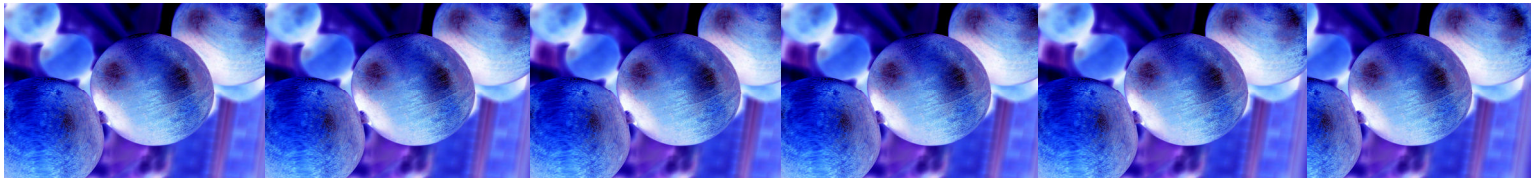
Anticipating Nanotechnology:

Real-Time Technology Assessment and the Center for Nanotechnology in Society



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[2]Manchester Institute of Innovation Research, Manchester Business School, UK
[3]Center for Nanotechnology in Society (CNS-ASU), Tempe, USA

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Presentation at Institute for Future Technology, Tokyo
March 13, 2009

Overview

1. Nanotechnology emergence
2. Center for Nanotechnology in Society (CNS-ASU)
   - Georgia Tech Nanotechnology Research Program Assessment Group
   - Other CNS-ASU programs and activities
3. Reflections and Comparisons

What is Nanotechnology?

- Science, engineering and technology of understanding and controlling matter at c. 1-100 nm scale
- To develop materials, devices, and systems that have novel properties and functions due to Nanoscale
- Argued to be a transformative general technology with fundamental technological, economic and societal consequences

*1 nm = 1 billionth of a meter

Nano products that exist today

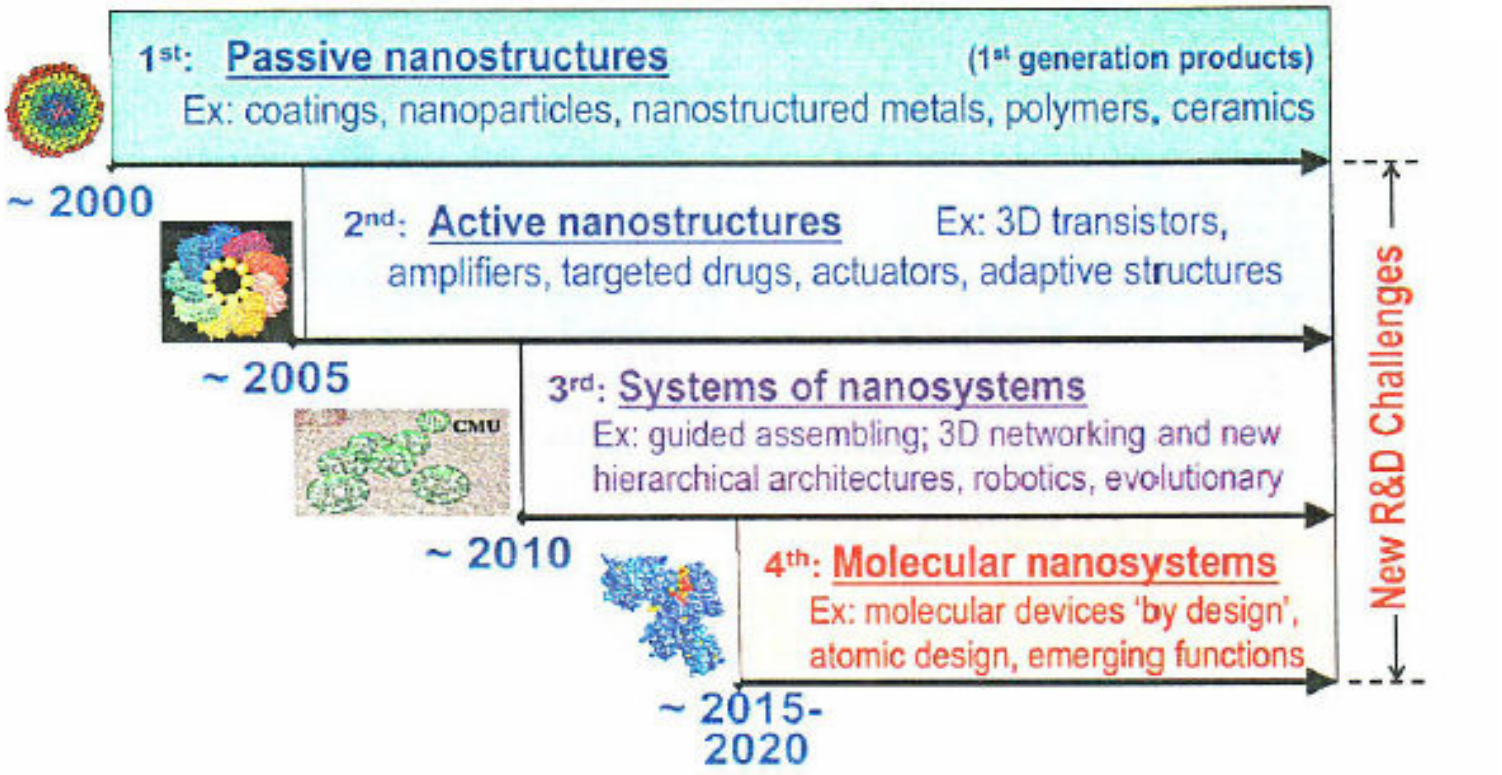
- Athletic equipment (golf clubs and balls, skis and snowboards, tennis rackets and balls, bicycles, bats)
- Sunscreen, cosmetics, and cleansers
- Stain-resistant clothing
- Anti-bacterial socks, dressings
- Cleansers and polishes
- Semiconductors and processors
- Paints, finishes, sealants
- Filters

Possible nano products that do not yet exist

- Implantable chips that relay information directly into the brain through nano-scale wires
- A floor that tracks the movements of everything on it with nano-sensors in the floor material
- Nano-scale "tagents" to stick to, label, and track anything and any exposure situation
- "Bar-free" prisons using nano-scale drugs in prisoners' bodies that radio frequencies can trigger to incapacitate potential escapees
- Attaching antibodies or toxins to nanoparticles that target cancer cells

Context: The emergence of nano

It is still early – but paths are being set



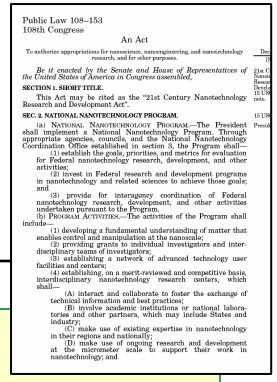
Timeline for beginning of industrial prototyping and nanotechnology commercialization. Roco (2005).

Three Societal Problems

- The Grey Goo / GMF problem
  - Avoid negative results
  - Responsibility and a precautionary approach
- The targeting problem
  - What are the goals? (esp. of public nano investment)
  - Society as the frontier: Equity, quality of life
- The process problem
  - Who decides? Can decision-making be inclusive?
  - Can decision-making be reflective and anticipatory?

2006-05-03 23:10:00
Scientist warns of nanotechnology dangers
LONDON, May 3 (UPI) -- A British scientist is warning that hundreds of...

The U.S. 21st Century Nanotechnology R&D Act of 2003 (PL 108-153)



Public Law 108–153
108th Congress

An Act

To authorize appropriations for nanoscience, nanoengineering, and nanotechnology research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "21st Century Nanotechnology Research and Development Act".

SEC. 2. NATIONAL NANOTECHNOLOGY PROGRAM.

(a) NATIONAL NANOTECHNOLOGY PROGRAM.—The President shall implement a National Nanotechnology Program. Through appropriate agencies, councils, and the National Nanotechnology Coordination Office established in section 3, the Program shall—

(1) establish the goals, priorities, and metrics for evaluation for Federal nanotechnology research, development, and other activities;

(2) invest in Federal research and development programs in nanotechnology and related sciences to achieve those goals; and

(3) provide for interagency coordination of Federal nanotechnology research, development, and other activities undertaken pursuant to the Program.

(b) PROGRAM ACTIVITIES.—The activities of the Program shall include—

(1) developing a fundamental understanding of matter that enables control and manipulation at the nanoscale;

(2) providing grants to individual investigators and interdisciplinary teams of investigators;

(3) establishing a network of advanced technology user facilities and centers;

(4) establishing, on a merit-reviewed and competitive basis, interdisciplinary nanotechnology research centers, which shall—

(A) interact and collaborate to foster the exchange of technical information and best practices;

(B) involve academic institutions or national laboratories and other partners, which may include States and industry;

(C) make use of existing expertise in nanotechnology in their regions and nationally;

(D) make use of ongoing research and development at the micrometer scale to support their work in nanotechnology; and

Four key objectives:

- Framework for integrated and interdisciplinary approach to nano R&D
- Encourages applications of nano for productivity, industrial competitiveness
- Provides for nano education and training
- Requires ethical, legal, environmental, and other societal concerns to be addressed

Sec 2(b)(10):

- Establishes societal implications research program
- Requires nano research centers (NSECs) to address societal implications
- Integrates societal concerns with nano R&D
- Ensure advances in nanotech lead to quality of life improvements for all
- Provides for public input

NSF Network for Nanotechnology in Society

Awards made Fall 2005 to Fall 2010

- **NSEC/Center for Nanotechnology in Society at Arizona State University**

  $6.2 million: Real-time technology assessment; education & outreach

- **NSEC/Center for Nanotechnology in Society at UC Santa Barbara**

  $5 million: Nano development; response to nano; education, outreach

- **Projects**
  - Nanoscale Interdisciplinary Research Team Projects
    - Harvard/UCLA/NBER ($1.7 M)
    - University of South Carolina ($1.4 M)
  - Also: Michigan State University; NanoBank; National Nanotechnology Infrastructure Network

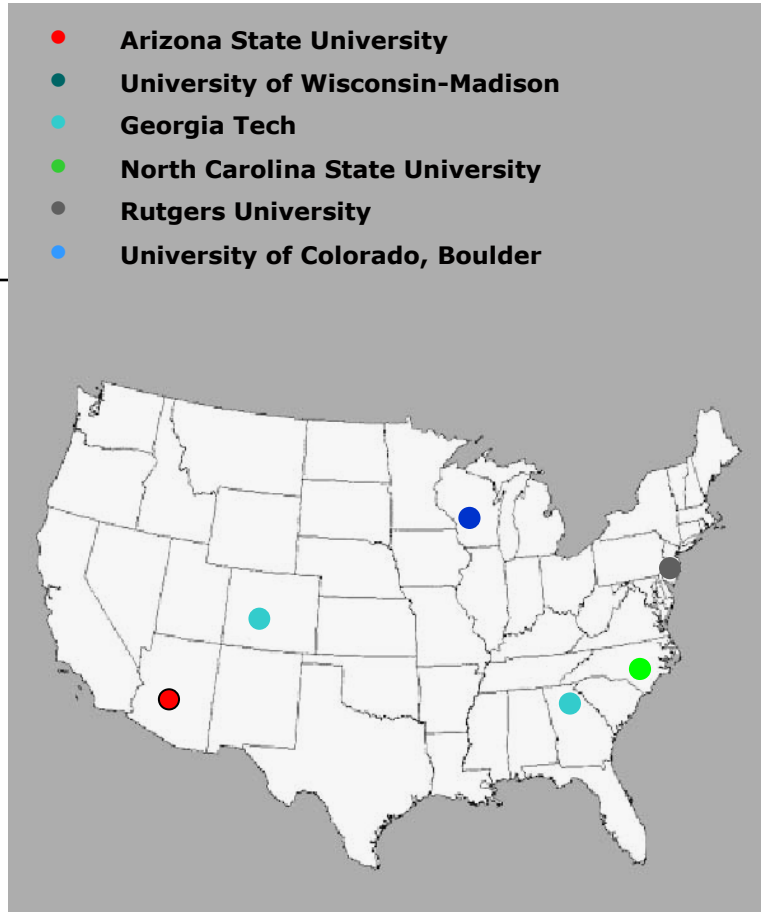
NSEC = Nanoscale Engineering and Science Center

Center for Nanotechnology and Society (CNS-ASU)

MISSION

- **Research** the societal implications of nanotechnologies
- **Train** a community of scholars with new insight into the societal dimensions of nanoscale science & engineering (NSE)
- **Engage** the public, policy makers, business leaders, and NSE researchers in dialogues about the goals and implications of NSE
- **Partner** with NSE laboratories to introduce greater reflexiveness in the R&D process

METHOD: Real-Time Technology Assessment



CNS-ASU involves the activities of more than 80 individuals at 6 major collaborating institutions, as well as other collaborators, partners, and consultants

SPONSORSHIP: NSF 2005-2010 → 2015 (planned)

CNS-ASU aims to encourage reflexivity among the NSE research establishment and build capacity for anticipatory governance

Reflexivity

- a capacity for social learning (by individuals, groups, institutions, publics) in the NSE enterprise narrowly and society broadly that expands the domain of and informs the available choices in decision making about nano.

Anticipatory Governance

- a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible.

CNS-ASU Research Programs

Real-Time Technology Assessment

1. Research and Innovation Systems Analysis (RISA)
2. Public Opinion and Values (POV)
3. Deliberation and Participation (D&P)
4. Reflexivity Assessment and Evaluation (RAE)

Thematic Research Clusters

1. Equity
2. Human Identity, Enhancement, & Biology (HIEB)

RTTA 1: Research and Innovation Systems Analysis

Who is doing what kind of NSE research?

How can we measure NSE's contribution to broad social goals?

What nano training do we need in regional markets?

- **Research Program Assessment (Georgia Tech)**
  - Data-mining, interviews, etc.
  - To ID core thrusts and actors
- **Public Value Mapping (UGA)**
  - Conceptual development
  - To connect research to promised public values
- **Workforce Assessment (Rutgers)**
  - Supply & demand analysis
  - To assess regional nano workforce

Georgia Tech RTTA-1 Research Program Assessment Group:

Group membership (2009)

Lead researchers
- Philip Shapira
- Jan Youtie
- Alan Porter

Group faculty members
- Juan Rogers
- Andrea Fernandez-Ribas

Doctoral students
- Li Tang
- Stephen Carley
- Luciano Kay
- Vrishali Subramanian
- Reynold Galope (CREA project)

Masters and BS
- Hari Naraynanan
- Ronak Kamdar
- John Garner (undergrad)

Associates
- Yu Meng
- Jue Wang

Visiting Researchers
- Ying Guao (BIT)
- Lu Huang (BIT)

IISC
- Nils Newman
- Webb Myers

RTTA-1 Research Program Assessment

Georgia Tech group

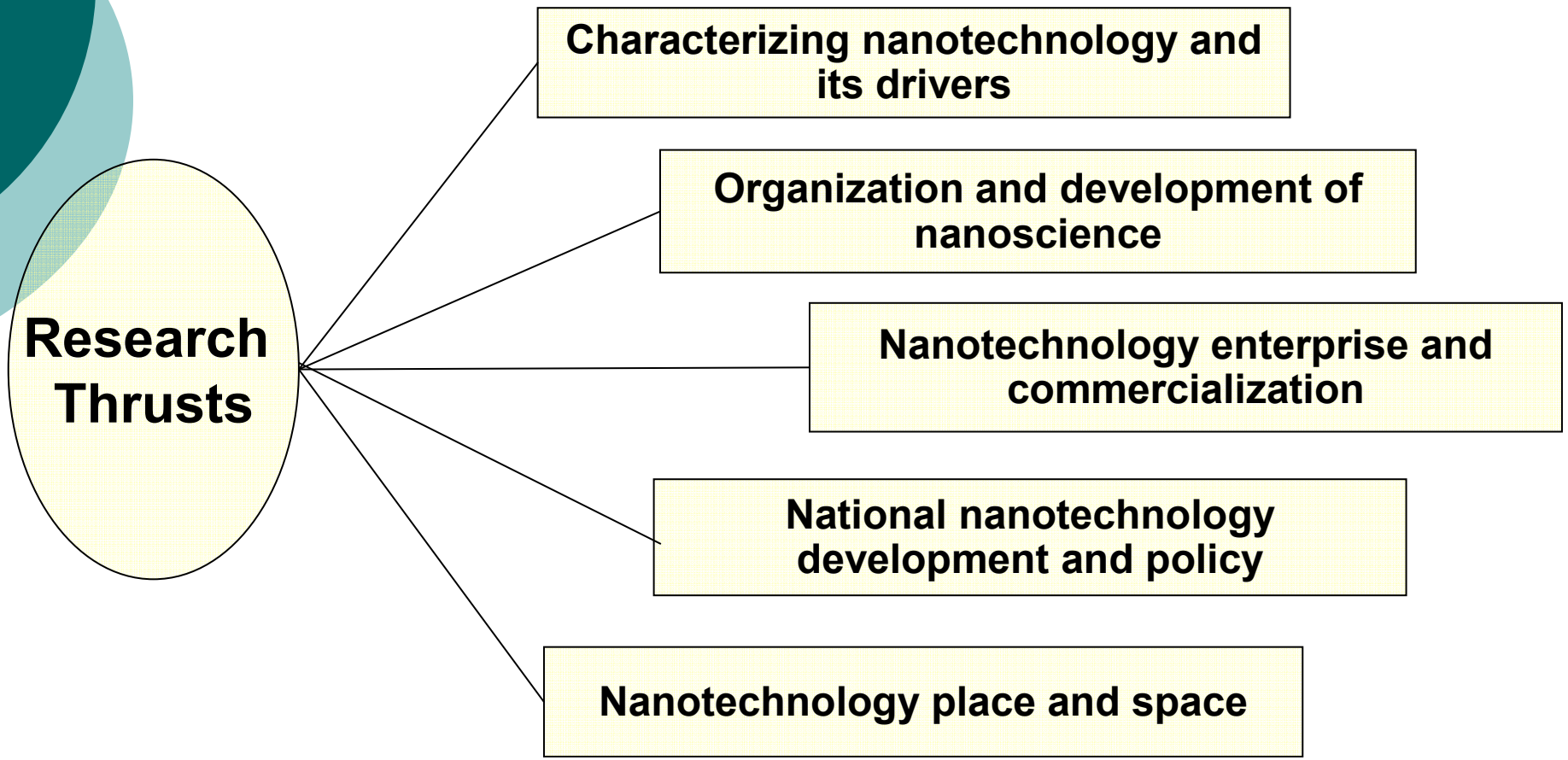
Core Resources:

- Refined two-stage two-stage bibliometric search method*
- Development of large-scale global databases of
  - Nanotechnology publications (1.1 million, 1990-2008, including 460,000 SCI)
  - 61,000 nano patents (70 patent offices, MicroPatents); + PATSTAT (1990-2008)
- Complementary data and tools (e.g. small nano-firm start-up data; MNE nano patent families)

***Key Publication: Refining search terms for nanotechnology.**
Porter, Youtie, Shapira, Schoeneck. *J. NanoParticle Research*, 2008.

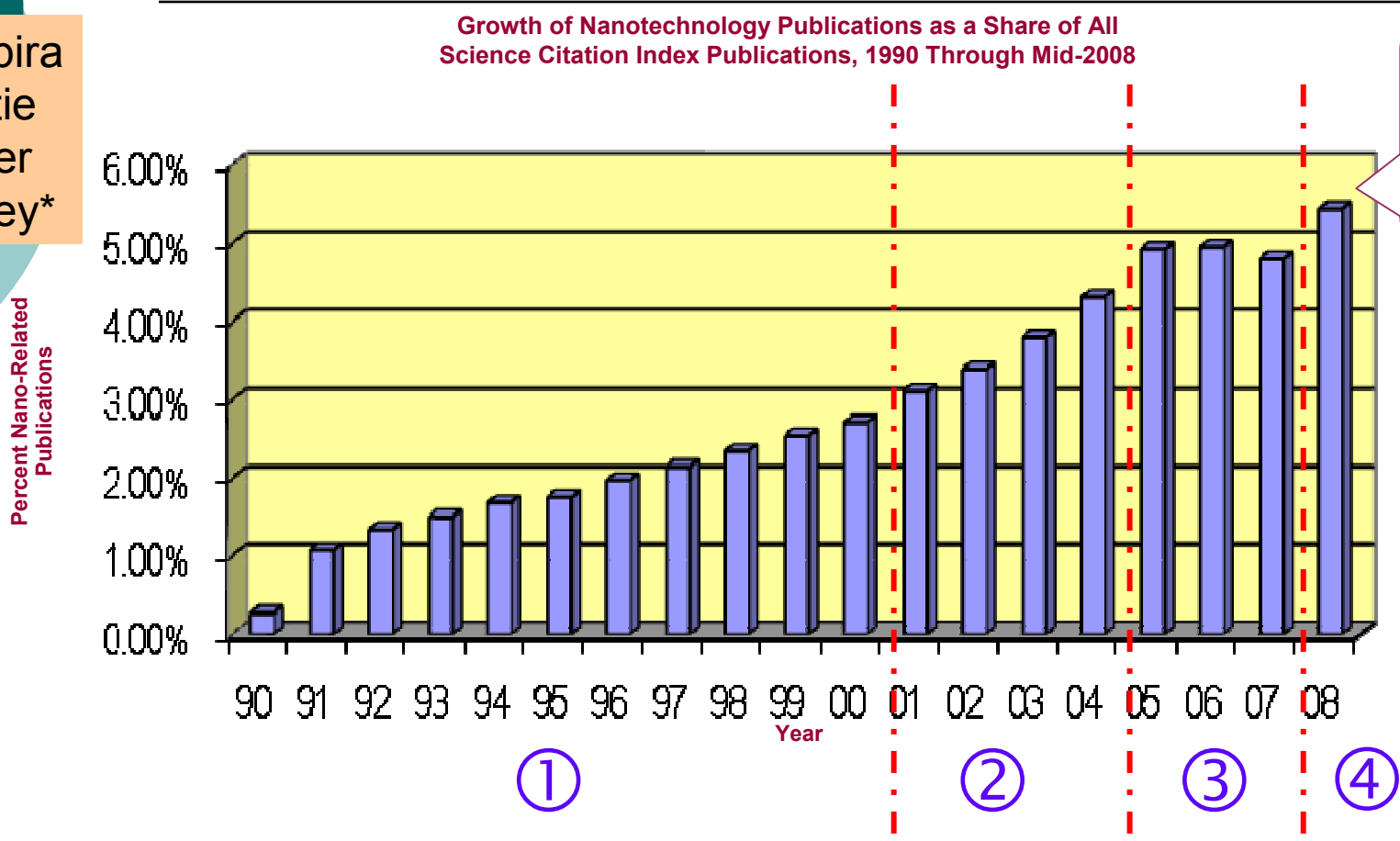
Georgia Tech Research Program Assessment Group:

Research Thrusts



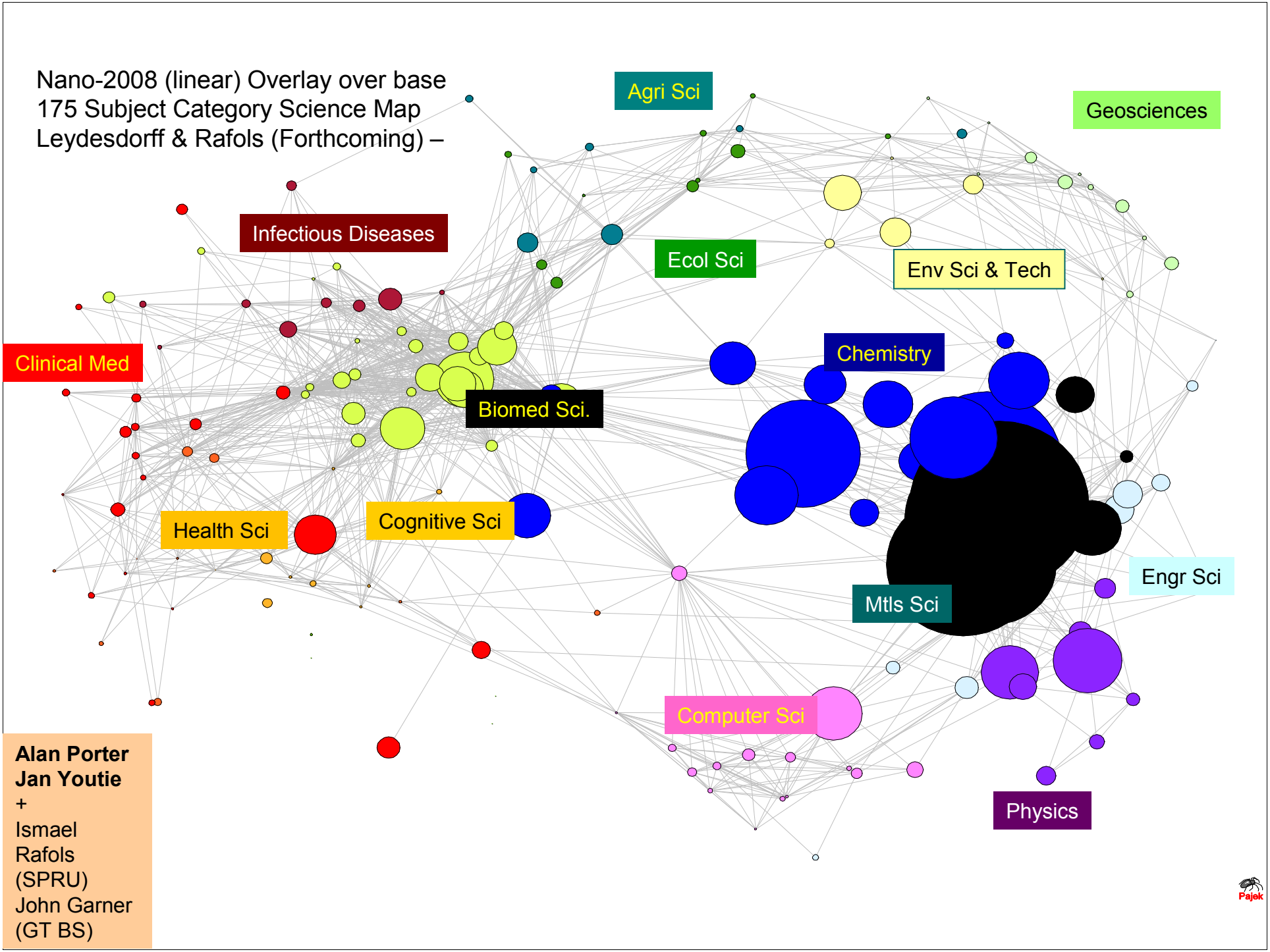
Nano research resumes growth (relative share, worldwide)

Shapira
Youtie
Porter
Carley*



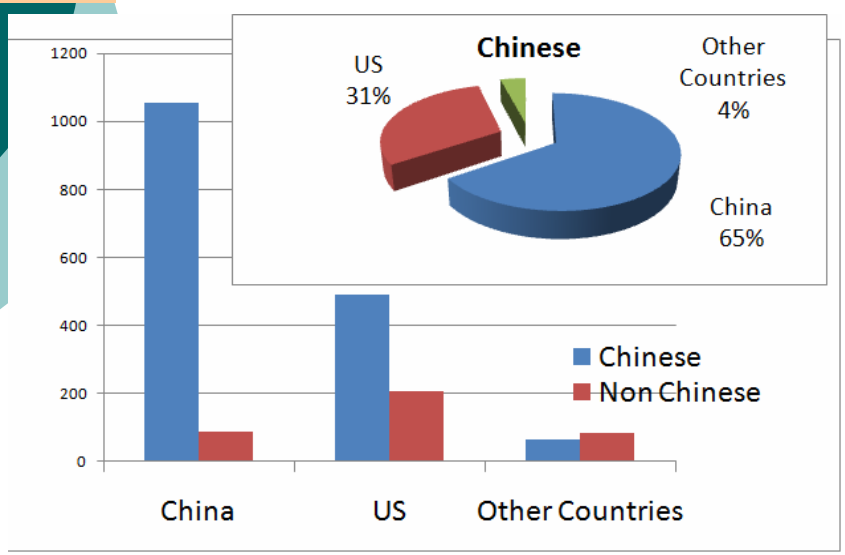
Next question: What's next?

References: Youtie, J., Shapira, P., Porter, A., "National Nanotechnology Publications and Citations," Journal of Nanoparticle Research, 2008; S. Carley, Nanotechnology Research Publication Databases, Updated to 2008, RTTA-1 Profile, 2008.


Nano-2008 (linear) Overlay over base
175 Subject Category Science Map
Leydesdorff & Rafols (Forthcoming) –
Agri Sci
Geosciences
Infectious Diseases
Ecol Sci
Env Sci & Tech
Clinical Med
Chemistry
Biomed Sci.
Health Sci
Cognitive Sci
Engr Sci
Mtls Sci
Computer Sci
Physics
Alan Porter
Jan Youtie
+
Ismael Rafols (SPRU)
John Garner (GT BS)
Pajek

US-China Nano Knowledge Moderation

Tang*



	China	US	Other Countries	*Total*
Chinese	1053	492	65	*1610*
Non Chinese	90	206	86	*382*
Total	*1143*	*698*	*155*	*1992*

- China #2 in world nano research output
- US-China nano coauthorship increasing
- Chinese Diaspora in the US plays important role in the knowledge flow between the US and China

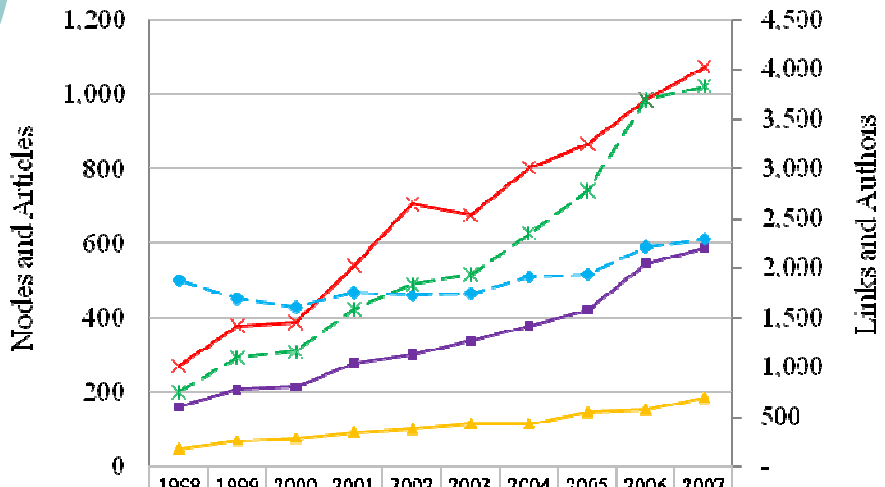
Next Question

- How does international knowledge moderation influence Chinese and US nanotechnology development?

Nanotechnology research in Brazil

Kay Shapira

Main statistics of the Brazilian nanotechnology research network



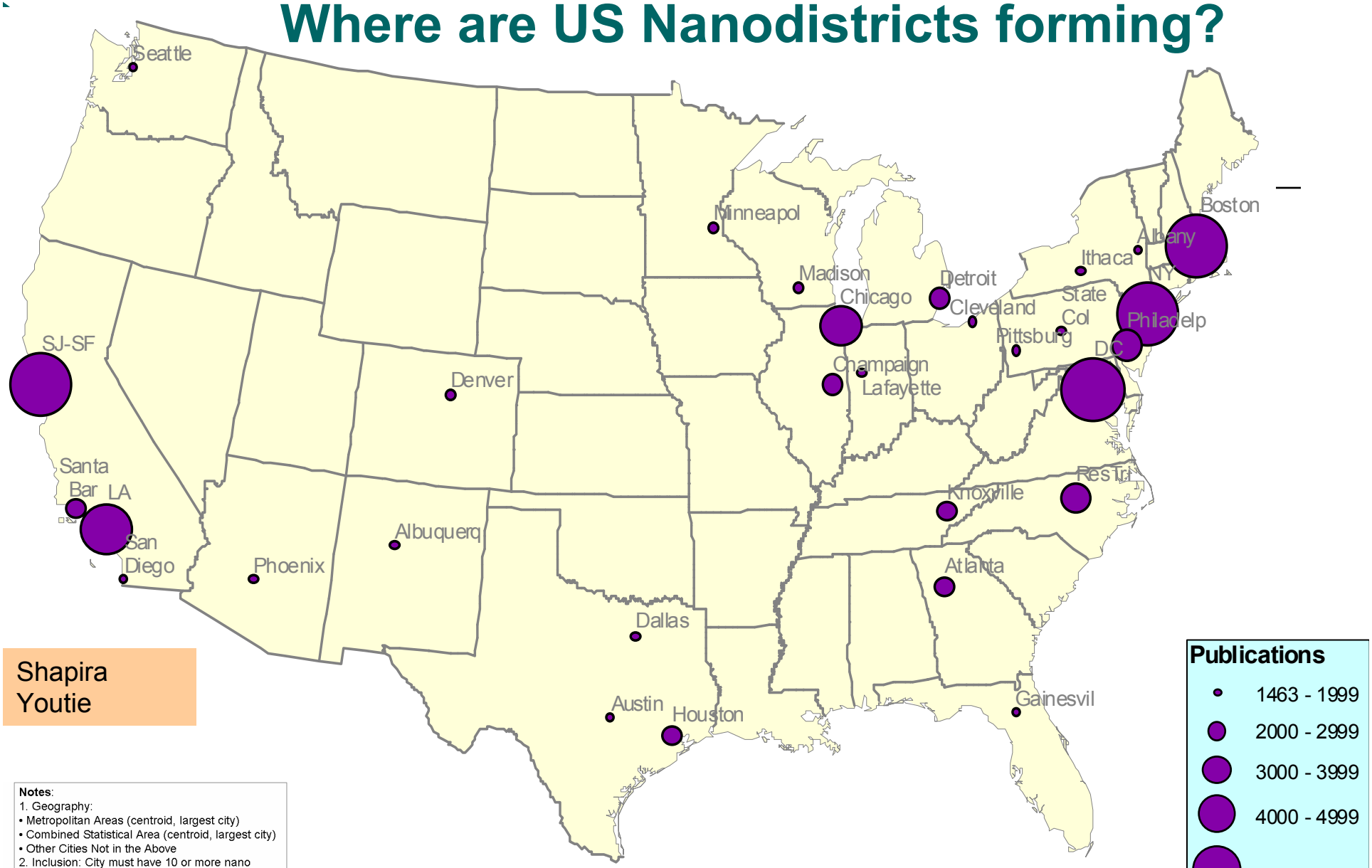
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Nodes (All inst.)	160	204	212	277	299	337	376	419	545	586
Nodes (Brazil inst.)	47	68	75	92	100	115	1.5	145	152	185
Articles	270	377	387	538	704	674	802	864	983	1,071
Links (collaborations)	1,873	1,686	1,601	1,743	1,724	1,740	1,909	1,936	2,213	2,237
Authors	746	1,09:	1,152	1,582	1,830	1,931	2,343	2,770	3,687	3,823

- Nano research networks are growing, based mostly on university research, intl. collaborations, and uneven participation of Brazilian regions.

Next questions:

- How does Brazil's nano research profile relate to the country's societal needs?
- What broader insights for developing economies facing significant economic, equity, environmental and other challenges.

Where are US Nanodistricts forming?



Shapira
Youtie

Notes:
1. Geography:
• Metropolitan Areas (centroid, largest city)
• Combined Statistical Area (centroid, largest city)
• Other Cities Not in the Above
2. Inclusion: City must have 10 or more nano publications
in Science Citation Index 1990 to mid-year 2006.
3. Source: Georgia Tech nano publication database
4. Nano definition based on Porter et al, 2007, Refining Search Terms for Nanotechnology. Journal of Nanoparticle Research, DOI 10.1007/s11051-007-9266-y.

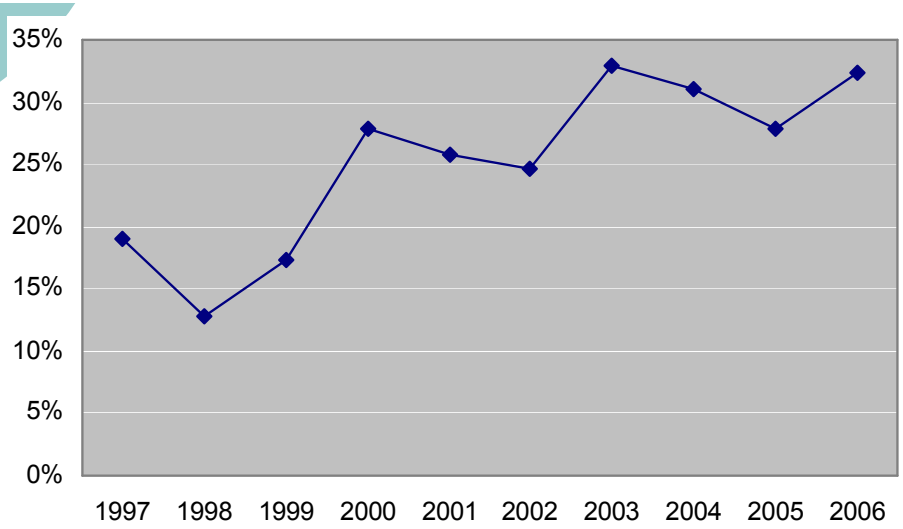
Nano publications, 1990-2006 (mid)
Data source: Porter et al., 2008.

Publications
- 1463 - 1999
- 2000 - 2999
- 3000 - 3999
- 4000 - 4999
- 5000 - 5999
- 6000 - 8939

Small Businesses International Nano Patent Strategies

Fernandez -Ribas

Proportion of U.S. SMEs* with WIPO PCT filings (relative to U.S. Large)



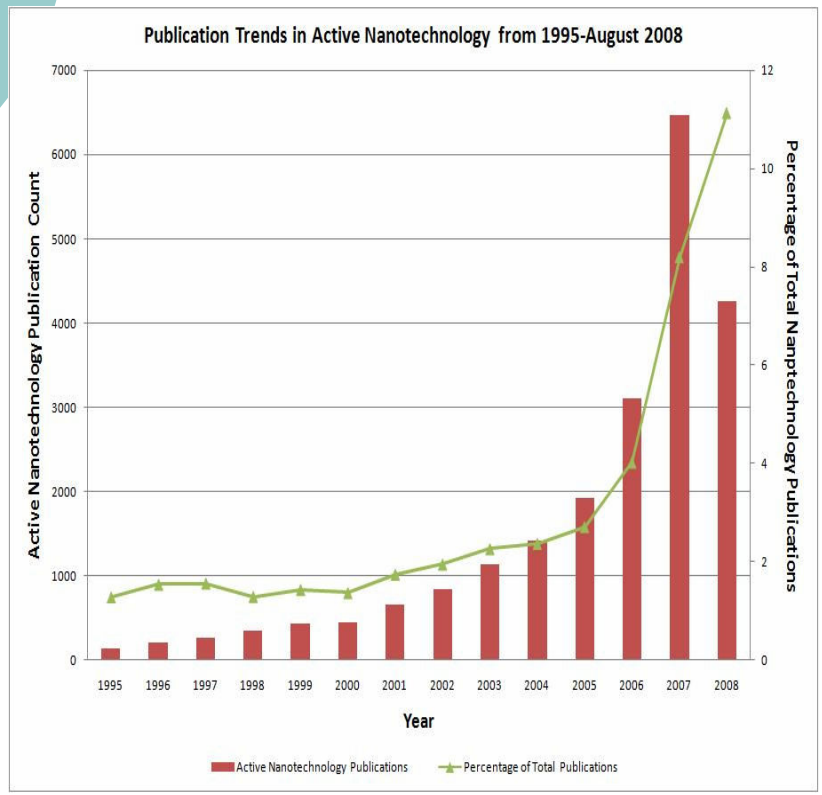
* SBA standard definition, less than 500 employees

Authors: Andrea Fernández-Ribas with research assistance Ronak Kamdar. Additional support obtained through the Kauffman Foundation and Georgia Research Alliance.

- Analysis of WIPO PTC nano-related applications 1997-2006 of 300+ US owned SMEs
- Increased geo-graphic breadth of patent protection; regional/ international (co-) invention patterns observed
- **Next Question**: What drives the growth of US SME international patenting?

Is there a shift to "active nanotechnology?"

Vrishali Subramanian*



- Active nanotechnology posited as 2nd generation, with important implications
- Filtered nano publication databases
  - Materials base (nano*, fullerene#, quantum dot#, dendri*, self assembl* and molecul*)
  - Active terms (motor, adaptive, self-healing, etc.)
- 21,000+ articles from WOS/SCI from 1995 to 2008
  - Shift? Yes, after 2006
- **Next question:** How to interpret this shift?

Uses (examples)

- Own dissemination
  - 20 Publications & Papers, 2008 – 2009 (to date)
- Cross-cutting in CNS-ASU
  - RTTA 2: Scientists surveys
  - TRC 2: Nano-brain research
  - New theme: nano & the city
- Cross-cutting external
  - UK Royal Commission (Environmental-nano)
  - Canadian National Research Council (nano clusters)

Georgia Tech Research Program Assessment

Plans for Year 6-10*

FOUR INTERRELATED ACTIVITY CLUSTERS

1. Organization, structure and trajectories of emerging nanoscience
2. Nanotechnology enterprise and applications.
   - New corporate nanotechnology panel (250 US; 250 international)
3. Collaboration and end-to-end engagements
   - New theme: Nanotechnology & city
4. Research management, innovation, economic development & policy implications

***2010 - 2015**

RTTA 2: Public Opinion and Values

What does the public know and feel about nanotechnology?

How does the media influence the public perspective?

What do NSE researchers know and feel about nanotechnology?

- Public Opinion
  - Longitudinal surveys, liked to themes
  - To assess changes in public opinion
- Media Influence
  - Experimental science news stories
  - To assess media influence
- Scientists' Opinion
  - Surveys of nano researchers
  - To assess & compare scientists' values

RTTA 3: Deliberation and Participation

What are plausible nano-enabled futures?

How can we envision responsible NSE products?

What are the cultural resonances of NSE futures?

How can the public be engaged in NSE decision-making?

- Scenario Development Workshops
  - Deliberative exercise among experts
  - To provide plausible technological futures
- Innovation Space
  - User-centered research & design course
  - To create new products/scenarios
- Critical Corps
  - Critical theory
  - To engage critically nano products & scenarios
- National Citizens' Technology Forum
  - Six inter-linked citizens' panels
  - To deliberate on nano issue of their framing

RTTA 4: Reflexivity Assessment and Evaluation

How does CNS-ASU know that it is being effective?

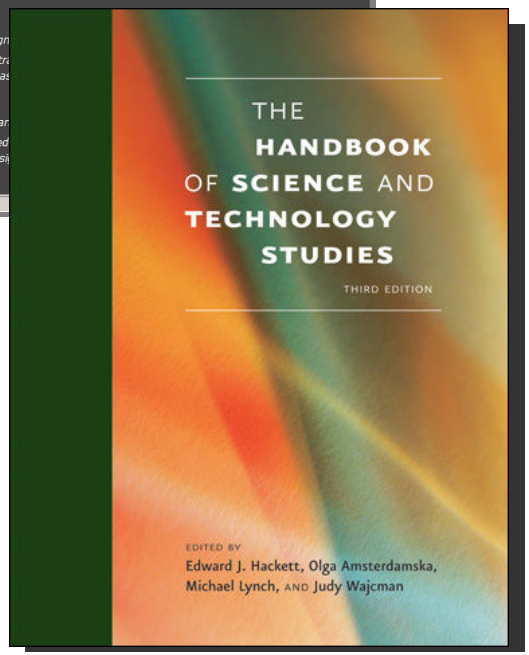
How have NSE researchers' views changed over time?

What has CNS-ASU contributed to institutional change?

- Reflexivity Assessment
  - Intensive interviews w/ nano researchers
  - To understand change in Identity, Knowledge, and Practice
- Boundary Organizations
  - Comparative case studies
  - To assess ability of CNS-ASU to bridge "ways of knowing" nano

Integration:
Foresight/Anticipation

- RTTA 3/1 Scenario Development
  - NanoFutures site
  - Doc-in-the-box workshop
- RTTA 3/2 InnovationSpace
  - Prospective nano-products
- RTTA 1/1 Research and Innovation Systems Assessment
  - Empirical basis to GPT
  - Trend analysis
- RTTA 1/3 Workforce Assessment
  - Nano-labor market
- RTTA 2 Public Opinion and Values
  - Expectations of public and NSE researchers



Integration:

Ensemble-ization

- RTTA 3/4 National Citizens Technology Forum
  - Uses scenes from RTTA 3/1
  - Uses expertise from across CNS
  - Pre/post-test uses input from TRCs
  - Combines data w/ RTTA 2/1
  - Provides data to TRCs
  - Disseminates findings

Integration:

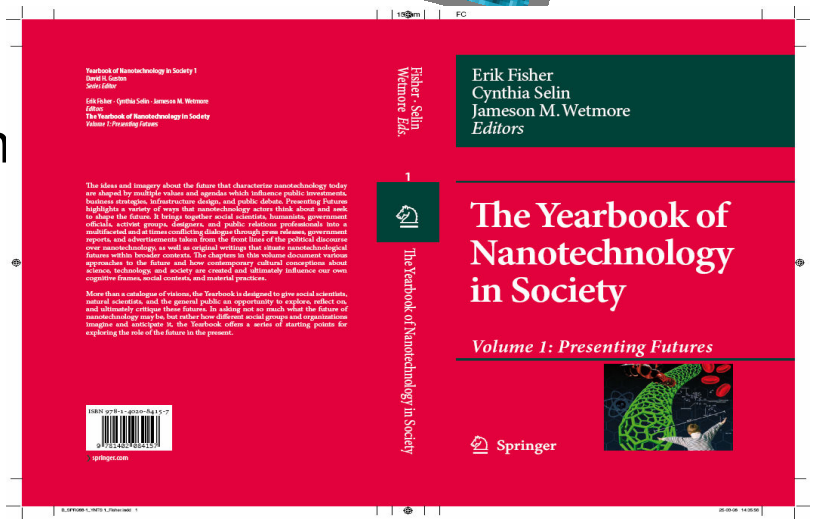
Engagement

- RTTA 3/4 NCTF (& TRC 2)
  - Six deliberative sites
- RTTA 3/1 Scenario Development
  - Wiki interaction
- TRC 1 Equity and Responsibility
  - Nano & Religion workshop
- Science Cafés
  - ~50 per at AZ SC
- NISE Net interactions
  - NanoDays, white paper

February, 2008 Science Cafe

Outputs: Publications

- Highlights
  - Barben et al. *Handbook* chapter
  - Scheufele et al. *Nature Nanotechnology*
  - Youtie et al. *J Technology Transfer*
  - Robert, *Nanotechnology and Society* chapter
  - Porter, Shapira, Youtie. *J Nanoparticle Research*
  - Fisher, *NanoEthics*
  - Selin, *Science & Engineering Ethics*
  - Guston, *Nature*
- Summary to date (published/in press/under review/in preparation
  - Six books
  - Twenty-seven PR journal articles
  - Eleven trade/other journal articles
  - Sixteen book chapters
  - > 150 presentations



Outcomes

- Capabilities
  - Student training; student projects
  - PhD+
    - Nano-science + assessment
  - Education & awareness (public)
- Dissemination
  - Washington briefings
    - In US Congress
    - CNS-ASU / PEN
  - State, local engagement
- Networking
  - NNIN; Science Museums; national Labs; other US nano initiatives
  - International linkages

CNS NEWS

Nanotechnology Briefing, Washington DC: CNS is hosting a nano briefing in Washington DC. Nanotechnology and Public: Data for Decision Makers. U.S. Congressional Nanotechnology Caucus. View the: Agenda, References, or Bios.

Society-Technology Relationships: CNS's own Jameson Wetmore, who contributed to "Technology and Society: Building our Sociotechnical Future", explains how he studies how society and technology influence one another and affect the world.

NanoSilver Socks Demonstration: The emergence of nanoparticles into everyday products is raising important questions. CNS explores the effects this may have on the environment.

Study finds religion in U.S. shapes a suspect view of nanotechnology. Americans are "partly relying on their religious beliefs when they make sense of science and technology issues," says CNS's Elizabeth Corley, co-author of a new report on the subject.

Reflections

CNS-ASU Mission

- **Research**
- **Train**
- **Engage**
- **Partner**

- CNS-ASU: A new national and international resource *informing* and *stimulating* scientific and policy dialogue about nanotechnology emergence
- Innovative approaches (for the US), incl. datamining, scenarios, wikis, citizen panels, science engagement
- Has caught attention of some scientists (but, of course, not the majority), policymakers (ntl, local)
- Resources: $6.2m / 5 years
  - Enough to establish a model, but not to replicate
- Limited to one technology (albeit a general purpose technology)

Situating CNS-ASU and RTTA

Mode 1 TA:

- US Office of Technology Assessment (OTA), 1974-1995

Mode 2 TA (mid-1990s-present)

- Distributed and Interactive approaches
  - **Strategic Intelligence** (Kuhlmann, Smits)
    - Multiple instruments: Technology Forecasting, Technology Foresight, Technology Assessment, Evaluation, and Road Mapping
  - **Constructive TA** (NL); **Real-Time TA** (Guston, Sarewitz)
    - Use TA to modify technology development
  - **Participatory TA**; Technology **Consensus Conferences** (DK)
    - Broaden participation & engagement in TA decision-making

Comparisons

OTA Model

- Focused on Washington
- Draws on informed experts and interest groups
- Multiple technology scope
- Embedded in policy cycle
- Established techniques
- Target group: policy decision makers
- Top-down forms of influence ⇨ stakeholders
- Reports, testimony, informal interactions
- Tried and tested
- *Mode 1?*

CNS Model

- Distributed structure
- Seeks to inform stakeholders and publics and foster reflexivity
- In-depth focus on an emerging technology
- Embedded in technology cycle & innovation system
- Able to experiment with new methods
- Target group: decision-makers + scientists, engineers + business + NGOs + public(s)
- Multiple dissemination modes
- Bottoms-up forms of influence ⇨ stakeholders
- Experimental
- *Mode 2?*

Roles and requirements: contrasts

	Focused (OTA)	**Distributed (CNS-ASU)**
Roles	Issue framing Decision-making Policy cycle Tested methods	Issue framing Decision-context Development cycle Experimental methods
Requirements	Strong legislature Bi-partisan support Synthesis expertise	Sponsorship of multiple sites Network capabilities Engagement expertise
Shared	TA personnel capabilities Independence/interdependence Credibility Transparent & open processes Multiple sources of information, expertise Anticipatory perspective	

*Ideal worlds of TA?

Anticipate technological impacts, avoid major problems, maximize benefits, open decision-making

- Re-establish a TA capability *in* Congress
- Expand new TA capabilities *for* the broader governance of science and technology

⇨ To build a **distributed and networked** system
- Building on concepts of **strategic intelligence**
- Outside of Congress, but inside the science and technology system
- Combining research, training, education and engagement with **real-time technology assessment**
- Caution: system bandwidth – so focus on key new **strategic challenges** in new technology – with flexibility to surface new challenges

Not just about establishing TA organizations …
but of embedding **real-time TA** processes for anticipatory governance in the S&T system

***for the USA**

More information

- Web sites:
  - http://cns.asu.edu/
  - http://www.nanopolicy.gatech.edu

- Acknowledgements: The Center for Nanotechnology in Society (CNS-ASU) is supported by the National Science Foundation (NSF Award No. 0531194). The findings and observations contained herein are those of the author and not necessarily those of NSF.