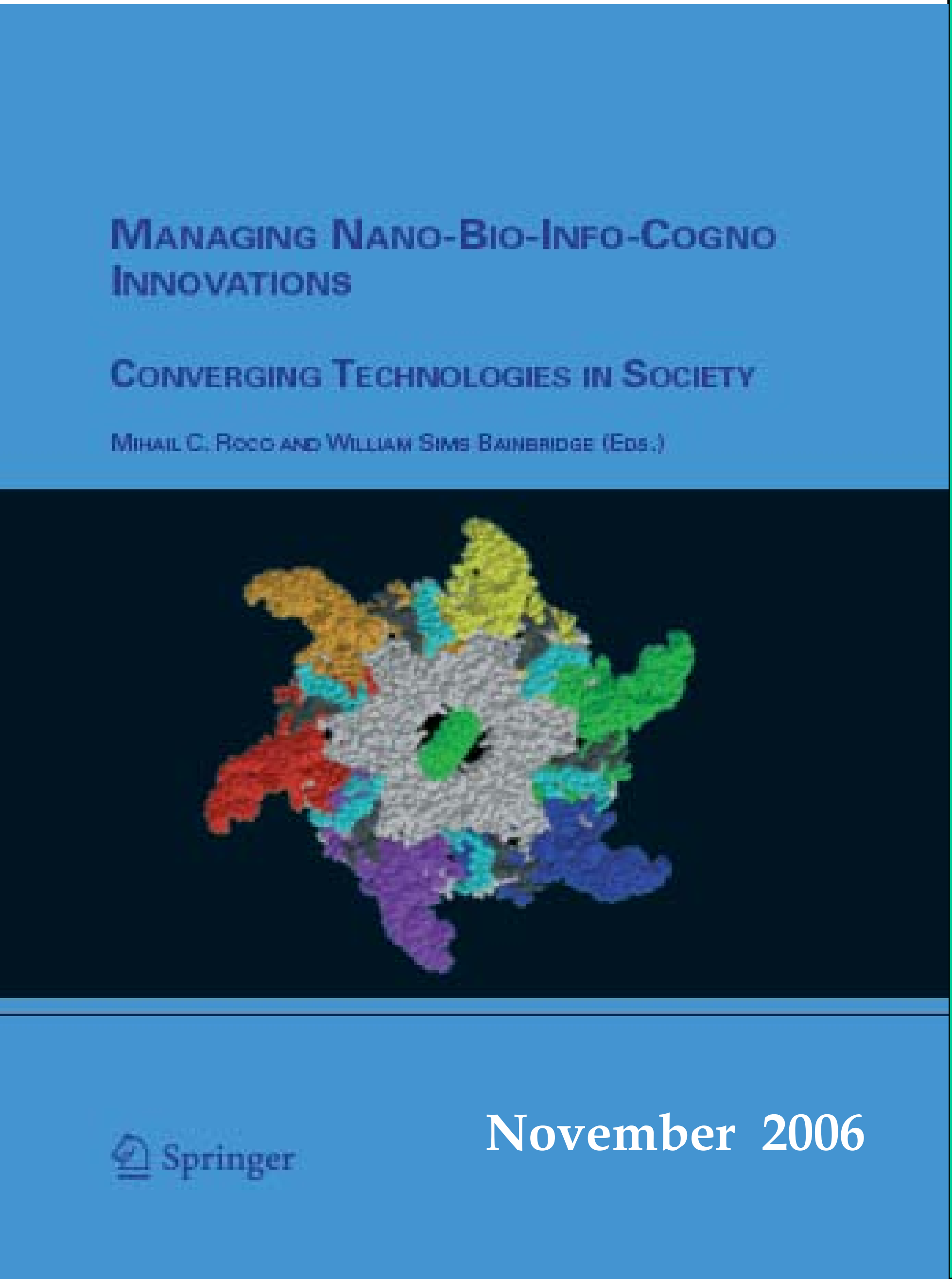
CT: Improving Human Health and Physical Capabilities

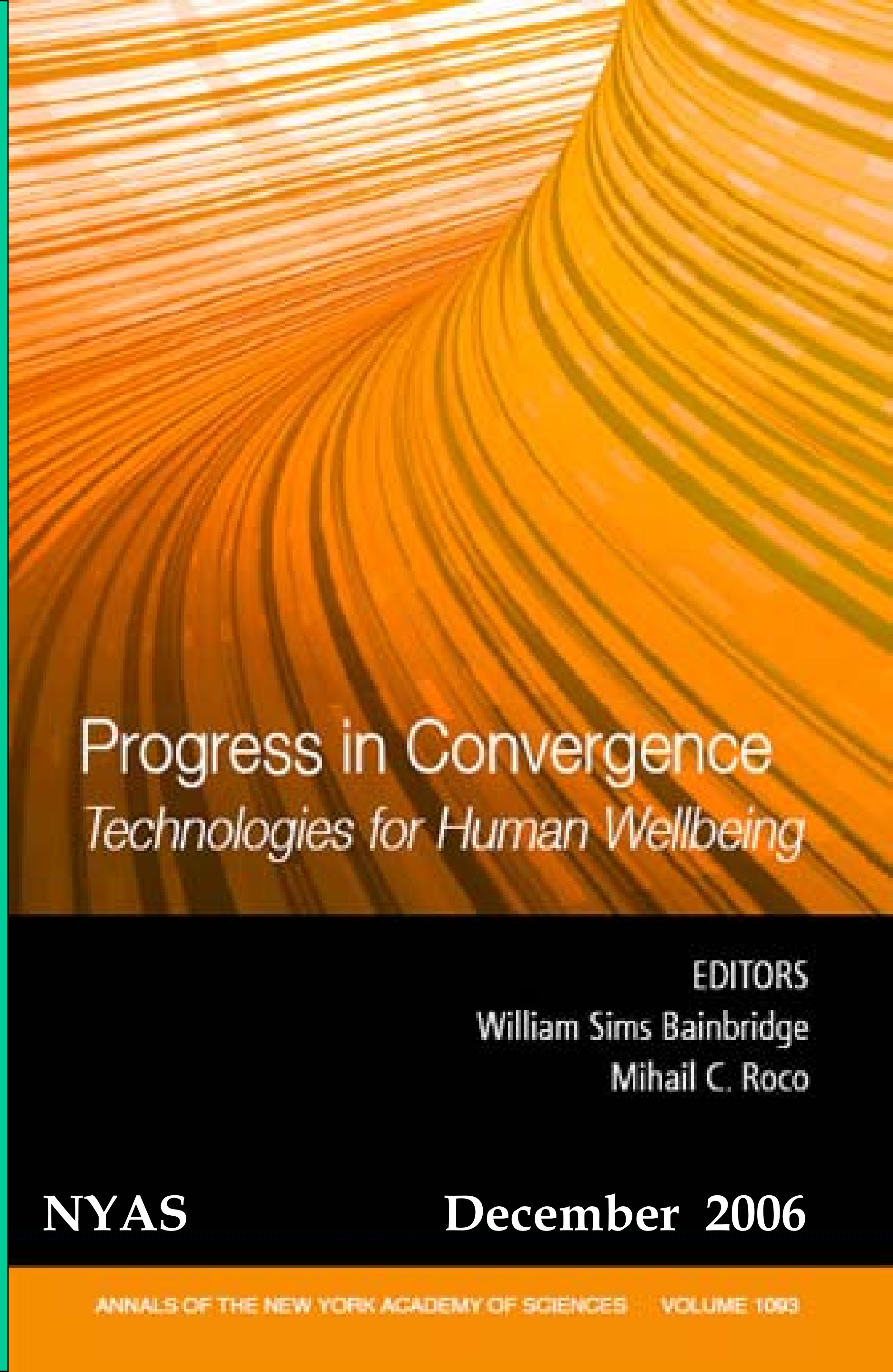
- Bio nanosystem approach for healthcare, regenerative and biocompatible body replacements, and physiological self-regulation
- Brain-machine interfaces, and neuromorphing engineering
- Improving sensorial capacities and expanding sensorial functions
- Improving quality of life of disabled people
- Aging with dignity, and average life extension

CT: Enhancing Group and Societal Outcomes (including new technologies and products)

- Methods for enhancing group interaction and creativity
- Cognitive engineering and enhancing productivity
- Revolutionary manufacturing processes, products and services. Ex: hybrid manufacturing, bio-inspired nanoelectronics, bio-robotics (muscles), "aircraft of the future", bio-chem lab on a chip, adaptive and emerging intelligence systems, multiphenomena software from the nanoscale, pharmaceutical genomics, neuromorphic engineering, intel. env.
- Networked society, with bio-inspired culture
- Business as agents of change for human perfomance

Five volumes on convergence (2003-)





Next generations of nanotechnology products

Several activities

- IRGC Risk Governance framework for Nanotechnology
  (Frame 1 and 2), and application for food and cosmetics
  http://www.irgc.org/irgc/projects/nanotechnology/
- EC project: Securing the promise of nanotechnologies
  WWCS (US) report: Oversight of next generation nanotechnology
- Definition of nanotechnology in regulatory agencies – open issue
- ASU activities – illustration introducing convergence in R & Ed
- EC solicitation on converging technologies;
  activities of social science group
- Korea, Japan, China - introducing converging new
  technologies in strategic plans

2000-2009
Expanding nanotechnology domains

2000-2001: nano expanding in almost all disciplines;
by 2009: 11% of NSF awards; 5% papers; 1-2% patents

2002-2003: industry moves behind nano development
by 2009: ~ $200B products incorporating nano worldwide

2003-2004: medical field sets up new goals

2004-2005: media, NGOs, public, organizations -involved

2006-2007: new focus on common Earth resources - water, food, environment, energy, materials

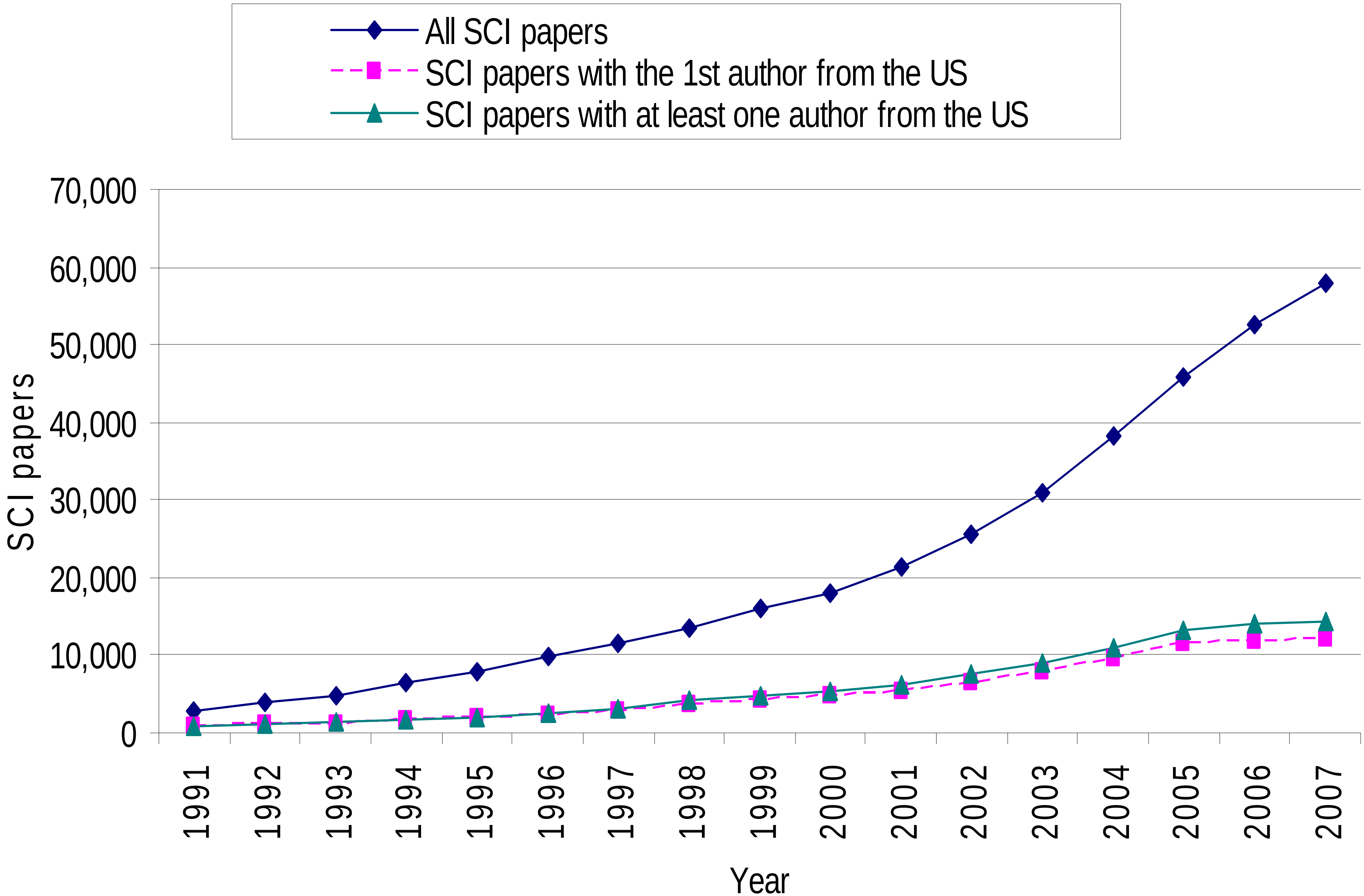
2008-2009: increased relevance to economy – policies - sustainability

Ten highly promising products incorporating nanotechnology in 2009

- Catalysts
- Transistors and memory devices
- Structural applications (coatings, hard materials,.)
- Biomedical applications (detection, implants,.)
- Treating cancer and chronic diseases
- Energy storage (batteries), conversion and utilization
- Water filtration
- Video displays
- Optical lithography
- Environmental applications

With safety concerns: cosmetics, food, disinfectants,..

WORDWIDE NUMBER OF NANOTECHNOLOGY SCI ARTICLES



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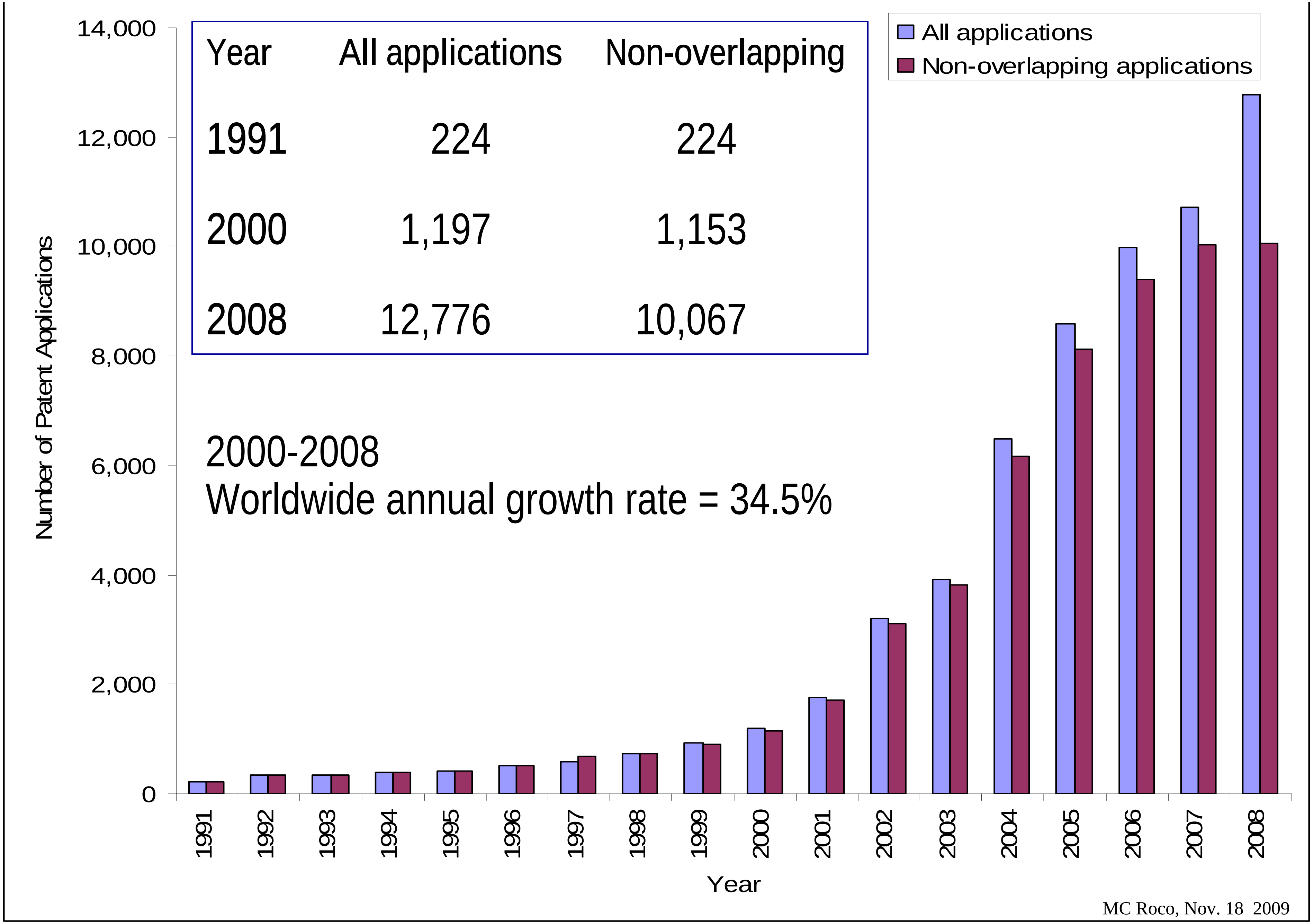
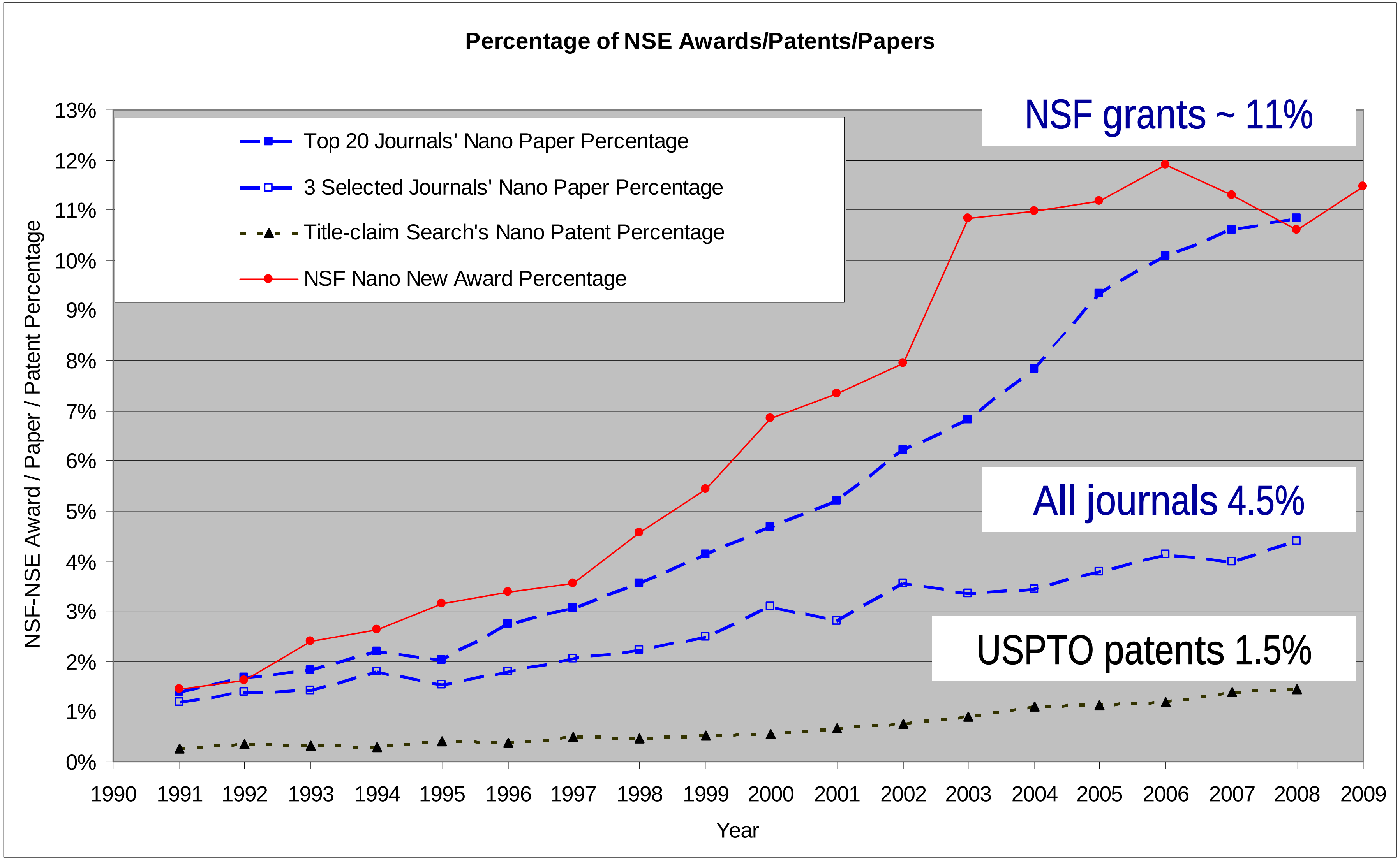
WORDWIDE NUMBER OF NANOTECHNOLOGY PATENT APPLICATIONS



Proportion of nanotechnology contents in NSF awards, ISO papers and USPTO patents (1991-2008)



Searched by keywords in the title and abstract/claims

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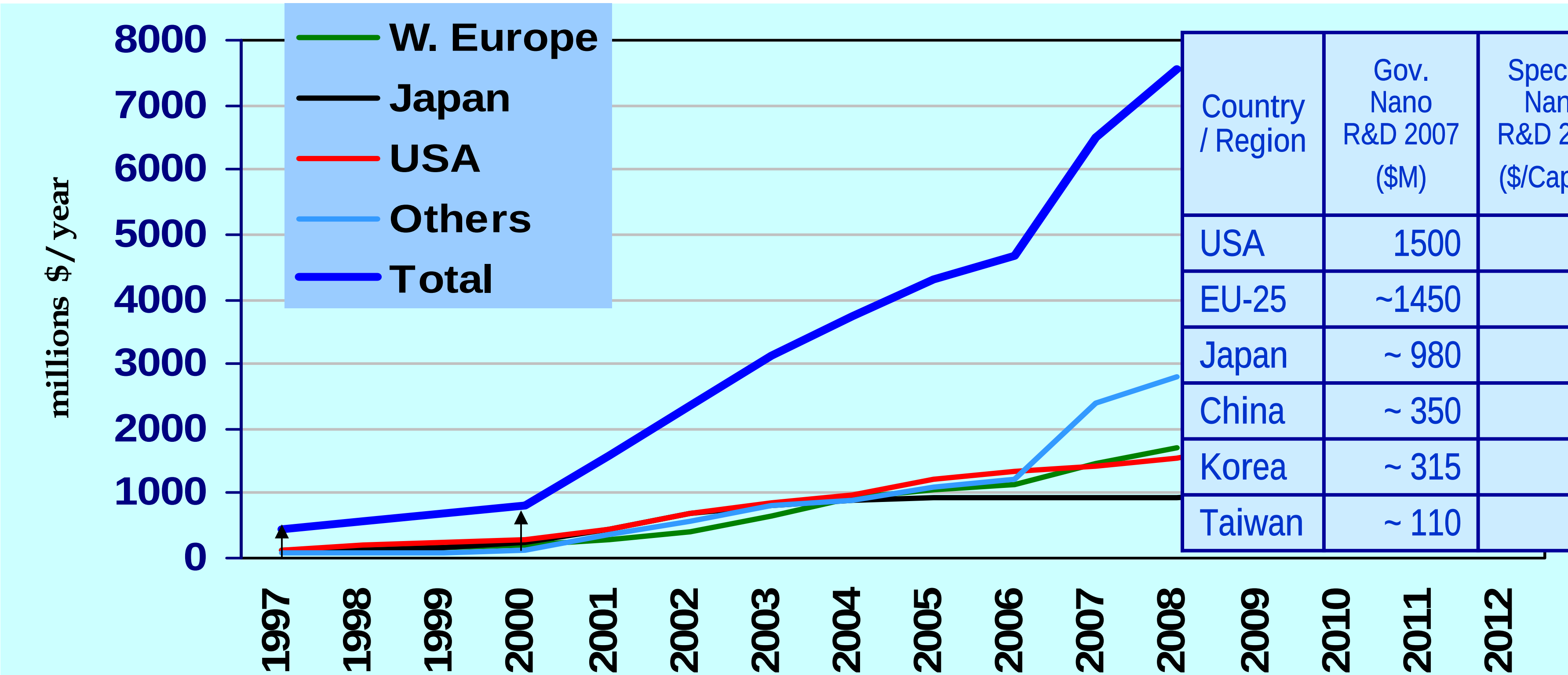
2000-2009

Changing international context: government funding



Country / Region	Gov. Nano R&D 2007 ($M)	Specific Nano R&D 2007 ($/Capita)
USA	1500	5.0
EU-25	~1450	4.0
Japan	~ 980	7.5
China	~ 350	0.3
Korea	~ 315	6.0
Taiwan	~ 110	4.5

Seed funding (1991 -)

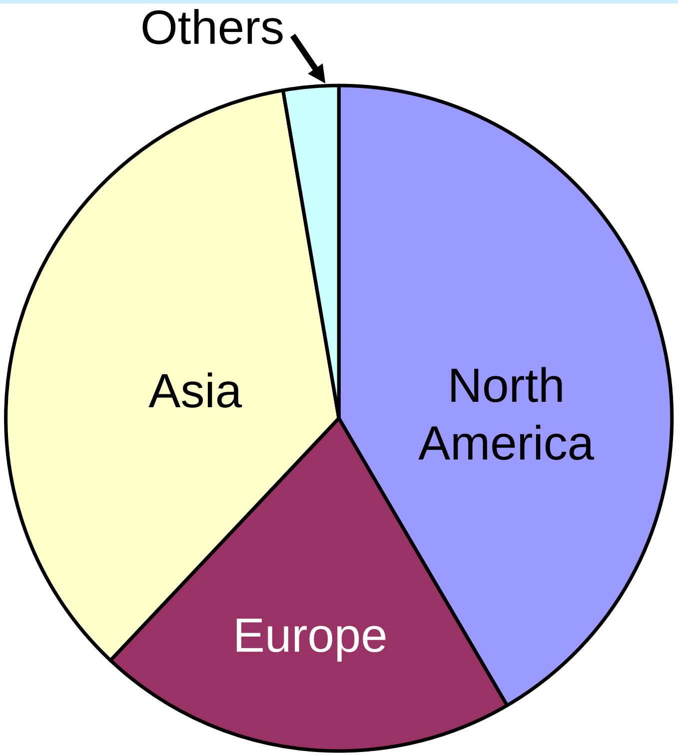
NNI Preparation (vision / benchmark)

1st Strategic Plan (passive nanostructures)

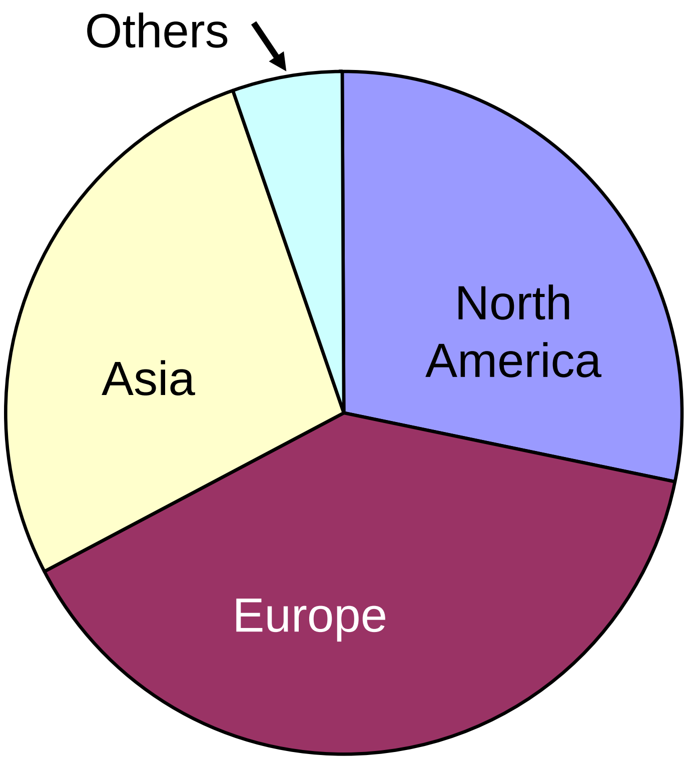
2nd Strategic Plan (active ns. & systems)

Industry R&D ($7.3B) has exceeded national government R&D ($6.5B) in 2007

Growing nanotechnology R&D investment - $13.8 billion in 2007



Private (Corp. + VC)
Total = $**7.3** billion



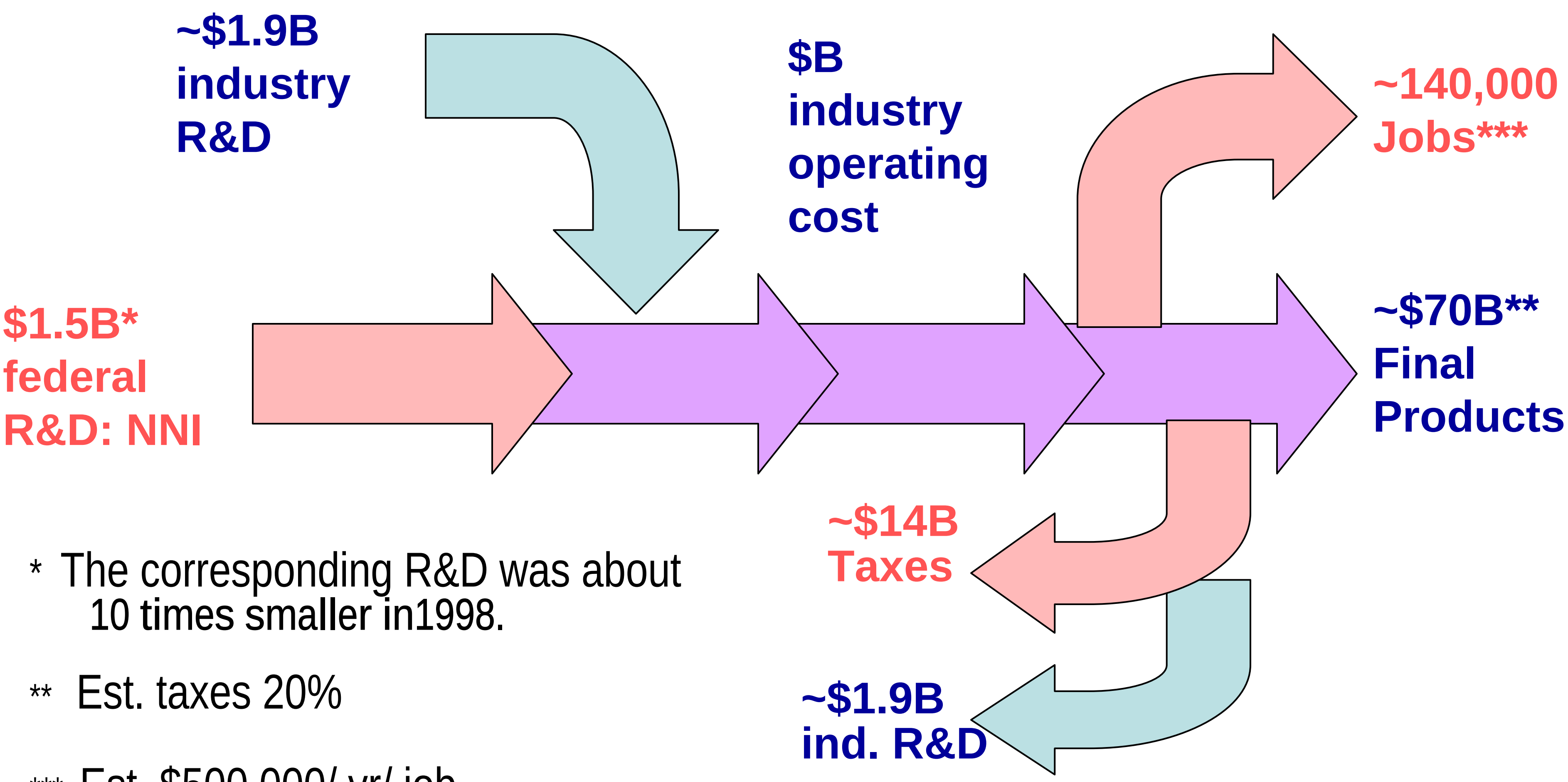
Public (National, regional, state)
Total = $**6.5** billion

National governments ~ $4.7 billion
Local governments and organizations ~ $1.8 billion

Source: Lux Research

MC Roco, Nov. 18 2009

Estimation of Annual Implications of U.S. Federal Investment in Nanotechnology R&D (2008)



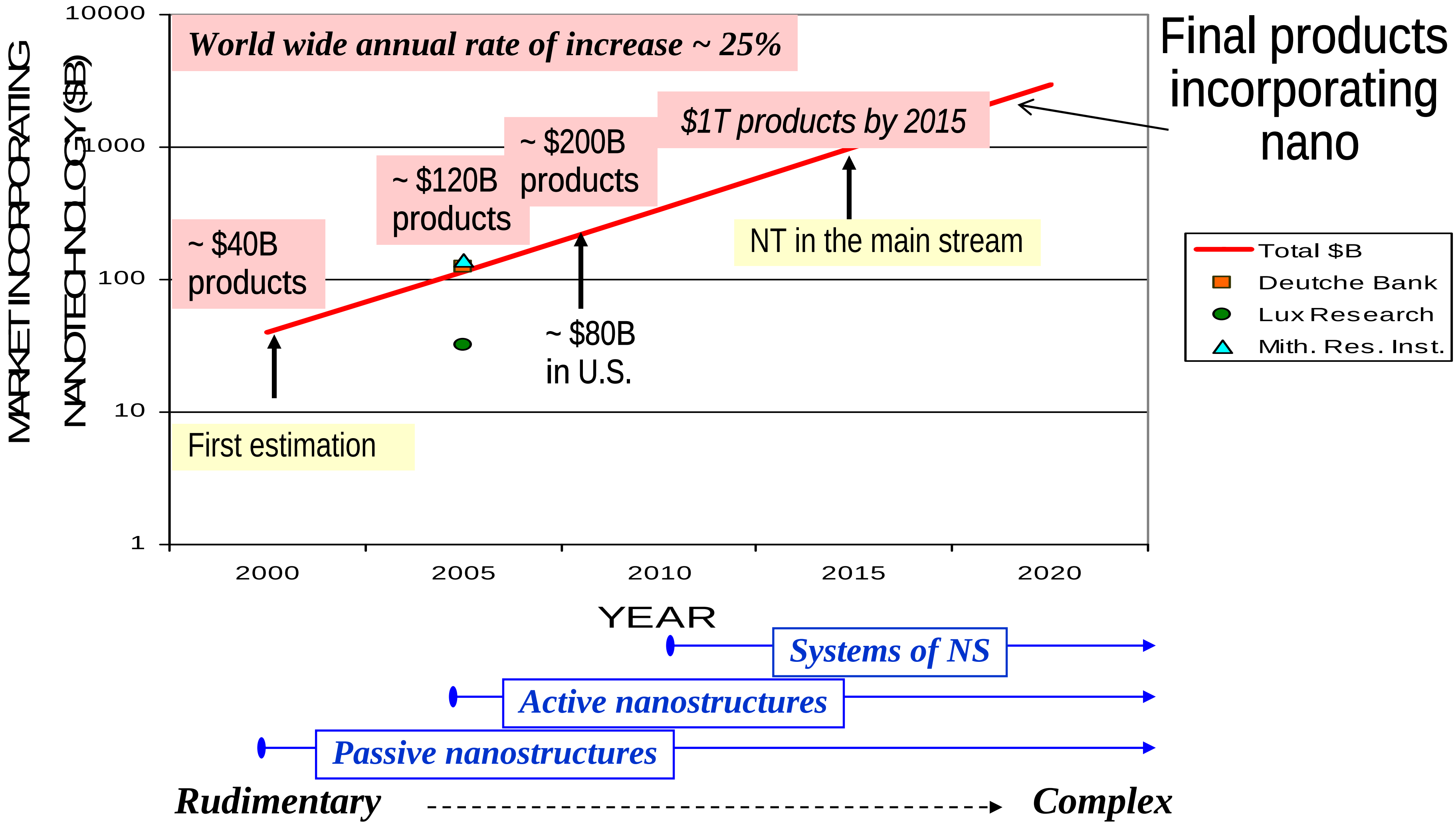
* The corresponding R&D was about 10 times smaller in1998.

** Est. taxes 20%

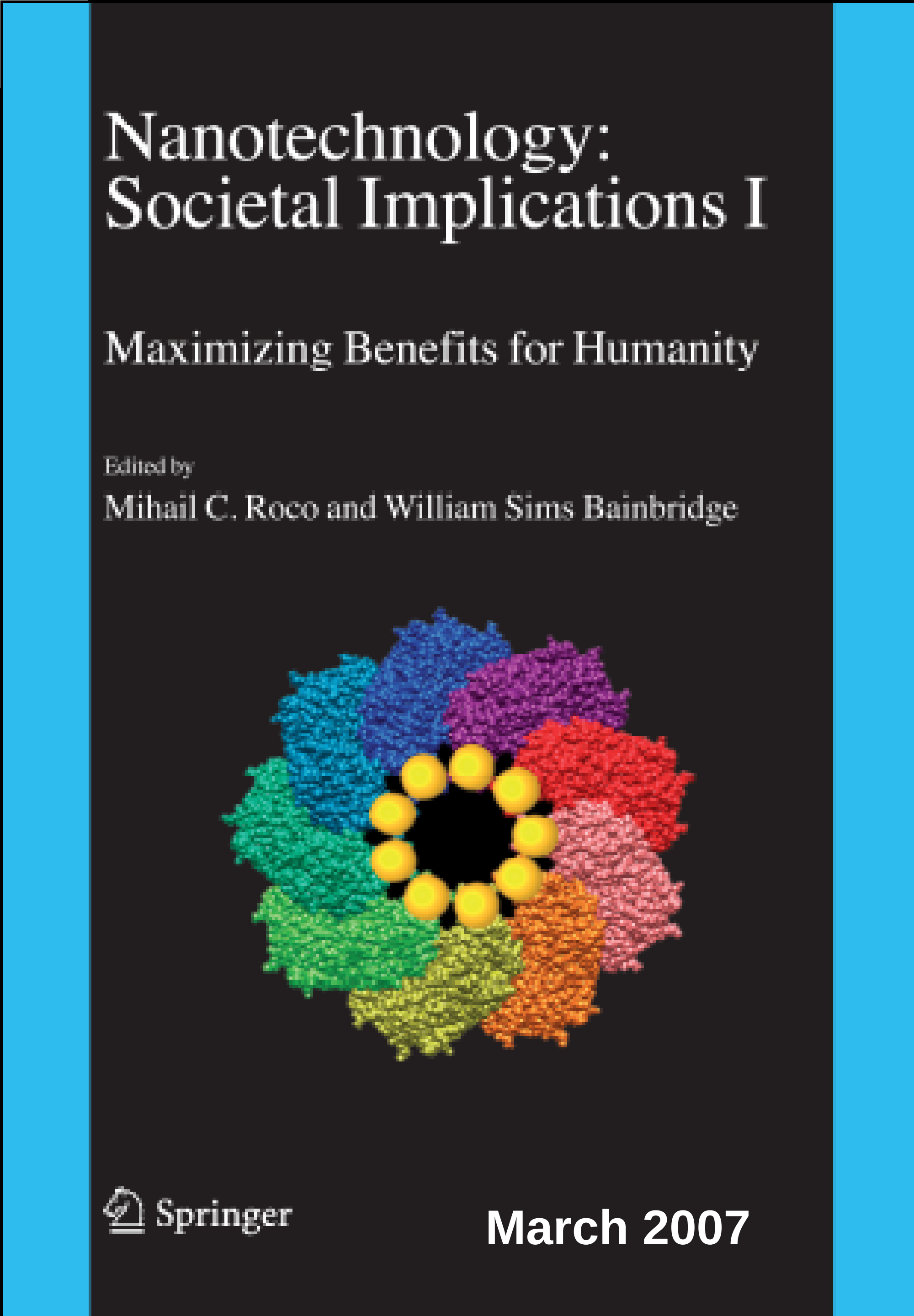
*** Est. $500,000/ yr/ job

WORLDWIDE MARKET INCORPORATING NANOTECNOLOGY

(Estimation made in 2000 after international study in > 20 countries)

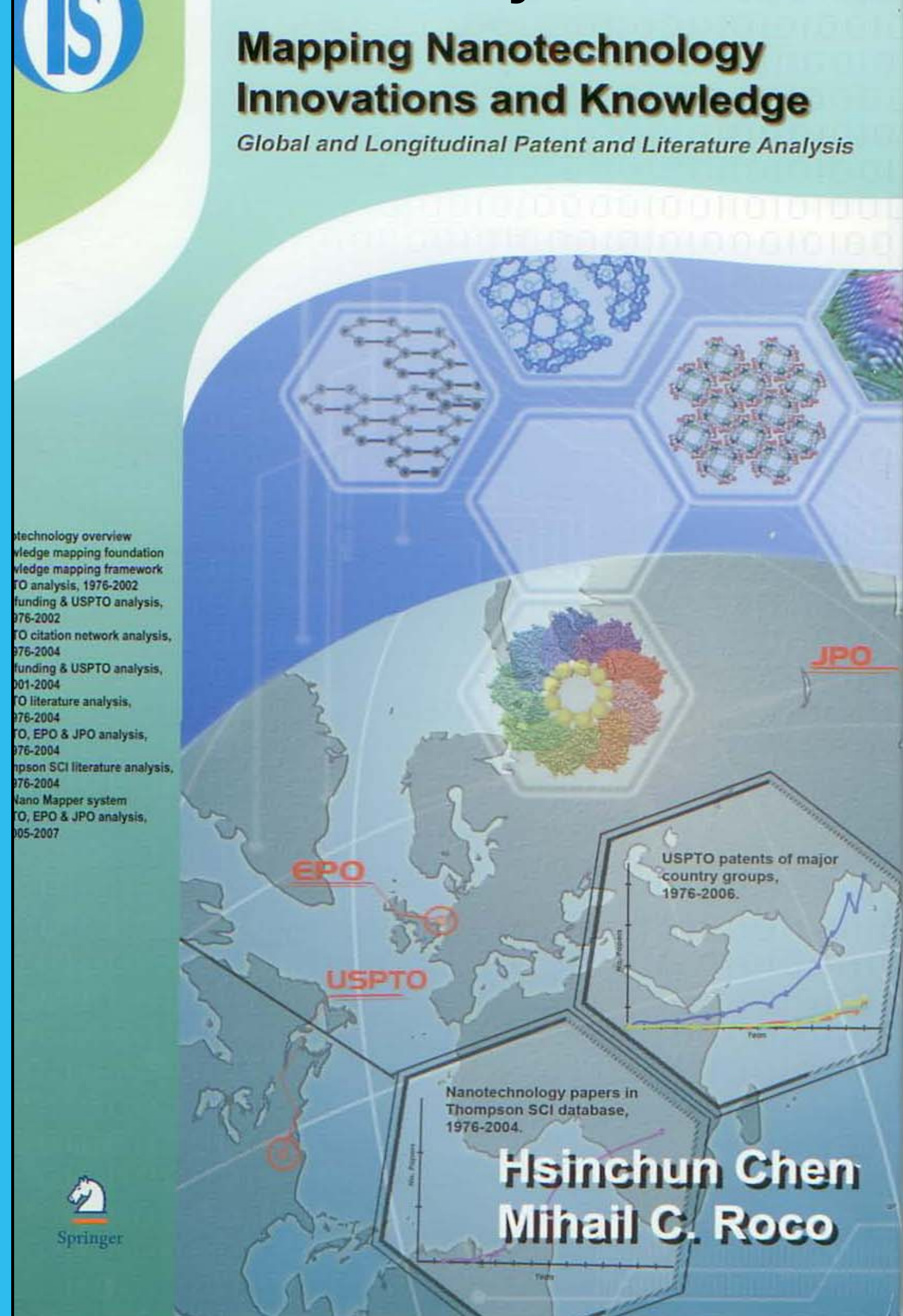


Reference: Roco and WS Bainbridge, Springer, 2001



March 2007

January 2009

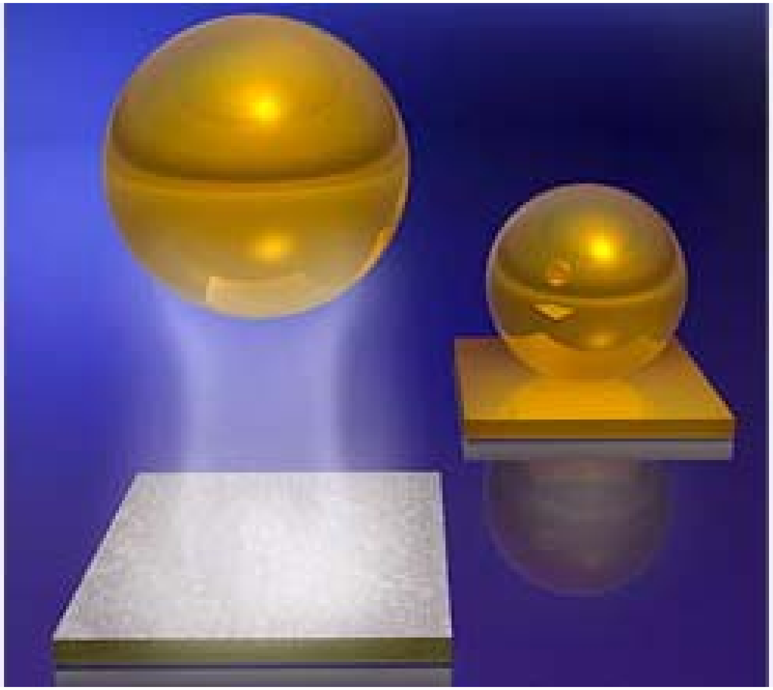


Nanotechnology in 2009 - still in an earlier formative phase of development

- 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

Discovery of Nanoscale Repulsion

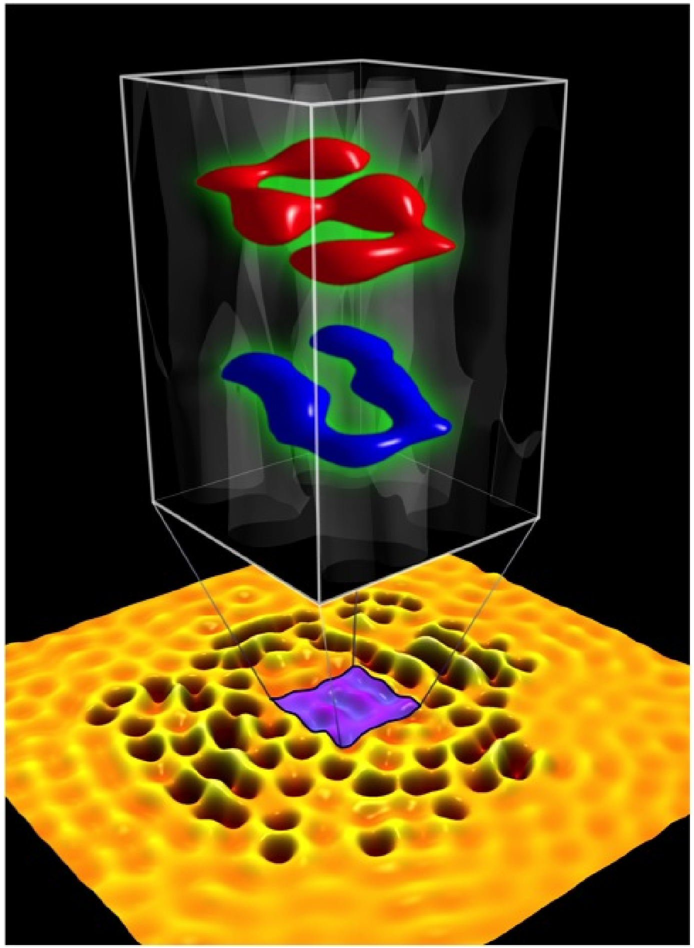
Federico Capasso, Harvard University

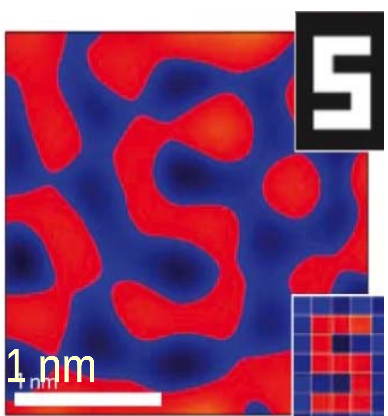


A repulsive force arising at nanoscale was identified similar to attractive repulsive Casimir-Lifshitz forces.

As a gold-coated sphere was brought closer to a silica plate - a repulsive force around one ten-billionth of a newton was measured starting at a separation of about 80 nanometers.

For nanocomponents of the right composition, immersed in a suitable liquid, this repulsive force would amount to a kind of quantum levitation that would keep surfaces slightly apart





Creating the World's Smallest Letters

Hari Manoharan, NSF – 0425897, NSEC Stanford U.

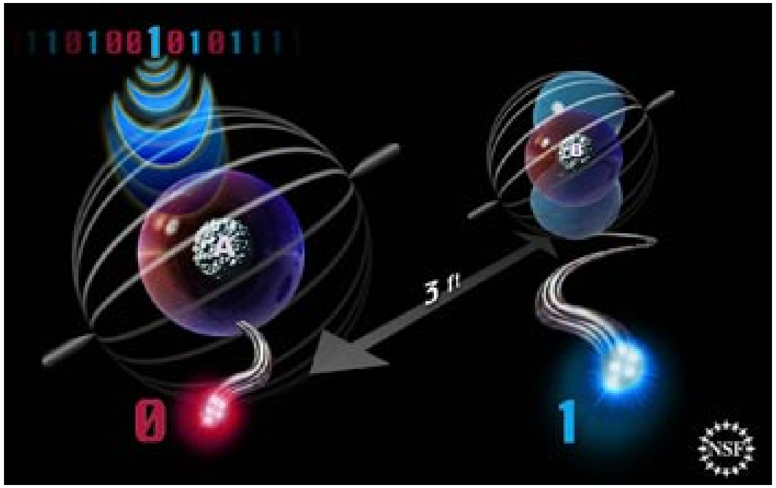
A STM is used to position CO molecules on a copper (111) surface and to read out by 2D illumination the **molecular holographic encoding** spelling the **letters SU of** **about 1 nm (0.8 by 1.5 nm) size in 3D**

The letters with features as small as 3 A are formed in the interference pattern generated by the 2D surface state electrons from the (111) face of the copper crystal and confined by the CO molecules acting as local gates (quantum holographic encoding)

C. Moon et al., Nature Nanotechnology, 4, (2009)

How to Teleport Quantum Information from One Atom to Another

Chris Monroe, University of Maryland, NSF 0829424



Teleportation carries information between entangled atoms.

Teleportation to transfer a quantum state over a significant distance from one atom to another was achieved.

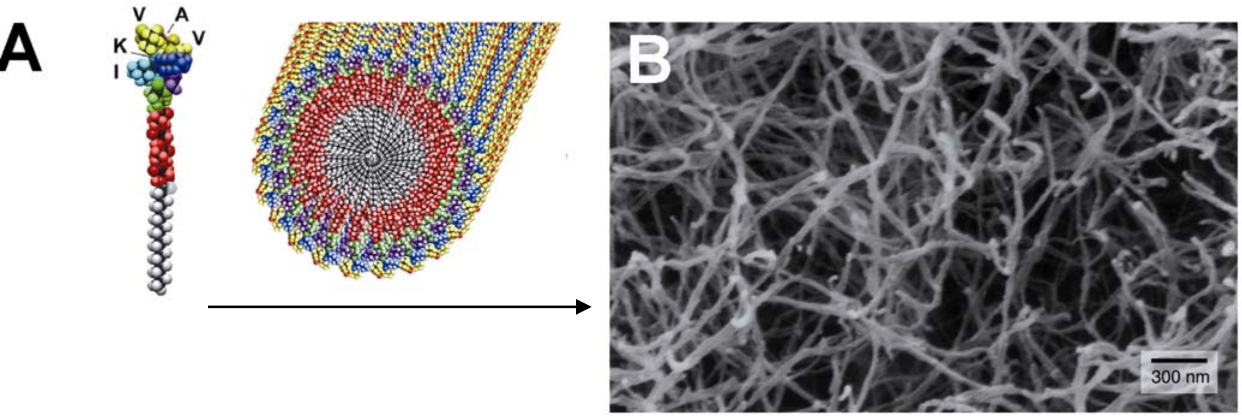
Two ions are entangled in a quantum way in which actions on one can have an instant effect on the other

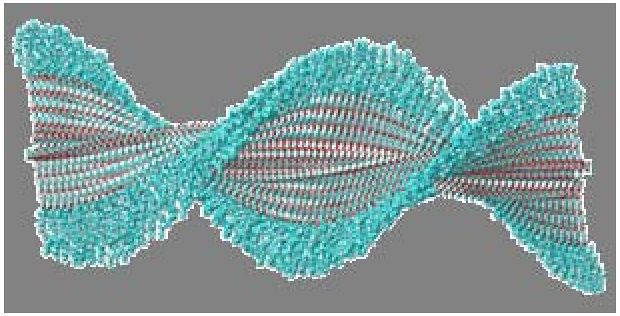
Experiments have attempted to teleport states tens of thousands of times per second. But only about 5 times in every billion attempts do they get the simultaneous signal at the beam splitter telling them they can proceed to the final step.

Example 4th generation (in research)

Designing molecules for hierarchical selfassembling

EX: - Biomaterials for human repair: nerves, tissues, wounds (Sam Stupp, NU)

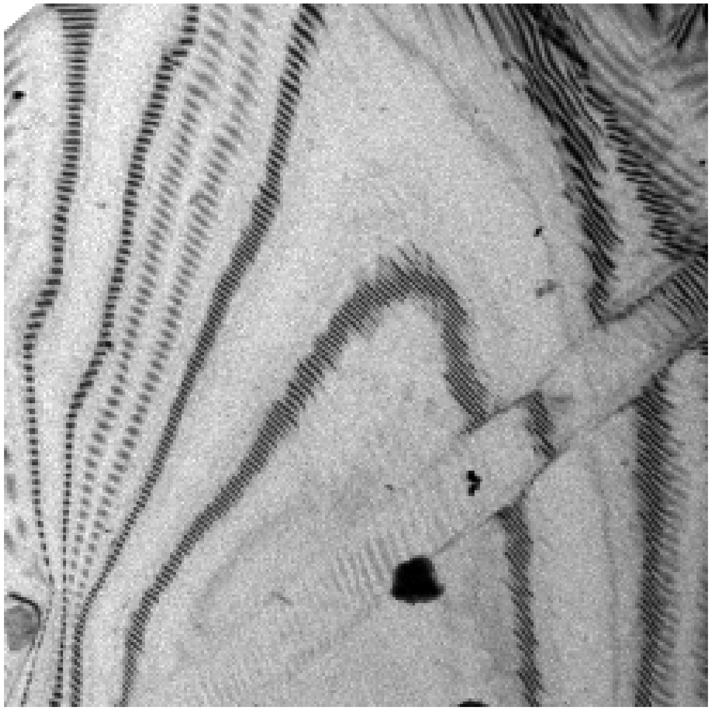




- New nanomachines, robotics - DNA architectures (Ned Seeman, Poly. Inst.)
- Designed molecules for self-assembled porous walls (Virgil Percec, U. PA)
- Self-assembly processing for artificial cells (Matt Tirrell, UCSB)
- Block co-polymers for 3-D structures on surfaces (U. Mass, U. Wisconsin)

4D Microscope Revolutionizes the Way We Look at the Nano World

A. Zewail, Caltech, and winner of the 1999 Nobel Prize in Chemistry



Nanodrumming of graphite, visualized with 4D microscopy.

http://ust.caltech.edu/movie_gallery/

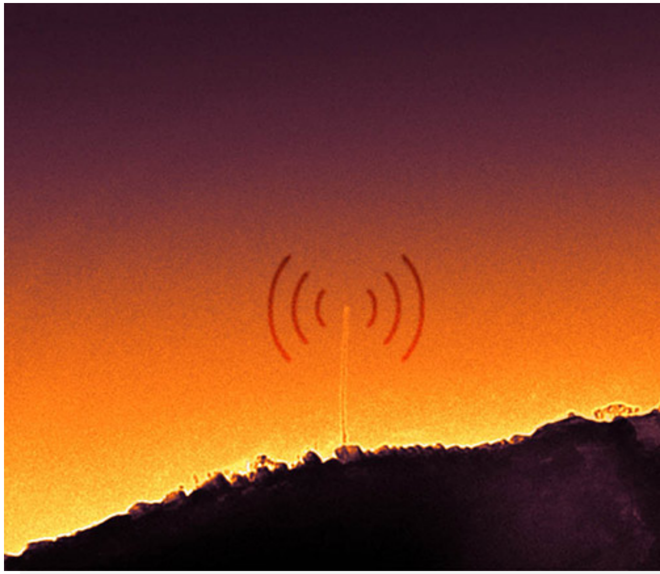
Use of ultra short laser flashes to observe fundamental motion and chemical reactions in real-time (timescale of a femtosecond, 10^{-15}s), with 3D real-space atomic resolution.

Allows for visualization of complex structural changes (dynamics, chemical reactions) in real space and real time. Such visualization may lead to fundamentally new ways of thinking about matter

Examples new topics in 2008

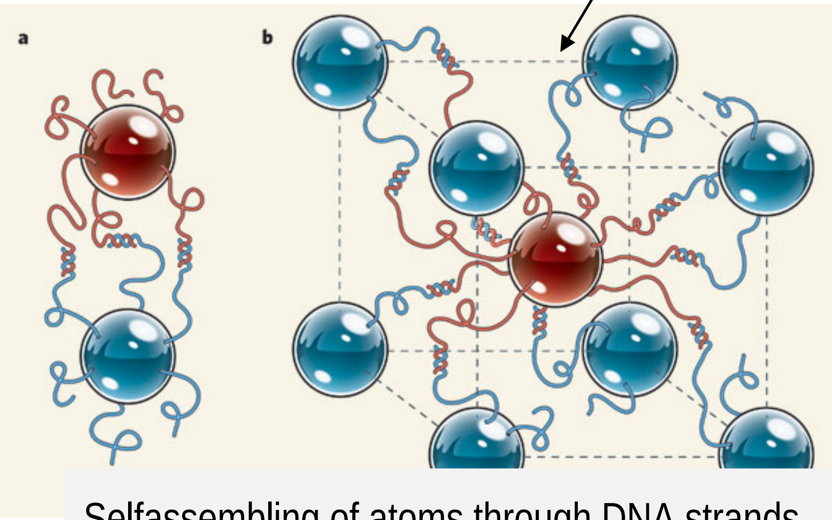
Nanodevices and components of nanosystems

- A. Zettl (UCB), J. Rogers (U Illinois): nano radio = antenna, filter, amplifier



This image, taken by a transmission electron microscope, shows the carbon-nanotube radio (UCB)

- C. Mirkin (NU), O. Gang (BNL) Architectures for new, designed crystals



Selfassembling of atoms through DNA strands

Converging technologies (NBIC) - Examples of new transdisciplinary domains

- **Quantum information science** (IT; Nano and subatomic physics; System approach for dynamic/ probabilistic processes, entanglement and measurement)
- **Eco-bio-complexity** (Bio; Nano; System approach for understanding how macroscopic ecological patterns and processes are maintained based on molecular mechanisms, evolutionary mechanisms; interface between ecology and economics; epidemiological dynamics)
- **Neuromorphic engineering** (Nano, Bio, IT, neurosc.)
- **Cyber-physical systems** (IT, NT, BIO, others)
- **Synthetic & system biology** (Bio, Nano, IT, neuroscience)
- **Cognitive enhancers** (Bio, Nano, neuroscience)

Examples of new transdisciplinary domains (2)

- **Nano sensors in the environment** (Nano, bio, IT networking, environment)
- **Emerging technologies for sustainable development** (energy conversion and storage using nano, filtration of water using nano, using exact nanomanufacturing for reducing environmental quality and weather implications, using nanotechnology to reduce consumption of raw materials, energy from fusion, etc.)
- **Adaptive systems engineering** (neuroscience, cognitive technologies, adaptive systems for unpredicted events, etc.)
- **Enhanced virtual reality** (using nano, IT, cognitive, BIO; personalized learning, reverse engineer the brain)

A specific framework is needed for risk governance of nanotechnology (IRGC)

Focus on risk analysis for the higher-risk, high production applications:

- Open and complex system
  - fundamental (high risk)
  - developments are not known (role organizations)
  - accelerated (upstream measures needed)
  - cross S,E&T (complex interactions)

- With broad implications (general platform)
  - affects most areas of economic activity, effect of the "food chain" of the nanotech products (need for comprehensive evaluation of societal implications)
  - global technological implications, cross-borders (connect models for governance at the national \and the international levels, E-W, N-S)

What is Governance?

- “Governance” – a versalite term of widespread use (see IRGC)
- Definition: Governance refers to processes, conventions and institutions that determine:
  - How power is exercised in the view of managing resources and interests
  - How important decisions are made and conflicts resolved, and
  - How various stakeholders are accorded participation
- General principles of “good governance” include e.g.:
  - Transparency
  - Responsibility, accountability, risk management
  - Participation
- Core principles + experience with NNI, ITR, BioCom + int.

  ⟹ to be applied to global CT governance

NT Governance and Risk Governance

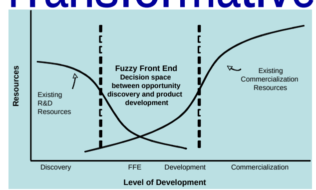
NANOTECHNOLOGY GOVERNANCE

- Investment policy
- Science policy
- Risk management
- Others . . . .

Four key functions:

Visionary

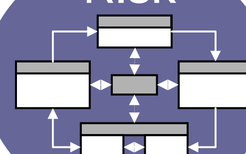
Transformative



Responsible

Benefit society

Risk



→ Risk Governance

Inclusive

MC Roco, Nov. 18 2009

Governance of nanotechnology: four main functions

- <u>Visionary</u>
  Long-term and global view in planning,
  including setting R&D priorities and human development / progress
- <u>Transformative</u>
  investment and S&T policy, support innovation,
  tools, informatics, prepare pipeline in education, facilitate commercialization; management (build-up, solicitations)
- <u>Responsible development</u>
  EHS, ELSI+, risk governance, evaluation, communication & participation, regulations and oversight including voluntary measures
- <u>Inclusive, collaborative</u>
  Building national capacity; national and international structure,
  multi-sector partnerships and leveraging

Possibilities for a Global Governance of Nanotechnology

Commitment to long-term view

- Detecting earlier signs of change using international expert groups; adopt real time technology assessment
- Commitment to long-term planning and priority setting using global scenarios, anticipatory measures and organizations for nanotechnology development
- Integrate nanotechnology development with other emerging and converging technologies; Conduct research specific for future generations of NT
- Evaluate the trends for exponential growth of nanoscale knowledge and technology capabilities

The long-term view drives NNI
2000-2020

- NNI was designed as a science project after two years of planning without dedicated funding in 1997-1999:
  - Long-term view ("Nanotechnology Research Directions")
  - Definitions and international benchmarking ("Nanostructure S&T")
  - Science and Engineering Priorities and Grand Challenges ("NNI")
  - Societal implications ("NSF Report", 2000)
  - Plan for government agencies ("National plans and budgets")
  - Public engagement brochure ("Reshaping the word", 1999)

- Combine four time scales in planning (2001-2005):
  - Vision - 10-20yrs, Strategic plan - 3-5yrs, Annual budget - 1yr, and Management decisions - 1 month;
  - at four levels: program, agency, national executive, legislative

A STRATEGY FOR AMERICAN INNOVATION
- U.S., White House paper, September 20, 2009 -

" Administration is committed to strengthening and focusing investments in our world-class **nanotechnology research and development pipeline; targeting support for nanotechnology transfer and facilitating commercial start-ups; and cross-disciplinary training and education of scientists and engineers in the new-generation workforce.** This will enable us to capitalize on our investments and stay at the cutting edge of this rapidly growing technology."

Possibilities for a Global Governance of Nanotechnology

Transformative function

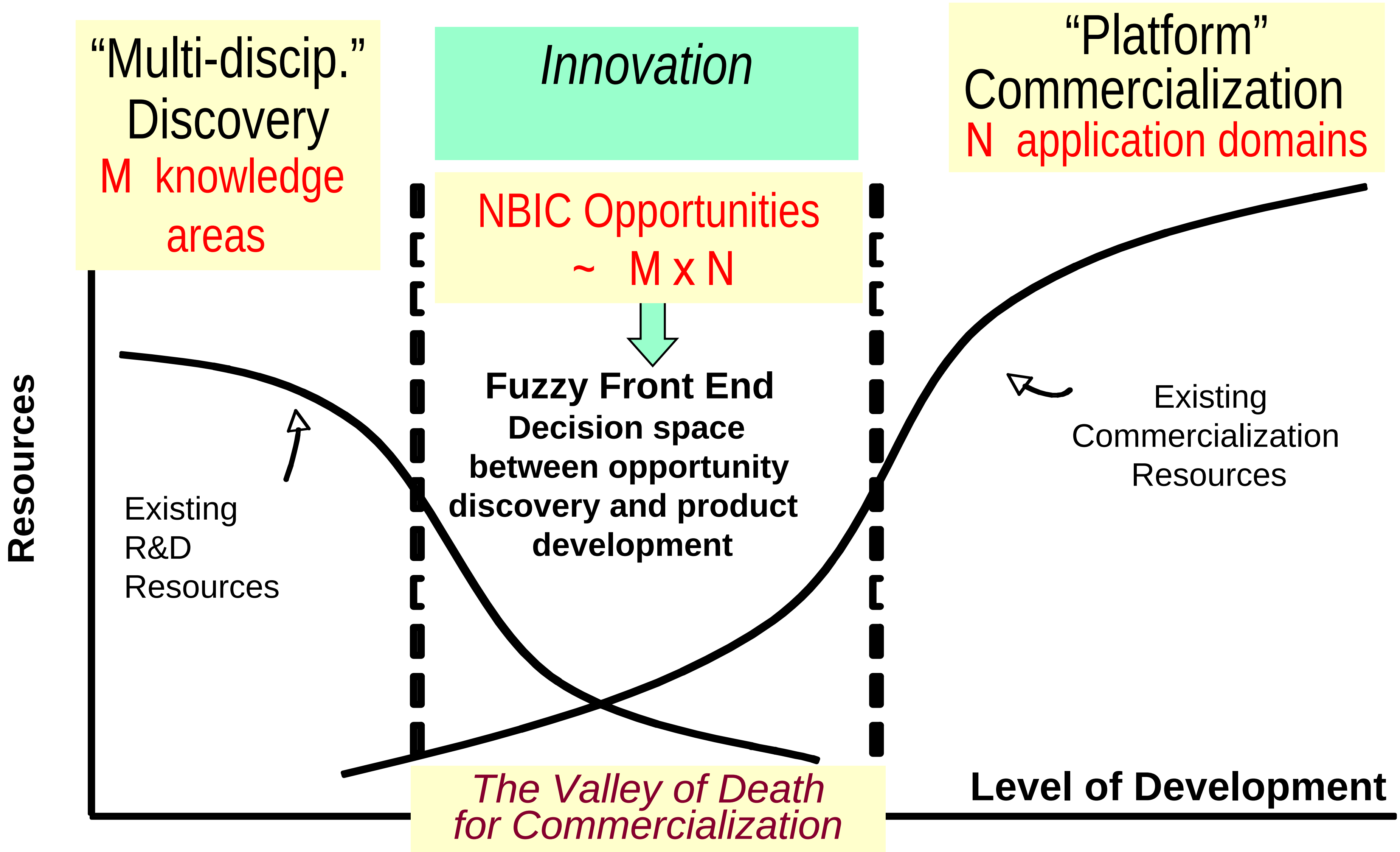
- Support tool development, knowledge creation, innovation, informatics, user-facilities and commercialization for nanotechnology

- Allocation of development funds for common topics: nomenclature, metrology, standards, patent evaluation, databases, and EHS methodologies

- Creating better opportunities in developing countries

- Use “incentives” and “empowering stakeholders” in the open and global ecosystem

Transformative: enhance innovation

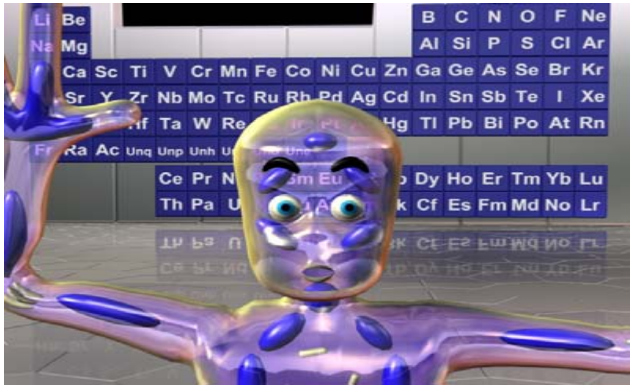


INNOVATION opportunities increase ~ M x N times

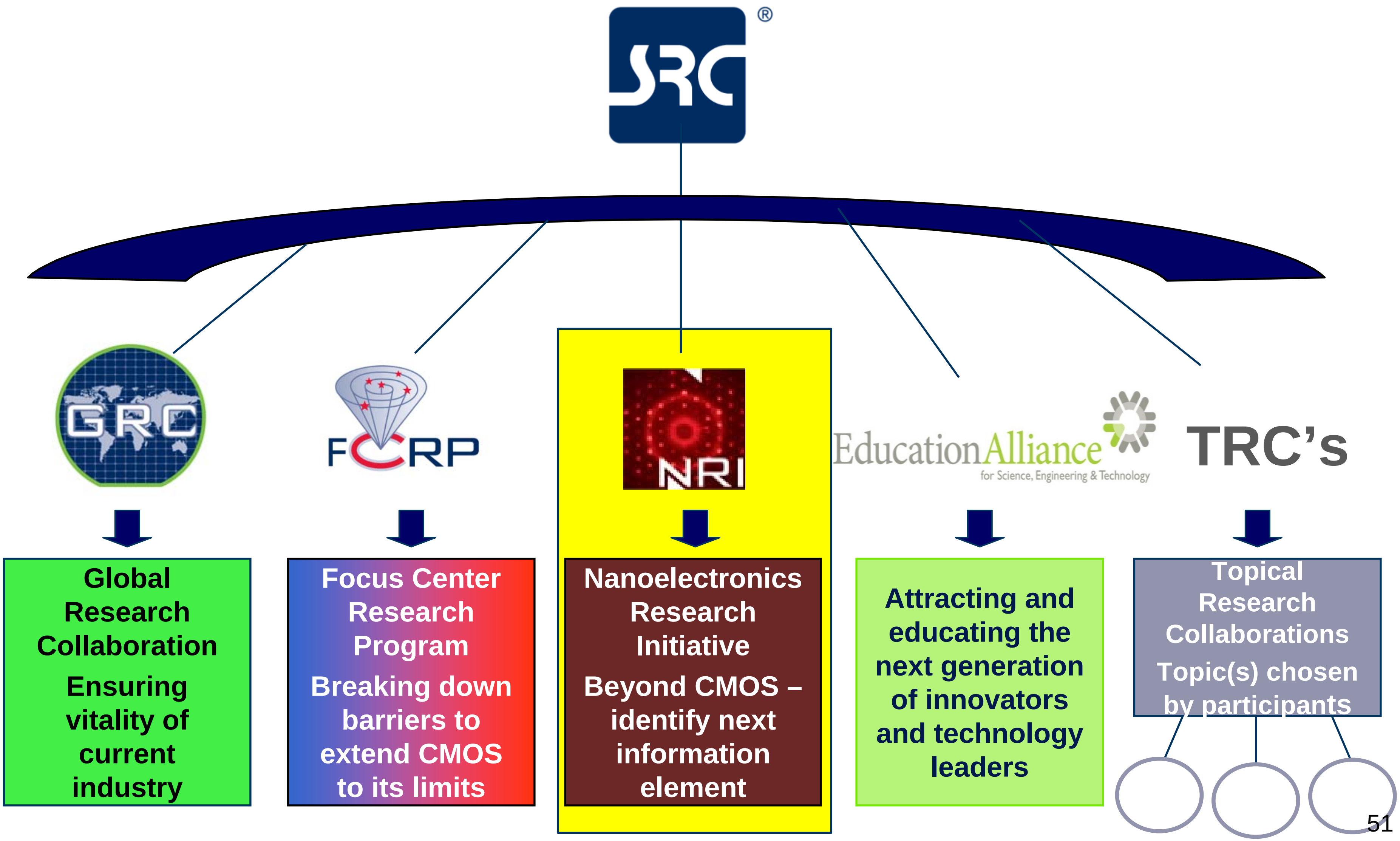
MC Roco, Nov. 18 2009

"Reverse pyramid" of learning to prepare for new generations of technologies

- Learning first unifying concepts of matter / biology/ information systems, and then averaging techniques specific to each discipline
- Sharing similar concepts in various disciplines and relevance areas: unifying concepts earlier in education



Example of emerging technology organization:
Semiconductor Research Corporation



Responsible development function

- Development with priority of general benefit applications such as increasing productivity and sustainable nanomanufacturing; Applying nanotechnology for improving availability of common Earth resources such as water, food, energy, and sustainable clean environment

- Voluntary measures and science-based decision for risk management ; Predictive models for human- and eco-tox

- Develop organizational capacity for effective oversight

- Evaluation at different interval and organizational levels

The World is NOT Currently Achieving Sustainable Development

Every major ecosystem is under threat at different time scales: food, water, risk of climate change, energy, biodiversity, mineral resources

Nanotechnology may offer efficient manufacturing with less resources, less waste, better functioning products

Need for global governance of converging technologies

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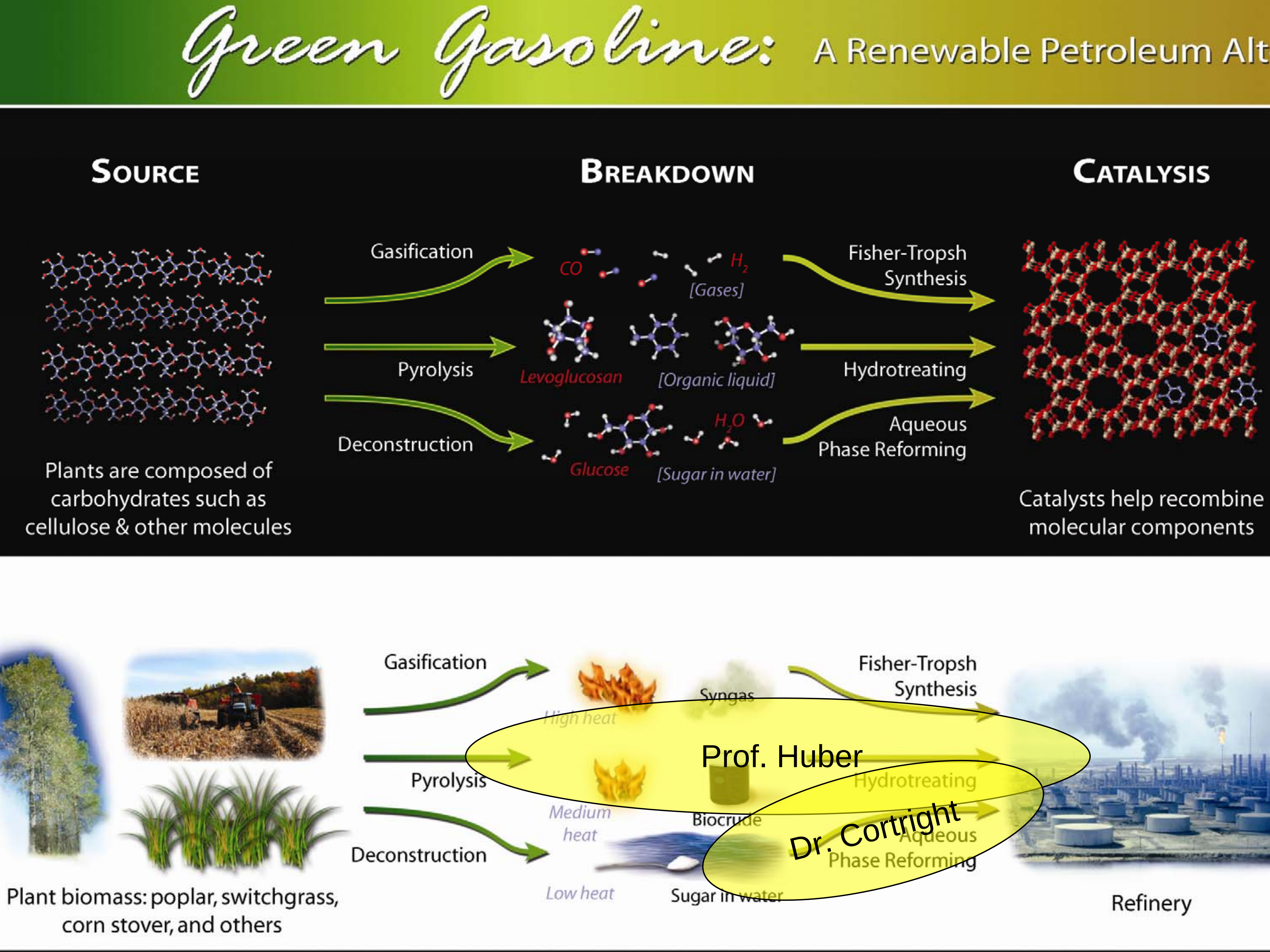
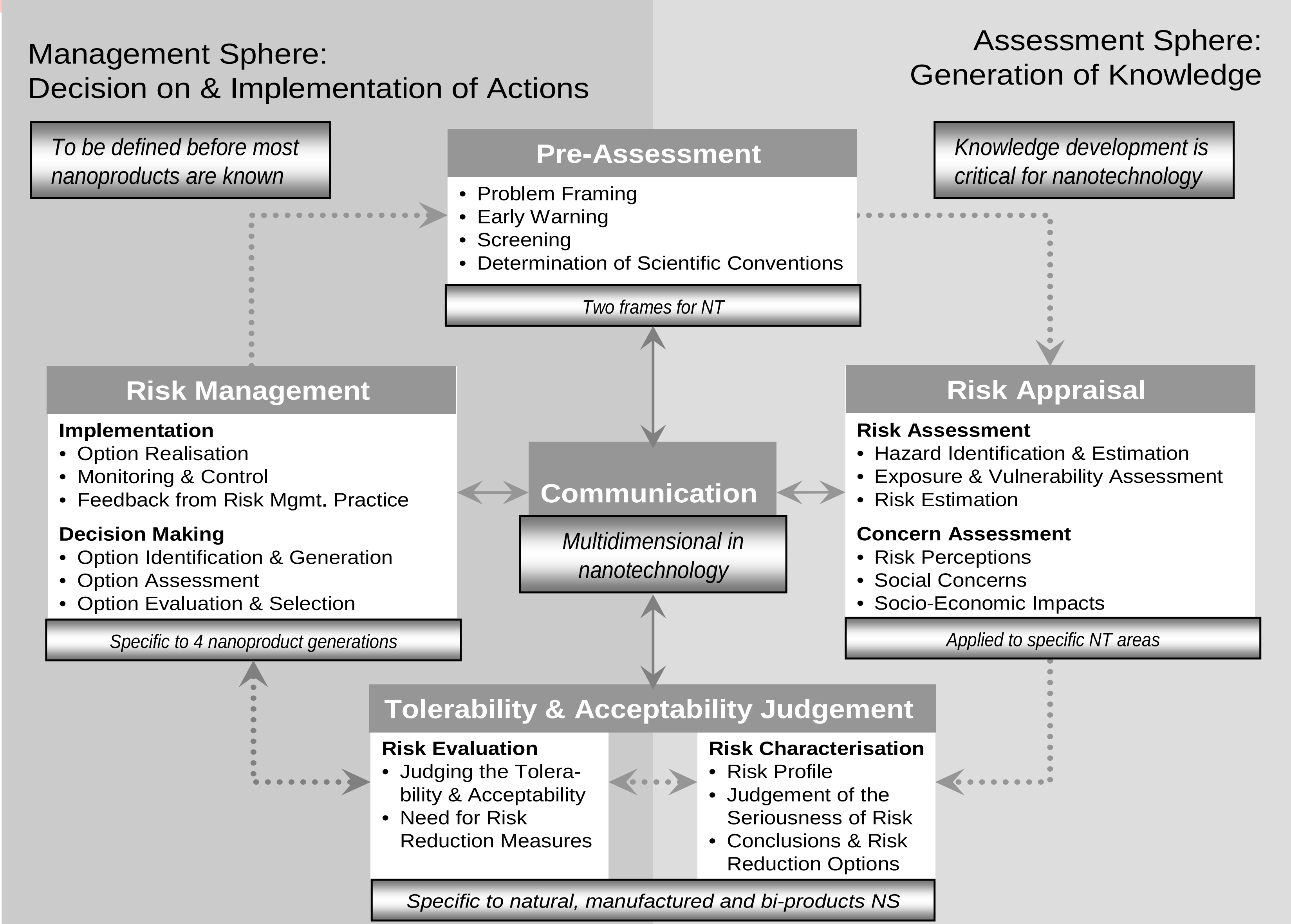

Green Gasoline: A Renewable Petroleum Alt
Source
Breakdown
Catalysis
Gasification
Pyrolysis
Deconstruction
CO
H2
[Gases]
Levoglucosan
[Organic liquid]
H2O
Glucose
[Sugar in water]
Fisher-Tropsh Synthesis
Hydrotreating
Aqueous Phase Reforming
Plants are composed of carbohydrates such as cellulose & other molecules
Catalysts help recombine molecular components
Gasification
Pyrolysis
Deconstruction
High heat
Syngas
Medium heat
Biocrude
Low heat
Sugar in water
Fisher-Tropsh Synthesis
Hydrotreating
Aqueous Phase Reforming
Prof. Huber
Dr. Cortright
Plant biomass: poplar, switchgrass, corn stover, and others
Refinery

IRGC RISK GOVERNANCE FRAMEWORK FOR NANOTECHNOLOGY



Strategies as a function of the generation of nanotechnology: Application to Frame 1 and Frame 2 (pre-assessment)

Increased
- Complexity,
- Knowledge needs
- Implications

Risk management escalator

Nanosystems

Frame 2 longer term
Unknown
(Higher ambiguity in society)

Future work on social and global dimensions (focus on ELSI +)

Active nanostructures

Frame 2 shorter term
Technological System
Uncertainty

Broader "strategy", design and recommendations are needed (focus on EHS, ELSI)

Passive nanostructures

Frame 1
Component Complexity
R&D underway
Regulatory measures considered

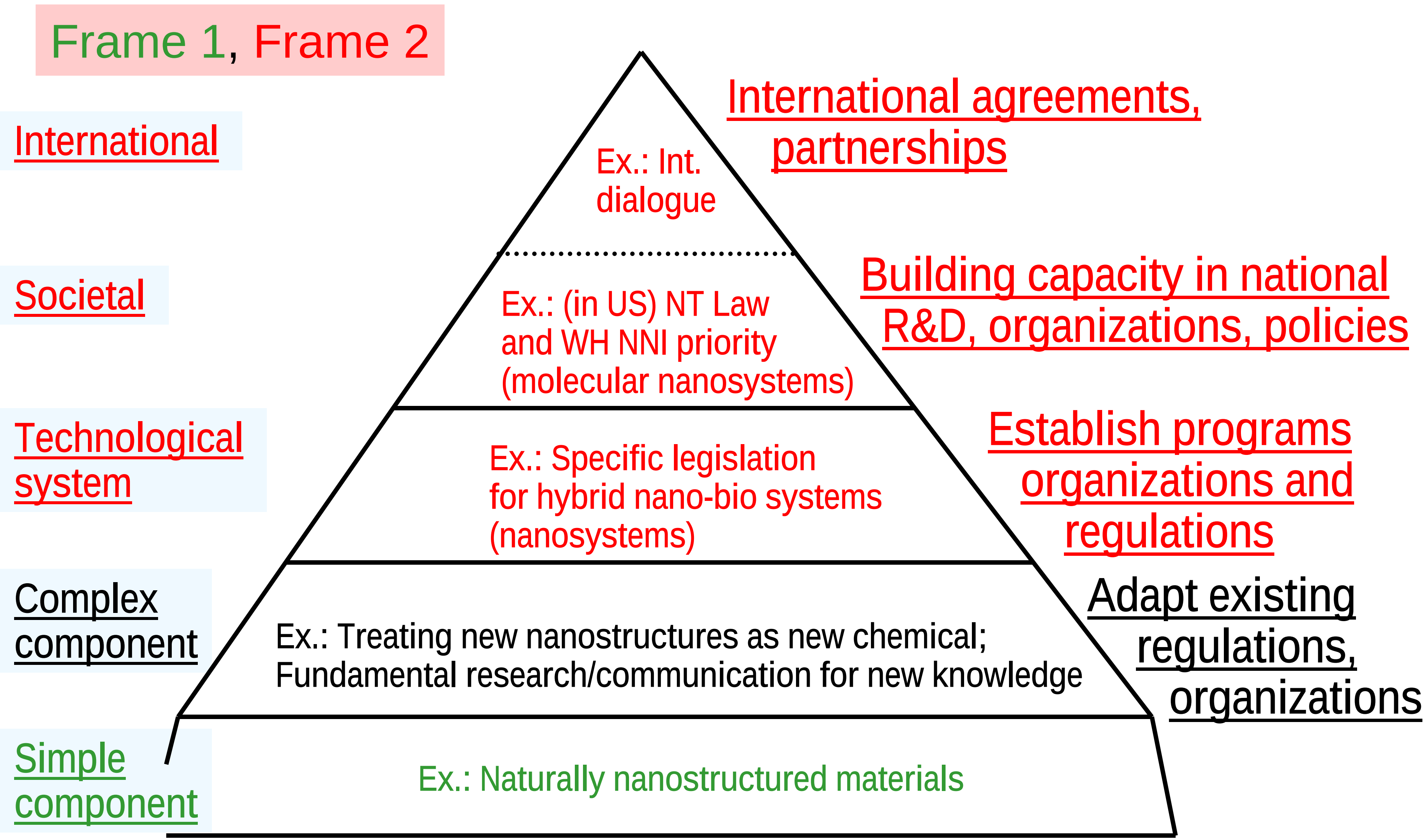
Some specific problems, with a focus on regulators (focus on EHS)

NT application areas

J. Nanoparticle Research, 2006, Vol. 8(2)

Responsible development

Multi-level structure for risk governance



MC Roco, Nov. 18 2009

The Risk Management Escalator and Stakeholder Involvement

(from Simple via Complex and Uncertain to Ambiguous Phenomena) with reference to nanotechnology

IRGC

Frame 1

Naturally nanostructured materials

Statistical Risk Analysis

Remedy

- Agency Staff
- External Experts

Actors

Instrumental

Type of Discourse

Simple

Risk Problem

Engineered nanostructured materials

Probabilistic Risk Modelling

Remedy

Cognitive

Type of Conflict

- Agency Staff
- External Experts
- Stakeholders

Actors

Epistemological

Type of Discourse

Component Complexity induced

Risk Problem

Frame 2

Active nanostructures and systems

Risk Balancing Necessary
+ Probabilistic Risk Modelling

Remedy

- Cognitive
- Evaluative

Type of Conflict

- Agency Staff
- External Experts
- Stakeholders
  - Industry
  - Directly affected groups

Actors

Reflective

Type of Discourse

System uncertainty induced

Risk Problem

Large and molecular nanosystems

Risk Trade -off Analysis & Deliberation necessary
+ Risk Balancing
+ Probabilistic Risk Modelling

Remedy

- Cognitive
- Evaluative
- Normative

Type of Conflict

- Agency Staff
- External Experts
- Stakeholders
  - Industry
  - Directly affected groups
  - General public

Actors

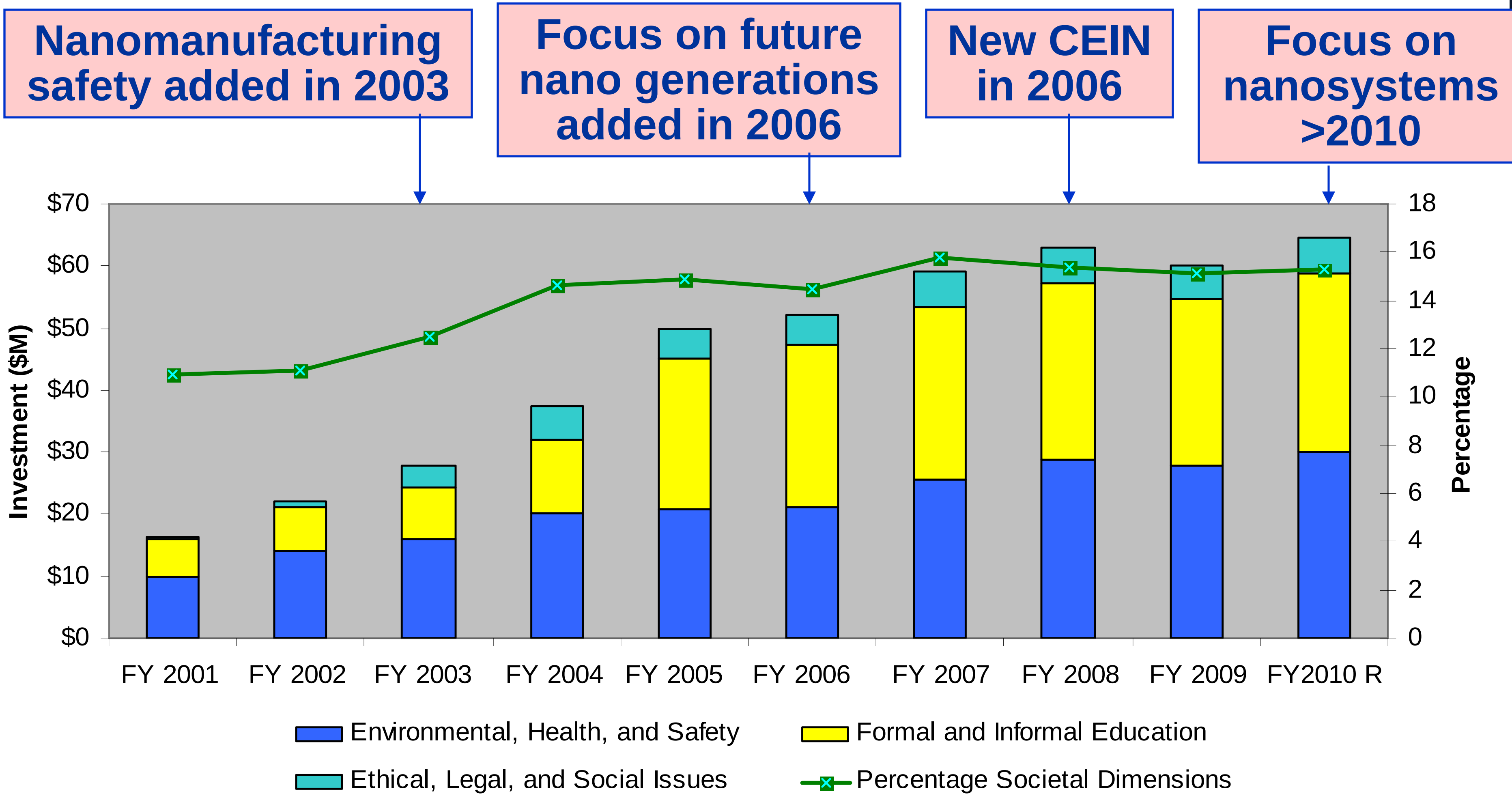
Participative

Type of Discourse

Ambiguity induced

Risk Problem

NSF Investment in Nanotechnology Implications for Safety and Society



MC Roco, Nov. 9 2009

The communication gap between emerging CT development and governance decisions

The Valley of Death
For Governance

EMERGING CT

RESEARCH
Creation of new information

COLLECT
VALIDATE
PRESENT
CRITIQUE

INFORM

FILTER
ORGANIZE
EXPLAIN
SUMMARIZE

EDUCATE

SYNTHESIZE
DEBATE
COMPARE

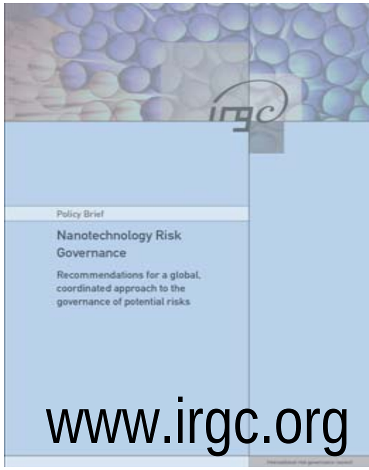
FRAME

GOVERNANCE

DECIDE
Recommend Actions

Modified M. Roco, ICON

Address changing <u>public perception</u> since 2000



www.irgc.org

Before 2000: Is anything special at nanoscale?
Is nanotechnology important?
When the first products?

2000-2003: Are there self-duplicating nano-bots?
Could they create "grey-goo"?

> *2003*: What are the risks of "long-term / catastrophic environmental and health events" of nanoparticles?

> *2005*: <u>Nanotechnology can help sustainable management</u> of global resources (water, energy, ..)
<u>Concerns on using nanotech in food, reaction to accidents, perception of transhumanism, buzz word</u>

2008: ~ 30% know something; ~ 70% benefits > concerns

Possibilities for a Global Governance of Nanotechnology

Inclusiveness and partnership function

- Supporting partnerships between various stakeholders active in nanotechnology and related emerging technologies
- Global communication and information
- Public inclusion and participation globally
- Involving international organizations to advance multi stakeholder global challenges
- Encourage international and cross-sector interactions

Inclusive governance - Ex: International Dialogue on Responsible Nanotechnology R&D since 2004

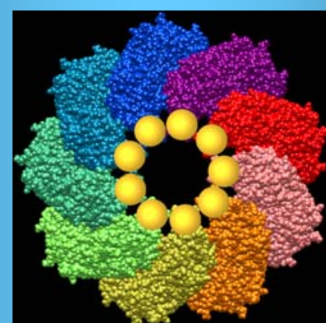
First: 2004, Virginia, USA
Second: 2006, Japan
Third: 2008 Brussels, EC

Survey Investments

Current Norms

Recommended measures

International Dialogue



26 countries

Joint Statement

Immediate Actions

June 2004, Virginia

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

First International Dialogue on Responsible Nanotechnology R&D (2004)

Coordinated activities after the June 2004 International Dialogue

- October 2004 / October 2005 - Occupational Safety Group (UK, US,.)
- November 2004 - OECD / EHS group on nanotechnology begins
- December 2004 - Meridian study for developing countries
- December 2004 - Nomenclature and standards (ISO, ANSI)
- February 2005 - North-South Dialogue on Nanotechnology (UNIDO)
- May 2005 - International Risk Governance Council (IRGC)
- May 2005 - "Nano-world", MRS (Materials, Education)
- July 2005 - Interim International Dialogue (host: EC)
- **October 2005 - OECD Nanotechnology Party in CSTP**
- **June 2006 - 2nd International Dialogue (host: Japan)**
- **2006 Int. awareness for: EHS, public participation, education**
- **2007-2009 - new activities**

Foster suitable international organizations

Ex: International standards organizations working on nanotechnology

National Body International Standards Organizations

Treaty-Based International Standards Organizations

Standards Development Orgs. With Global Reach

ASME International

OECD, Chemicals Committee, WPMN

2005- (**http://www.oecd.org/env/nanosafety/**)

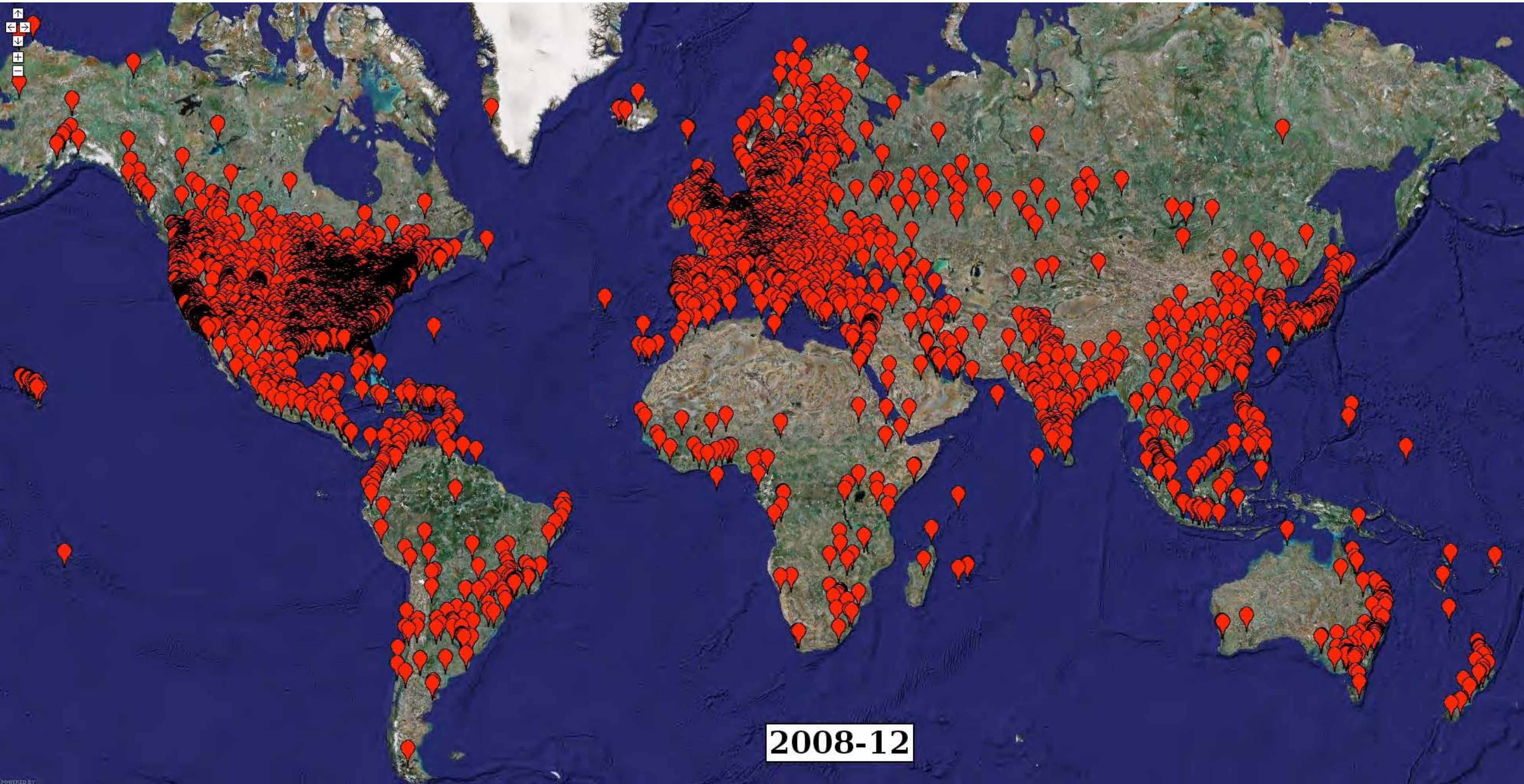
OECD: Working Party on Nanotechnology (WPN)

Working Party on Nanotechnology, 2007- (http://www.oecd.org/sti/nano)

A. Statistics and Measurement
B. Impacts and Business Environment
C. International Research Collaboration
D. Outreach and public engagement
E. Dialogue on Policy Strategies
F. Contribution of Nanotech to Global Challenges

Support global eco-systems via COLLABORATION

NETWORK FOR COMPUTATIONAL NANOTECHNOLOGY
nanoHUB.org is a resource for the global Nanotechnology Community.
The map below indicates a red-peg for every nanoHUB user on the planet.



Five Possibilities for Global Nanotechnology Governance

1. *Establish open-source models for the global self-regulating ecosystem* to enhance discovery, education, innovation, informatics, commercialization and broad societal goals

2. *Create and leverage S&T nanotech platforms* (ind., med.) for new products in areas of highest societal interest

3. Develop institutional capability to address sustainability of resources, *EHS and unexpected consequences*

4. Support *global communication and international partnerships*, facilitated by international organizations

5. Commitment to *long-term, priority driven gov., global view* using scenarios, anticipatory and adaptive measures

Several background references

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