Where is Nano Going?

Explorations in Research and Innovation Systems Assessment: Where is Nano Going?©

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STIP
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NSF/SRS WORKSHOP
Advancing Measures of Innovation:
Knowledge Flows, Business Metrics, and Measurement Strategies
June 6-7, 2006

Overview

- Approach to Research and Innovation Systems Assessment
  - Emerging technology focus; micro-based; multi-measure; real-time
- Nanotechnology Examples
  - Mapping the Nanotechnology Enterprise: Recent Work in the US South
  - Early Evidence on US Regional Nano Trends
  - Current Work: Center for Nanotechnology and Society
- Broader Conclusions about Measuring Innovation

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

- **Mapping the Nanotechnology Enterprise: Recent Work in the US South**
- Early Evidence on US Regional Nano Trends
- Future Work: Center for Nanotechnology and Society

Nanotechnology in the US South

- Study sponsor: Southern Technology Council (STC)
  - 13 states in US South + Puerto Rico
- Study aims:
  - Identify and map US South's nano "assets"
  - Assess US South's strengths and weaknesses in nano.
  - Provide basis for policy dialogue and action steps.
- Undertaken Fall 2005 at Georgia Tech
  - Illustrates emerging state and local policy demand in nano
- Publication "Connecting the Dots: Creating a Southern Nanotechnology Network" (published by STC, April 2006)

Measures

Category	*Indicator*
Knowledge Generation	1. Nanotechnology publications based on author location 2. Institutions with clusters of primary researchers in nanotechnology 3. Co-authorship linkages in nanotechnology
Human Capital	4. Highly cited researchers in nanotechnology 5. Editors of nanotechnology-related journals 6. Doctoral dissertations in the nanotechnology field 7. Prize winners in the nanotechnology field
Research and Development Funding	8. Nanotechnology-related National Science Foundation Awards 9. Nanotechnology-related Small Businesses Innovation Research awards
Patenting	10. Patenting in the field, including both individual inventors and companies
Early Commercialization Trends	11. Interviews with 10 nanotechnology companies with an office located in the South

Publication and Patent Data

Nano definition (CREA / STC)

	Search Filter	Number of Records Identified in SCI	Number of Records Identified in USPTO
1	nano* NOT (nanomet* OR nano2 OR nano3 OR nano4 OR nano5 OR nanosecon* OR (nano secon*))	>100,000	3,092
2	(nanomet* scale*) OR nanometerscale* OR (nanometer length) OR (nano meter length) or nanot* OR nanou* OR nanov* OR nanow* OR nanox* OR nanoy* OR nanoz*	25,451	1,172
3	nanoa* OR nanob* OR nanoc* OR nanod* OR nanoe* OR nanof* OR nanog* OR nanoh* OR nanoi OR nanoj* OR nanok* OR nanol* OR nanon* OR nanoo* OR nanop* OR nanoq* OR nanor*	69,974	3,627
4	(atom* force microscop*) or (tunnel* microscop*) or (scanning probe microscop*) or (scanning force microscop*) or (semiconductor quantum dot)	43,441	1,639
5	(silicon quantum dot) or (quantum dot array) or (coulomb blockade) or (self-organized growth) or (drug carriers) or (positional assembly) or (modified virus) or (molecular templates) or (supramolecular chemistry)	5,807	0
6	(drug delivery OR drug targeting OR gene therapy OR gene delivery) AND (po-lymer OR particles OR encapsulation OR conjugate)	3,226	1,123
7	immobilized AND (DNA OR template OR primer OR oligonucleotide OR poly-nucleotide)	2,093	726
8	polymer AND (protein OR antibody OR enzyme OR DNA OR RNA OR poly-nucleotide OR virus)	10,320	2,208
9	(surface modification) AND ((self assembling) OR (molecular layers) OR multi-layer OR (layer-by-layer))	64	40
10	(self assembling) AND (biocompatibility OR bloodcompatibility OR (blood compatibility) OR cellseeding OR (cell seeding) OR (cell therapy) OR (tissue repair) OR (extracellular matrix) OR (tissue engineering))	32	9
11	(self assembling) AND (biosensors OR immunosensor OR biochip OR nano-particles OR (cell adhesion))	43	0
12	Site-specific AND ((gene therapy) OR (drug delivery) OR (gene delivery))	563	496
13	encapsulation AND virus	146	132
14	(Patterns OR patterning) AND ((organized assemblies) OR biocompatibility OR bloodcompatibility OR (blood compatibility) OR cellseeding OR (cell seeding) OR (cell therapy) OR (tissue repair))	147	398
15	(Patterns or patterning) AND ((extra-cellular matrix) OR (tissue engineering) OR biosensors OR immunosensor OR biochip OR (cell adhesion))	1,519	328
16	(single molecule) or (molecular motor) or (molecular beacon) or (biosensor)	12,494	2,030
	1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14 OR 15 OR 16	126,122*	11,996

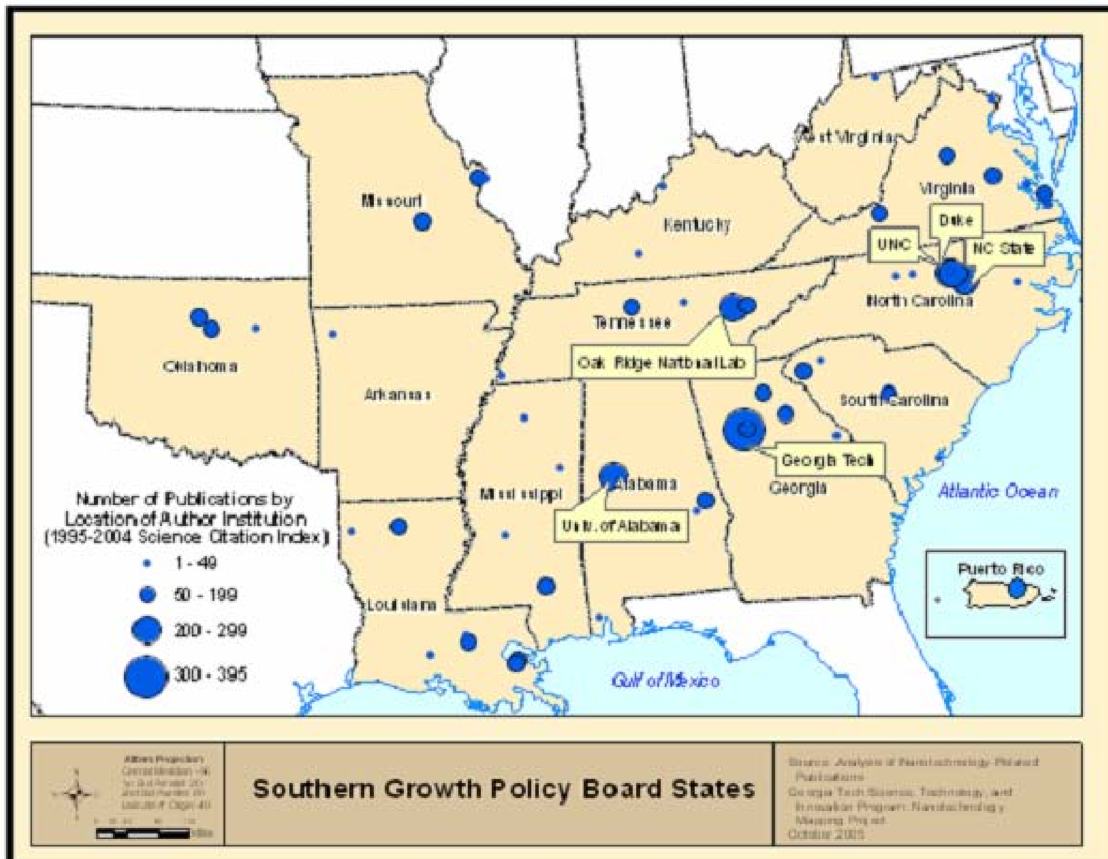
*This total represents all records downloaded for researchers worldwide. However, only 27,777 of the records had U.S. first authors.

Source: Science Citation Index 1995-2004 SCI record counts based on search performed in January 2005. Nano definition from ISI (2002)

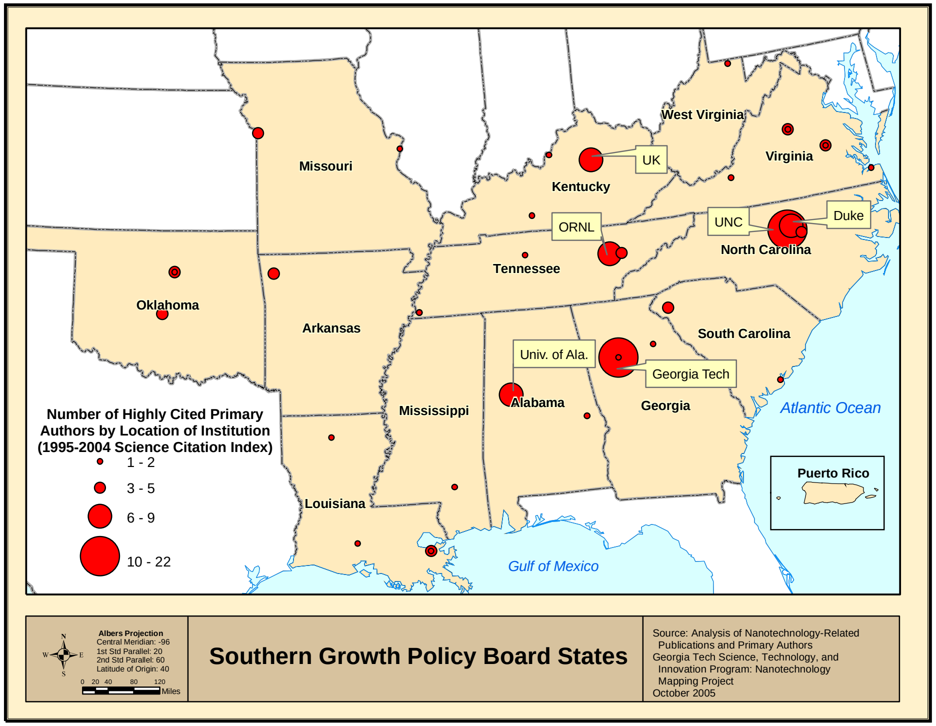
Nano Publication Clusters in the US South

Number of publications at institutions with three or more different first authors (1995-2004).

Source: Analysis of SCI publications, 1995-2004, by first-author location. CREA (ISI, 2002) nano definition. Institutions with 200 or more first authored publications are labeled.



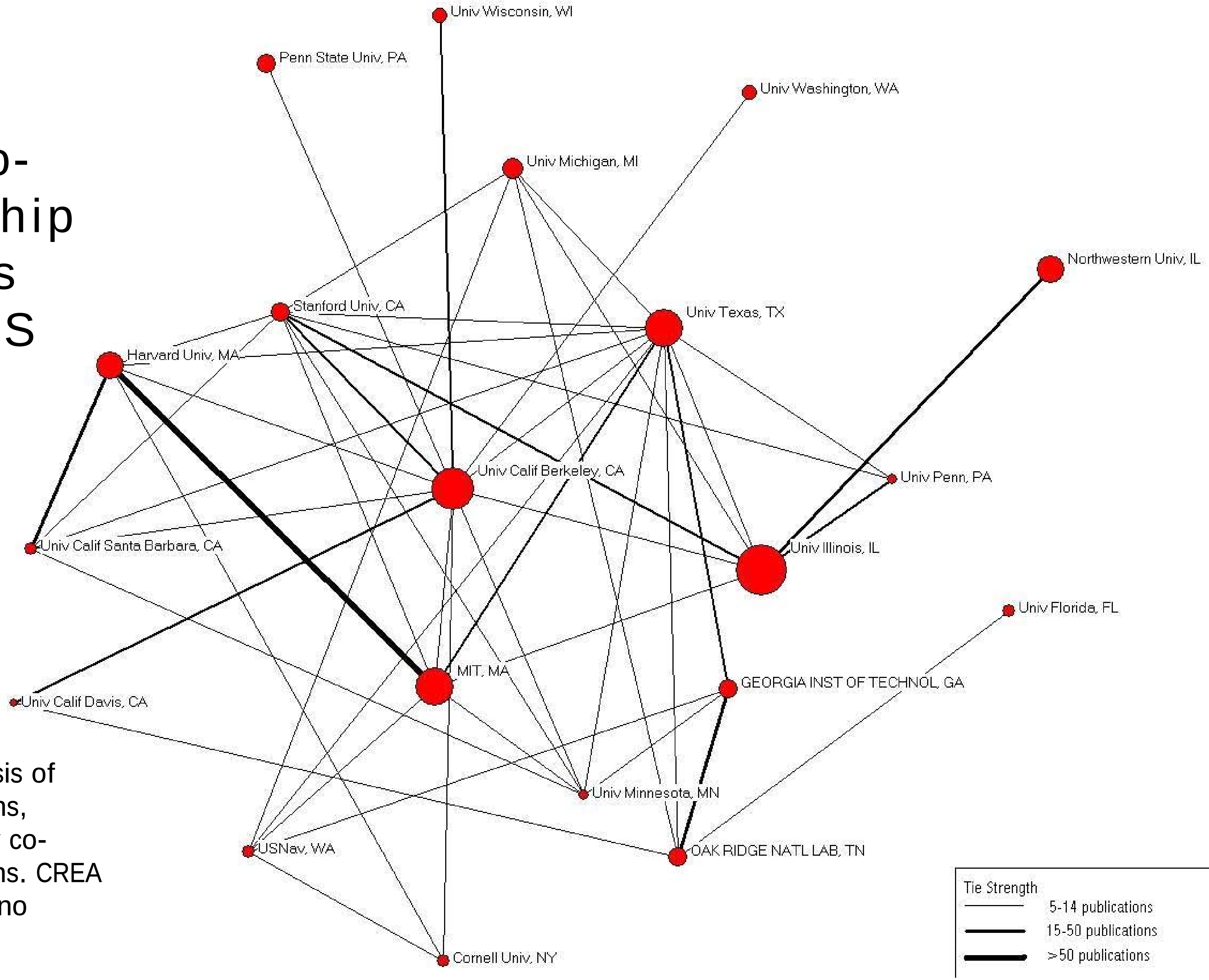
Highly-Cited Nano Researchers in the US South



State	*Number of Highly Cited Primary Researchers*	*Number of Highly Cited Primary Researchers per Million People*
North Carolina	30	3.51
Georgia	24	2.72
Tennessee	14	2.37
Virginia	11	1.47
South Carolina	10	2.38
Louisiana	8	1.77
Kentucky	8	1.93
Alabama	8	1.77
Missouri	7	1.22
Oklahoma	6	1.70
Arkansas	4	1.45
West Virginia	1	0.55
Mississippi	1	0.34
Puerto Rico	0	0.00
SGPB Region	111	1.61
United States	611	2.08

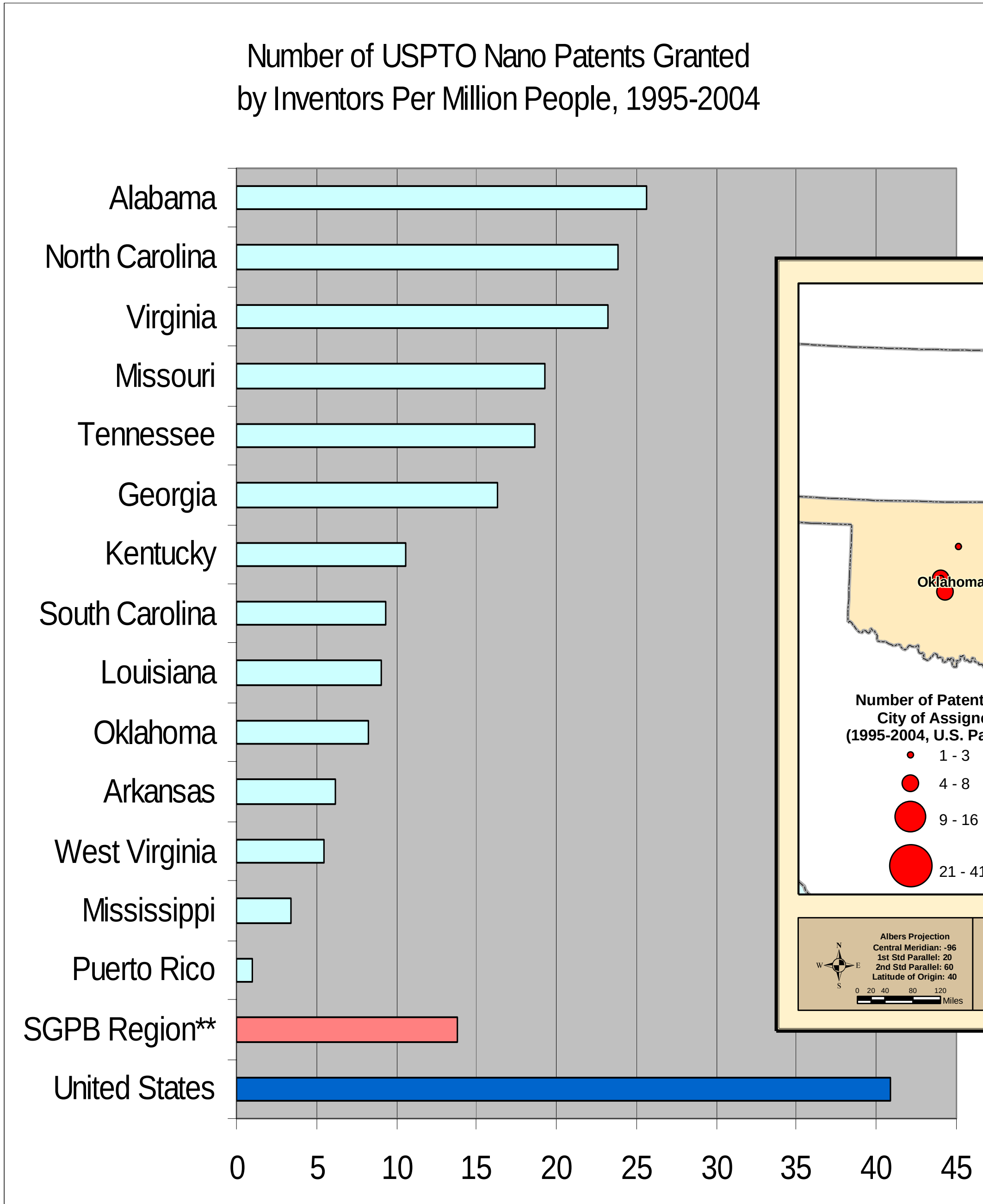
Analysis of SCI publications, 1995-2004, by primary (first authors). 1,000 most cited scientists, worldwide. CREA (ISI, 2002) nano definition.

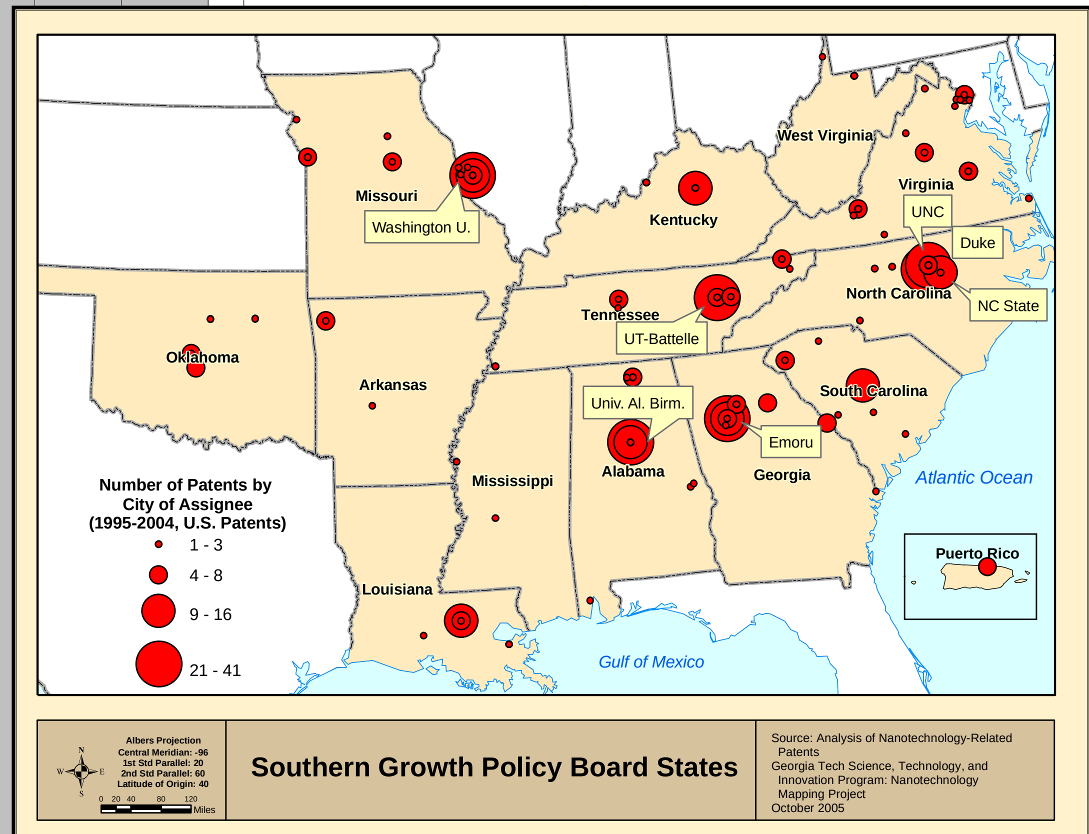
Nano co-authorship linkages in the US



Source: Analysis of SCI publications, 1995-2004, by co-author locations. CREA (ISI, 2002) nano definition.

Nano Patenting in US South





Source: USPTO patents granted, 1995-2004. CREA (ISI, 2002) nano definition.

Southern Nano Strengths and Weaknesses

Southern (STC) Strengths

- Twenty percent of all nanotechnology research publications in the U.S.
  - Four of the top 25 national nanotechnology institutions.
- Nearly 20 percent of all highly cited nanotechnology researchers in the U.S.
- Ten percent of all nanotechnology journals editors in the U.S.
- Fifteen percent of all nanotechnology doctoral dissertations in the U.S.

Southern (STC) Weaknesses

- The region's institutions lack strong linkages to critical U.S. centers in California and the Northeast
- Private R&D effort in nano is weak
- The South is significantly weak in patenting
  - 14.8 nanotechnology patents per million in the Southern Growth region compared with 40.9 for the nation.
  - A large proportion of the South's patents are assigned to organizations outside the region.
- The South lags behind the nation in commercialization funding

Two Propositions

- Public policy can foster nano research clusters

- Commercialization is significantly regional path dependent
  - Regional structure of existing private firms (incumbents) and private R&D
  - Regional capabilities and experience in start-ups
  - Knowledge bases, human capital, institutional links
  - Regional capital pools
  - “Accumulation” of prior policies

- Mapping the Nanotechnology Enterprise: Current Work in the US South
- **Early Evidence on US Regional Nano Trends (Commercial)**
- Future Work: Center for Nanotechnology and Society

Corporate Nano Publications

SCI publications, 1995-2004, by CMSA first-author location. CREA (ISI, 2002) nano definition.

STIP Program in Science, Technology and Innovation Policy

Georgia Tech School of Public Policy and Georgia Tech Enterprise Innovation Institute

Corporate Nano Patents

USPTO patents granted, 1995-2004, by CMSA assignee location. CREA (ISI, 2002) nano definition.

Nano Metros

Publications: SCI, 1995-2004, by first author affiliation and location. **Patents**: Granted USPTO patents, 1995-2004. CREA (ISI, 2002) nano definition.

US Census Bureau definitions of CMSAs and MSAs. Location by assignee. Biometro class: BC = Major Biotech Center; RC = Bio Research Center (Cortright and Mayer, Signs of Life, 2002).

Patenting Rank	Metro	Corporate Publications	Corporate Patents	Biometro Class
1	San Francisco, CA	15.6%	20.4%	BC
2	New York, NY	19.3%	13.9%	BC
3	Boston, MA	6.7%	9.6%	BC
4	San Diego, CA	5.0%	5.9%	BC
5	Chicago, IL	3.3%	4.1%	RC
6	Minneapolis, MN	2.3%	3.9%	
7	Los Angeles, CA	3.0%	3.6%	BC
8	Philadelphia, PA	6.6%	3.2%	BC
9	Rochester, NY	2.6%	2.7%	
	Top 9 Metros	**64.5%**	**67.1%**	
10	Boise, ID	0.2%	2.4%	
11	Seattle, WA	1.2%	2.3%	BC
12	Denver, CO	1.1%	2.1%	
13	Washington, DC	3.0%	1.9%	BC
14	Houston, TX	1.4%	1.5%	RC
15	Dallas, TX	1.2%	1.2%	
20	Raleigh, NC	1.5%	0.8%	BC
24	Atlanta, GA	0.7%	0.7%	
	N (US Totals)	**2,361**	**5,929**	

Future Directions for Regional Analysis

- Probe characteristics and specializations of leading regional nano centers
- Role of accumulated assets from prior / concurrent rounds of institutional, corporate, and technology development
- Opportunities for “regional breakthroughs” – new areas to enter the nano “round”

- Mapping the Nanotechnology Enterprise: Current Work in the US South
- Early Evidence on US Regional Nano Trends
- **Future Work: Center for Nanotechnology and Society**

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;

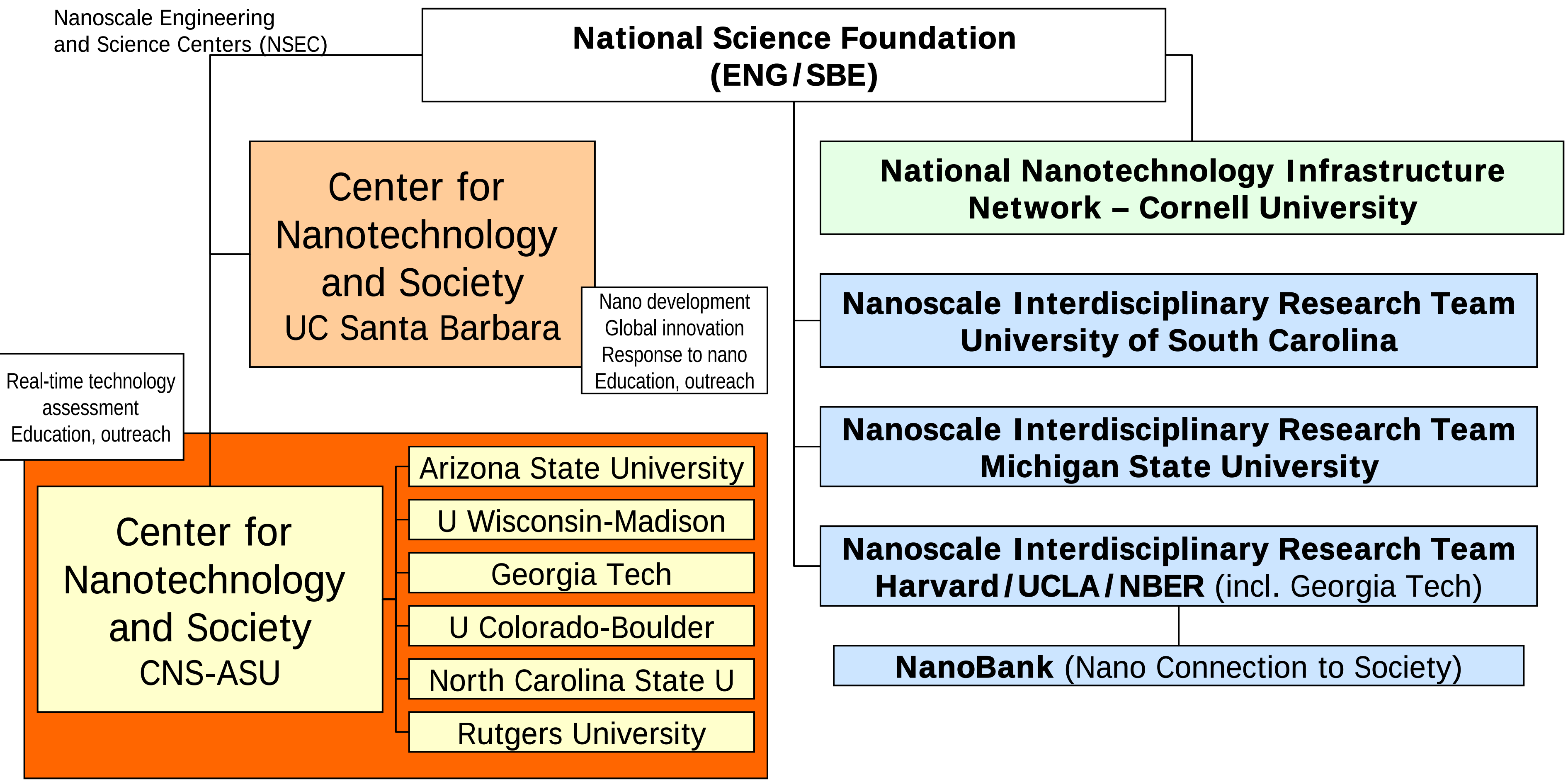
(C) make use of existing expertise in nanotechnology in their regions and nationally;

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

- 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 Nano and Society Initiatives
[Ongoing and new major projects]



Nanoscale Science and Engineering Center (NSEC)

CNS-ASU Goals

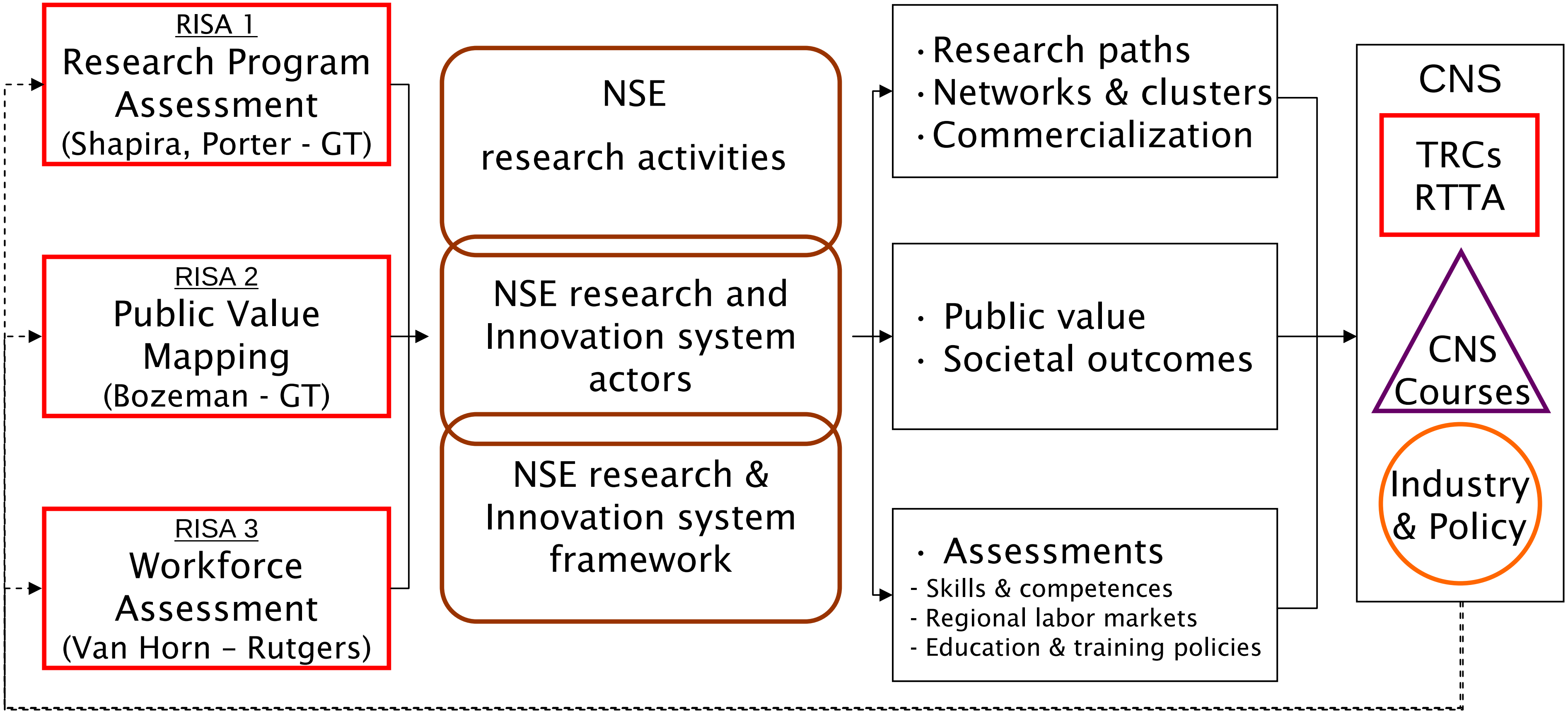
- Conduct fundamental and problem-oriented **research on the societal implications of nanotechnologies**;
- Expand -- through undergraduate, graduate, and post-doctoral **training** -- the community of scholars with the skills to create new insight into these societal dimensions of NSE;
- **Engage publics**, policy makers, business leaders, and NSE researchers in dialogues about the goals and implications of NSE, and use this process to build a network committed to making NSE socially beneficial and addressing NSE-related societal conflicts; and
- **Build partnerships** with NSE laboratories to introduce greater reflexiveness in the R&D process, so that problems may be addressed as ideas are being generated, evaluated, and developed, rather than after products enter society and the marketplace.

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. **Freedom, Privacy, & Security (FPS)**
  2. **Human Identity, Enhancement, & Biology (HIEB)**

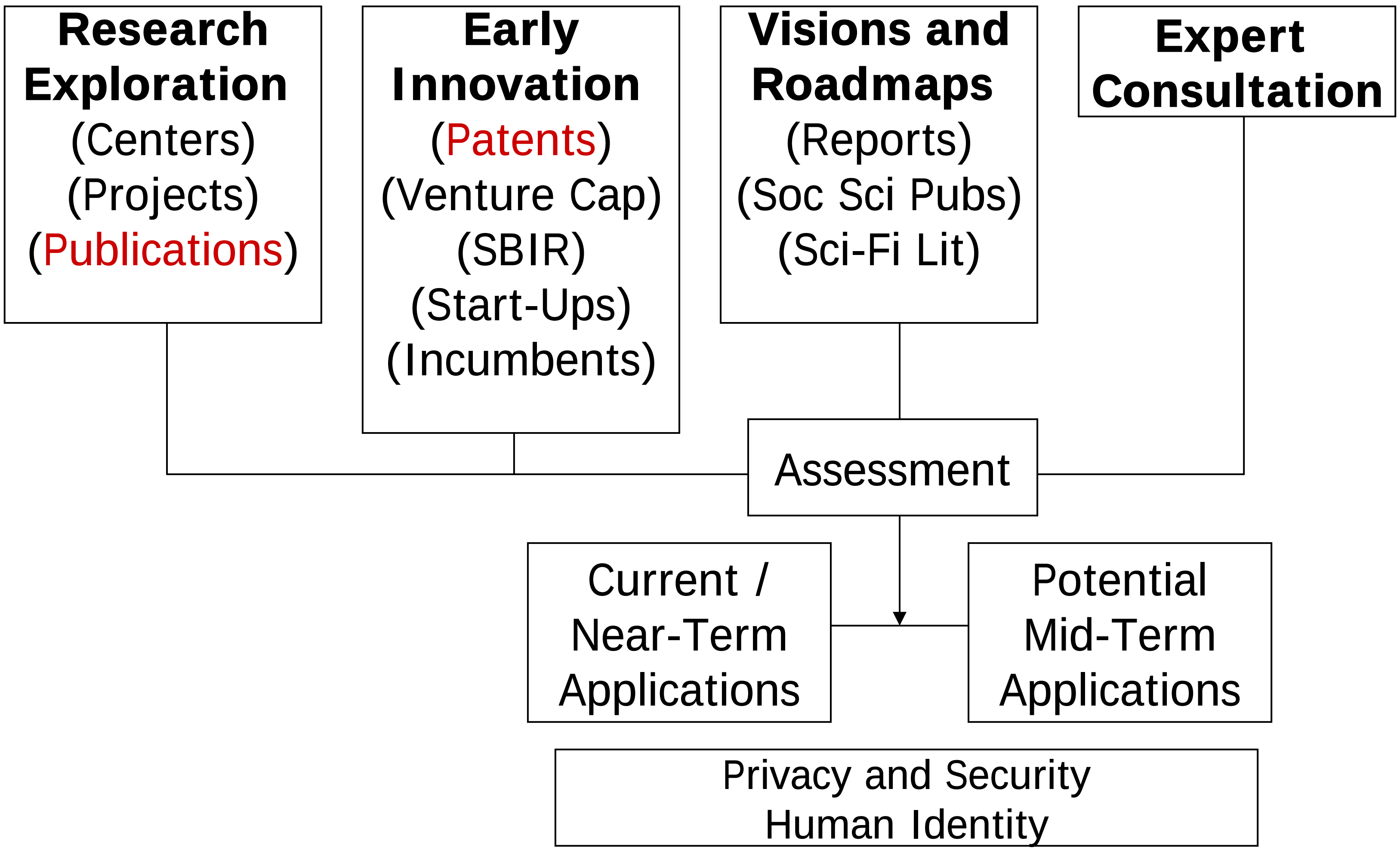
RTTA Program 1
Research & Innovation Systems Analysis (RISA)



RISA 1: Research Program Assessment
Key Questions

- **What?**
  - Core nano thrusts (in theme domains): emergent sub-topics & interconnections
  - Frontier activity assessment: 1) "hot" topics – those with high rates of increase; 2) "new" topics – concepts/tools first identified in the past year
  - Emerging "applications" (esp. in privacy, human identity)
- **Who?**
  - Leading research institutions
  - Leading researchers
  - Leading industrial companies
  - Emergence of knowledge networks and clusters
- **Where?**
  - Regional concentrations in the US
  - International comparisons [US vs. China, Japan, EU] – publishing & patenting
- **When?**
  - Assessments and projections: topical emphases, networks, clusters, industrial outcomes as take-offs for discussion and scenario-building
- **How?**
  - Datamining (e.g. bibliometric and patent analyses) using VantagePoint
  - Other secondary data sources (national, regional, industrial, corporate)
  - Selected primary sources (interviews, expert consultation)
  - RISA analysis, networking and linkages, clusters, modeling, discontinuities

RISA 1: Research Program Assessment
Data Sources



Georgia Tech nano team(s)

RISA – Senior Team Members

- Philip Shapira
- Alan Porter
- Barry Bozeman
- Jan Youtie
- Maurizio Iiacopetta

Junior Team Members

- Dave Schoeneck
- Dirk Libaers
- Li Tang
- Jue Wang
- 2 undergrads + 1 new GRA

GT Participation & Deliberation

- Susan Cozzens

GT Nano Scientists

- Z.L. Wang
- R. Tannebaum
- W. DeHeer

GT / UCLA / Harvard / NBER

- Stu Graham
  - Chien-Chun Liu
- Marie Thursby

Nano Search-Terms: Re-tuning

Search	Terms	RESULT -SCI 2005 as of 4/22
Moderators - Inclusive (*Mod-I)*	(monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array* or molecul* or polymer* or (co-polymer*) or copolymer* or mater* or biolog* or supramolecul*)	>100000
Moderators - Restrictive *(Mod-R)*	(monolayer* or (mono-layer*) or film* or quantum* or multilayer* or (multi-layer*) or array*)	78390
nano*	nano*	39101
Quantum	(quantum dot* OR quantum well* OR quantum wire*) NOT nano*	3633
Self-Assembly	(((SELF ASSEMBL*) or (SELF ORGANIZ*) or (DIRECTED ASSEMBL*)) AND MolEnv-I) NOT nano*	3532
Bio and Molecular	((molecul* motor*) or (molecul* ruler*) or (molecul* wir*) or (molecul* devic*) or (molecular engineering) or (molecular electronic*) or (single molecul*) or (fullerene*) or (coulomb blockad*) or (bionano*) or (langmuir-blodgett) or (Coulomb-staircase*) or (PDMS stamp*)) NOT nano*	3550
Microscopy	((TEM or STM or EDX or AFM or HRTEM or SEM or EELS) or (atom* force microscop*) or (tunnel* microscop*) or (scanning probe microscop*) or (transmission electron microscop*) or (scanning electron microscop*) or (energy dispersive X-ray) or (X-ray photoelectron*) or (electron energy loss spectroscop*)) AND MolEnv-I) NOT nano*	11665
Futurist Terms	(pebbles OR NEMS OR Quasicrystal* OR (quasi-crystal*)) AND MolEnv-I) NOT nano*	128
Nano-Related	(biosensor* or (sol gel* or solgel*) or dendrimer* or soft lithograph* or molecular simul* or quantum effect* or molecular sieve* or mesoporous material*) AND (MolEnv-R)) NOT nano*	2104
	1 or 2 or 3 or 4 or 5 or 6 or 7	**61173**
Journals	fullerene* or ieee transactions on nano* or journal of nano* or nano* or materials science & engineering C - biomimetic and supramolecular systems (in JOURNAL title field) NOT nano*	506
Total	**1 or 2 or 3 or 4 or 5 or 6 or 7 or 8**	**61479**

In conclusion

- Measurement of Emergence of New Technology
  - Moving target
  - Definition of the target is apt to change
- Multi-measure approach
  - Quantitative
  - Qualitative
  - Flexible
  - Fast
- Disaggregated methods built from micro records
  - Timeliness requires using “first level” data
- Link to real time policy making