Putting the Science in Science Measurement: The Case of Nanotechnology

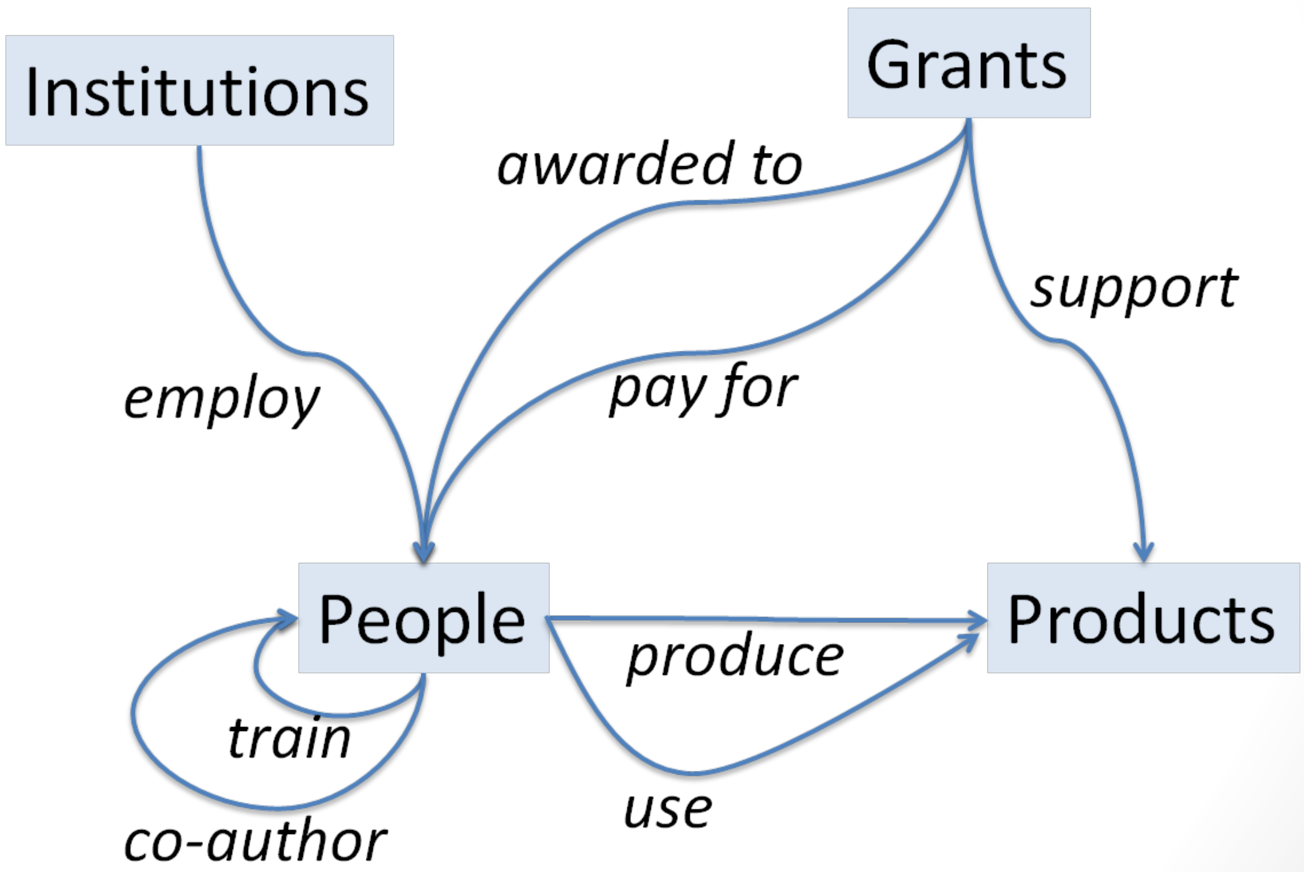
Julia Lane

Overview

- Why measurement is hard to do
- Designing a better system: the nascent approach in the US
  - Workforce Information
  - Investment information
  - (Some) initial output information

Why good measurement is hard to do

Complex conceptual framework

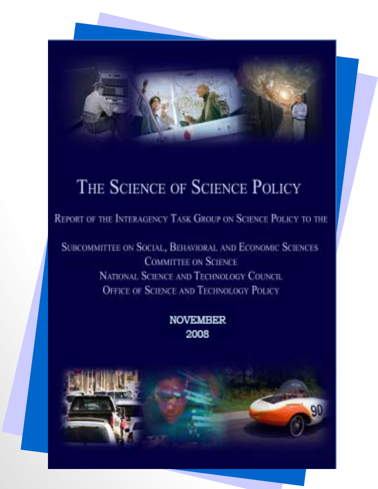


And the data don’t exist

The ITG undertook a literature review to determine the state of the science to date. A questionnaire was also circulated to Federal agencies to ascertain what methods are currently in use for programmatic investment decision making, as well as to ask what tools and resources are needed by Federal agencies that are currently unavailable. The ITG found that:

- There is a well developed body of social science knowledge that could be readily applied to the study of science and innovation.
- Although many Federal agencies have their own communities of practice, the collection and analysis of data about the science and scientific communities they support is heterogeneous and unsystematic.
- Agencies are using very different models, data and tools to understand their investments in science and technology.
- The data infrastructure is inadequate for decision-making.

THE SCIENCE OF SCIENCE POLICY: A FEDERAL RESEARCH ROADMAP 1



The Nascent System in the U.S.

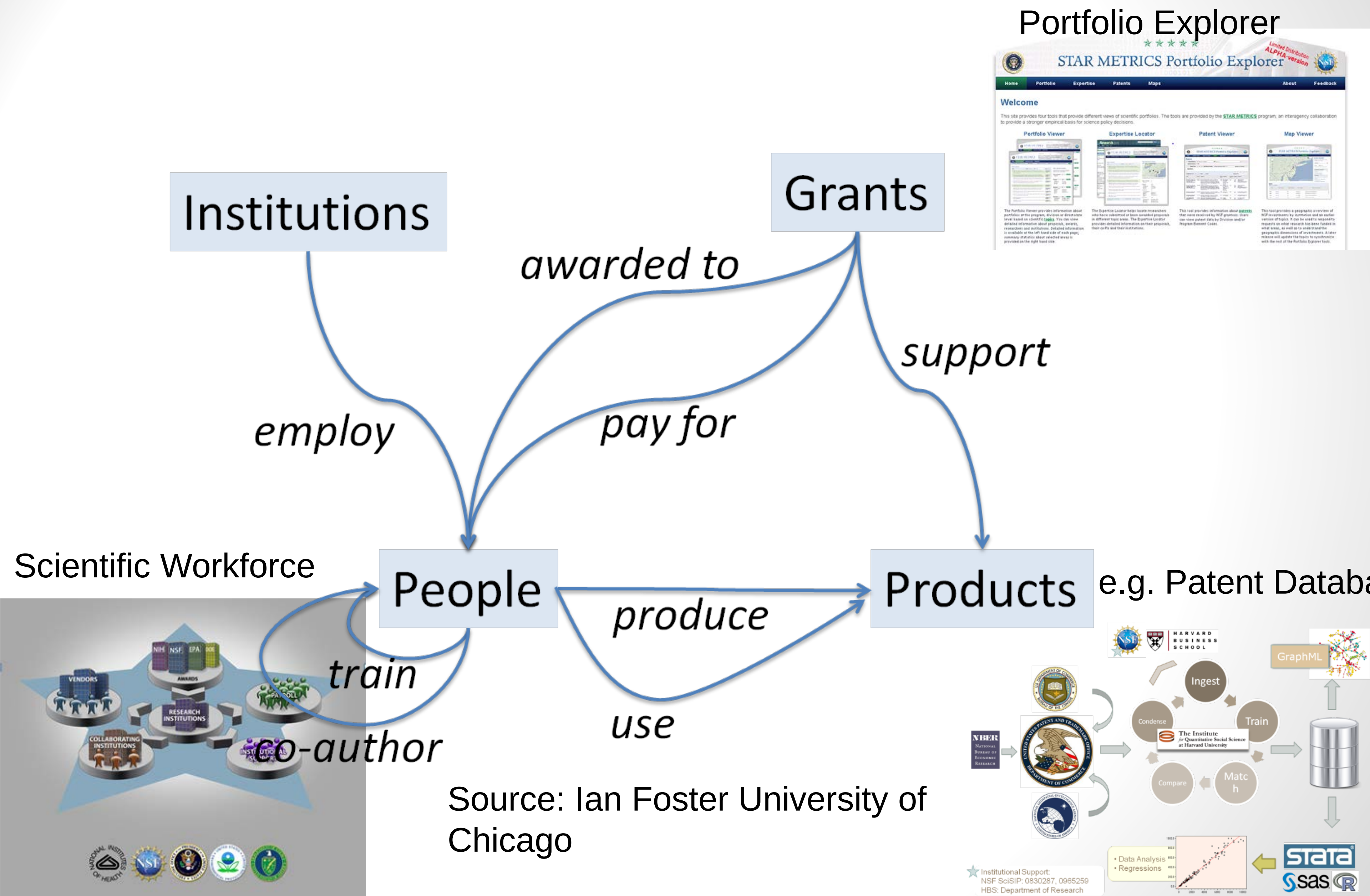
Brief Background: Evolution

- 2006: Science of Science Policy established – NSTC interagency group plus NSF SciSIP program
- 2008: Roadmap finds “data inadequate for decision-making” across all science agencies
- 2009: ARRA reporting requirements demonstrated uneven capacity across agencies; STAR pilot
- 2010: STAR METRICS established
- 2012: 6 federal agencies, 85 research institutions (~40% of NSF/NIH extramural research portfolios)

Brief Background: Interagency collaboration

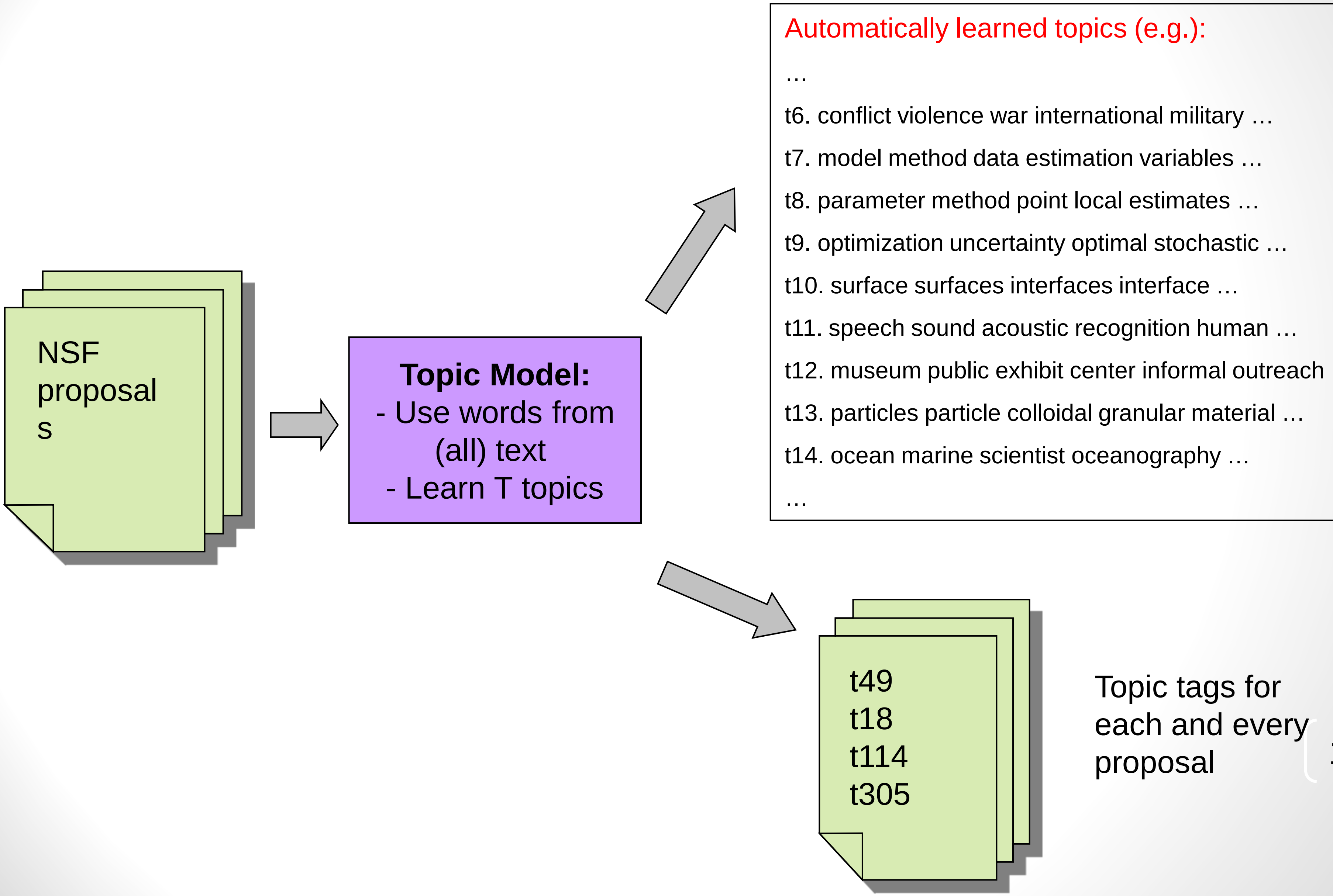
- Provide a better empirical basis for science policy by:
  - providing an open and automated data infrastructure that can be used by federal agencies, research institutions, and researchers,
  - documenting federal investments in science, and
  - analyzing the resulting relationship between inputs, outputs, and outcomes.

Approach: automatically capture data about the conduct of science – inputs, outputs and the connections between the two

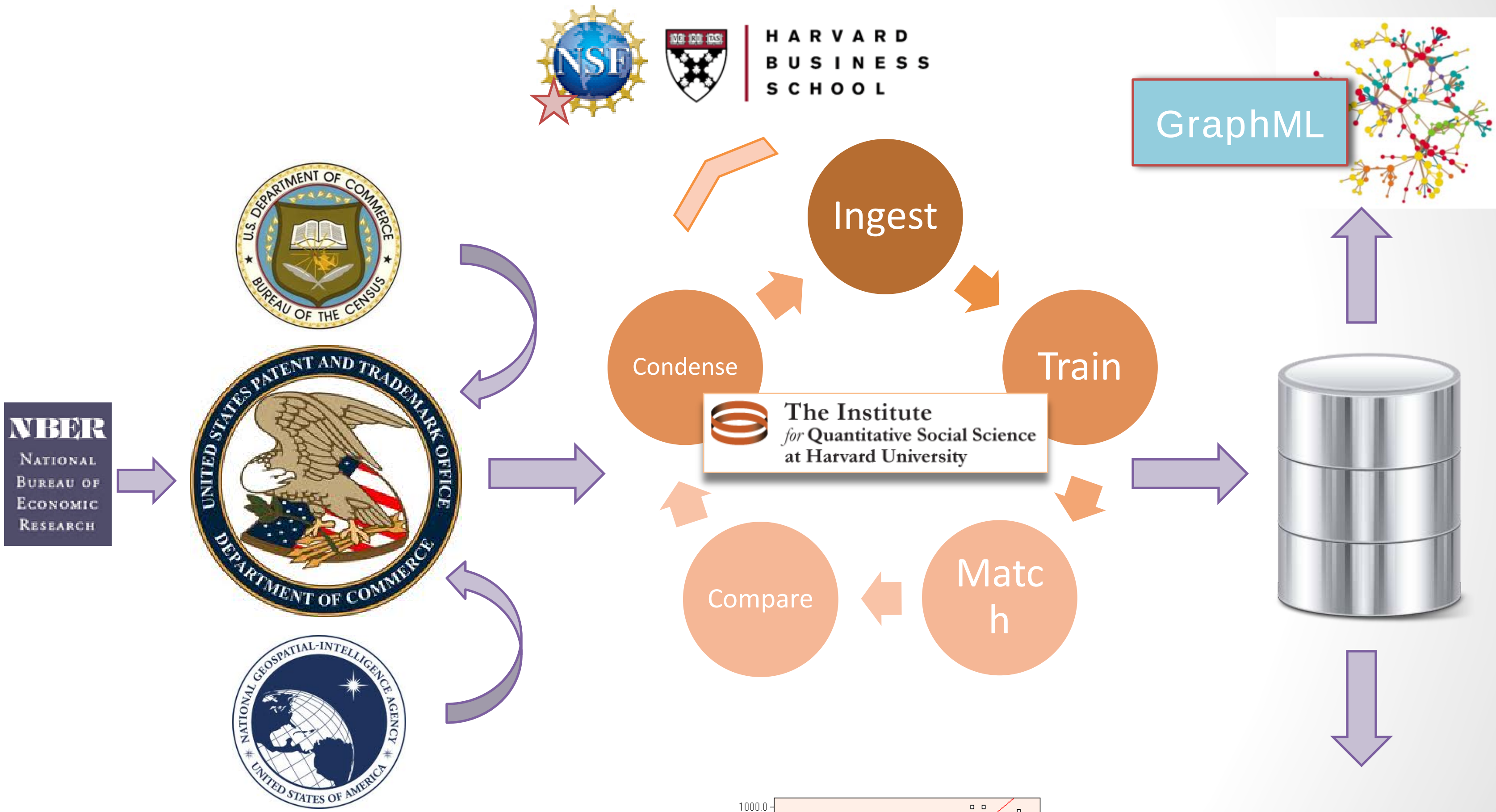


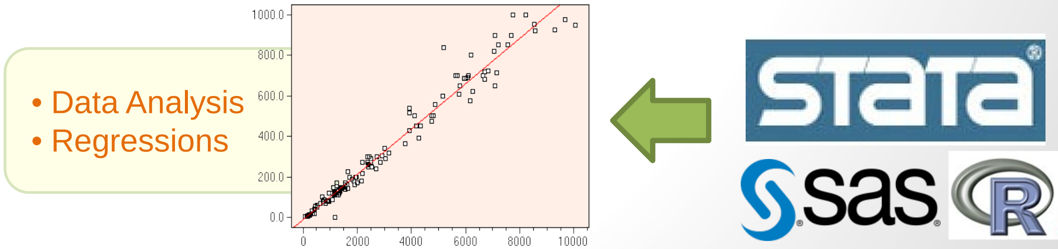
Source: Ian Foster University of Chicago

Automated capture of scientific topics



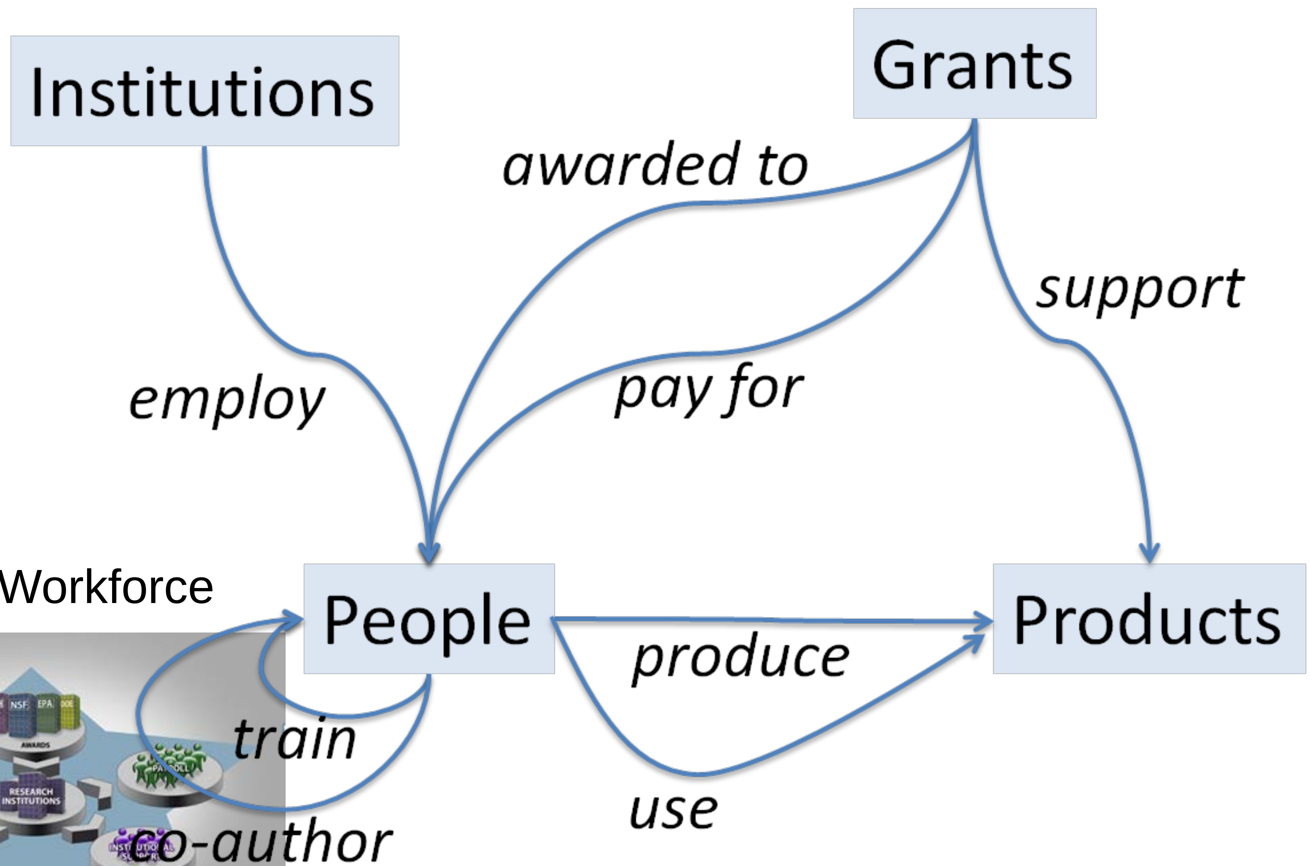
Automated capture of economic outcomes





Institutional Support:
NSF SciSIP: 0830287, 0965259
HBS: Department of Research

Approach: automatically capture data about the conduct of science – inputs, outputs and the connections between the two



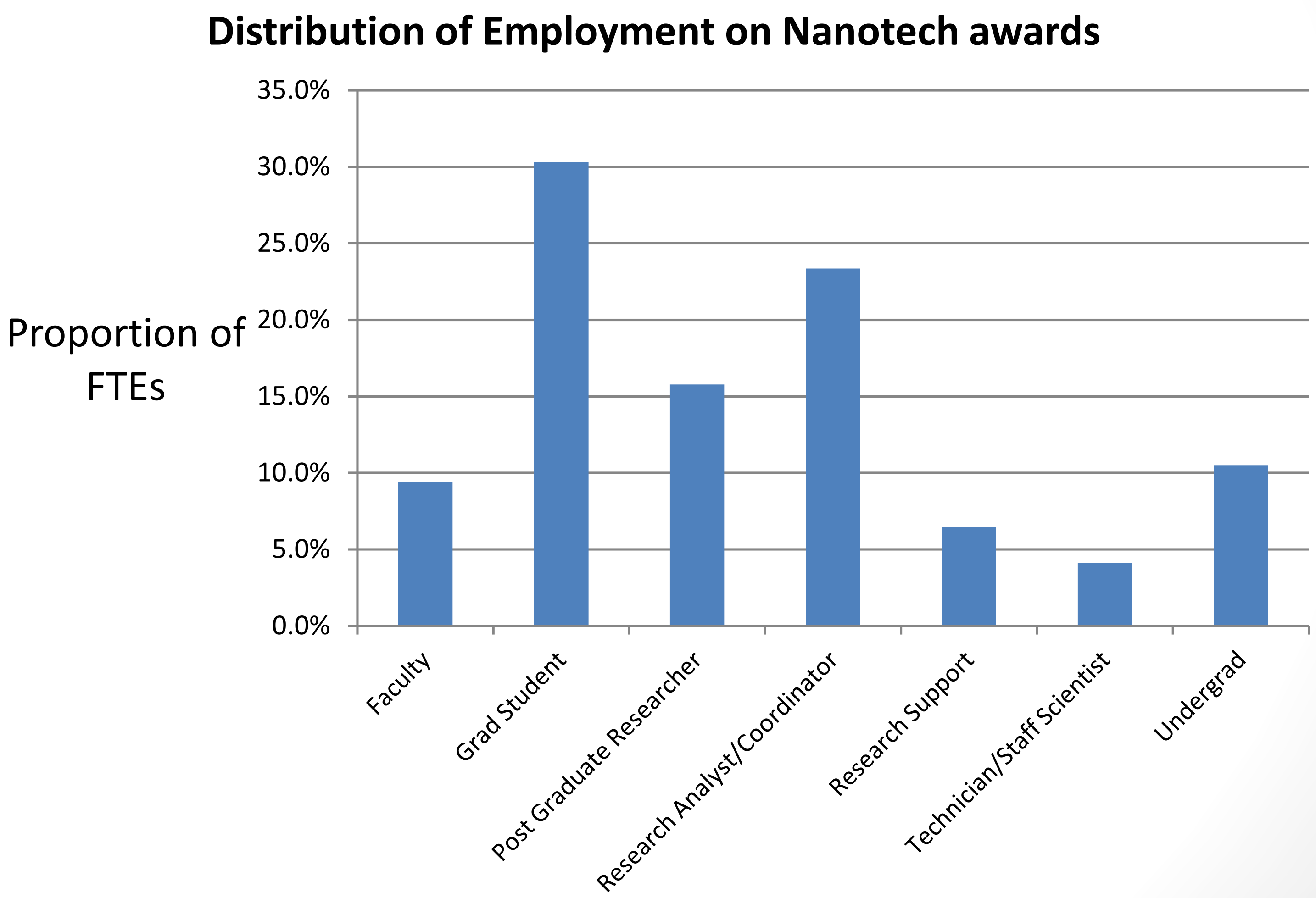
Scientific Workforce

Source: Ian Foster University of Chicago

Example for selected institutions

Nano Tech Science Topics		
Values		
nanoparticle polymer solvent polymerization monomer gel particle surfactant NPs solution ...	Individuals	276
	Number of Awards	57
environment environmental degradation contaminant pollutant concentration pollution toxicity nanomaterial EPA ...	Individuals	152
	Number of Awards	19
CNT nanowire nanotechnology nanostructure nanotube graphene carbon_nanotube nanoscale nanomaterial nano ...	Individuals	126
	Number of Awards	32
composite fiber polymer dispersion nanocomposite nanofiber matrix resin clay fabric ...	Individuals	20
	Number of Awards	5

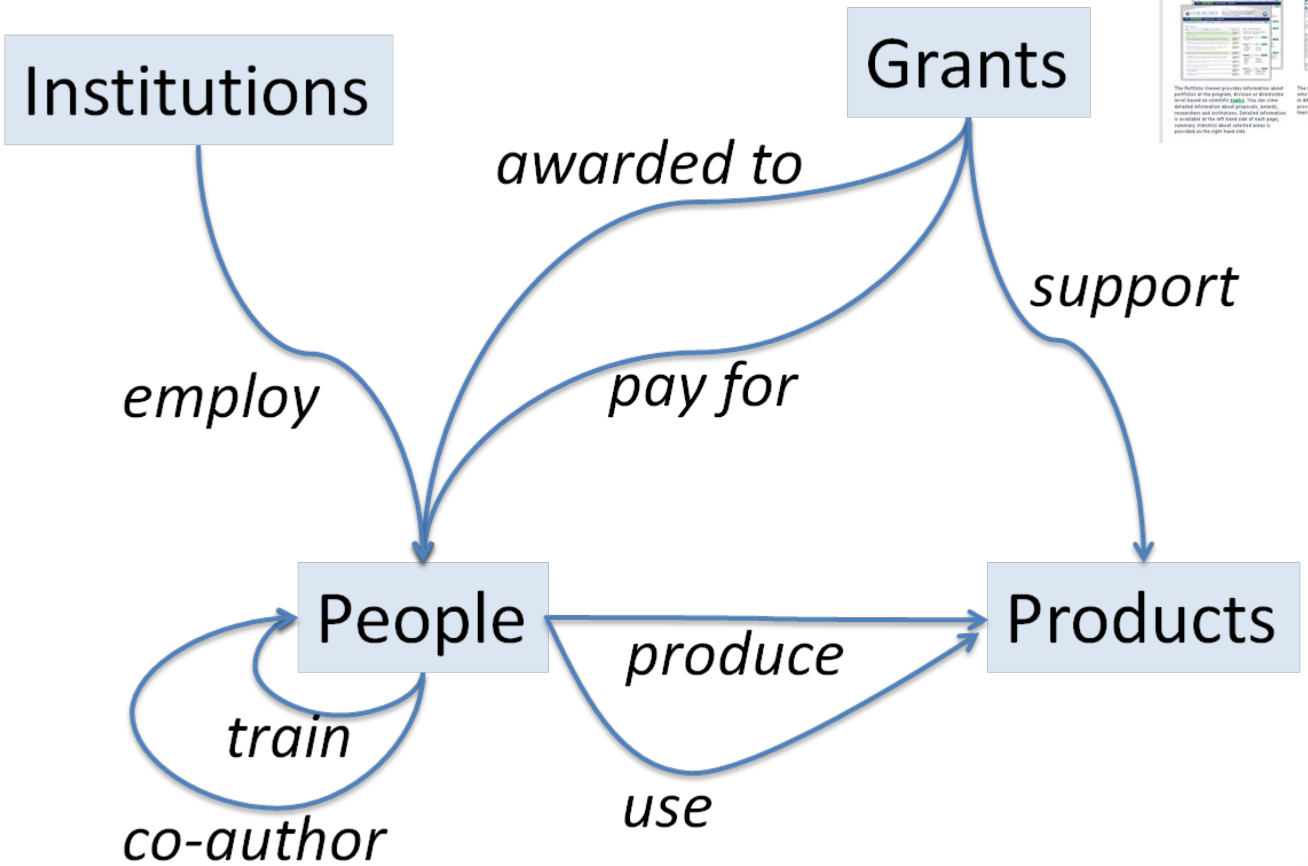
Information About Individuals Tells Us About Future Supply



Where did Nanotech award expenditures get spent?

DISTRIBUTION OF SUB-AWARD AND VENDOR JOBS BY INDUSTRY:	Rolling 12 months thru 9/2011		
Industry	**Subawards/ Subcontracts**	**Vendors**	**Grand Total**
Accommodation and Food Services	0.0%	2.7%	0.1%
Arts, Entertainment, and Recreation	0.0%	0.1%	0.0%
Construction	1.3%	0.0%	1.3%
Educational Services	93.6%	0.9%	88.9%
Information	0.0%	0.5%	0.0%
Manufacturing	0.0%	25.7%	1.3%
Other Services (except Public Administration)	0.0%	2.9%	0.1%
Professional, Scientific, and Technical Services	5.1%	42.9%	7.0%
Retail Trade	0.0%	1.6%	0.1%
Transportation and Warehousing	0.0%	0.1%	0.0%
Wholesale Trade	0.0%	22.6%	1.1%
Grand Total	**100.0%**	**100.0%**	**100.0%**

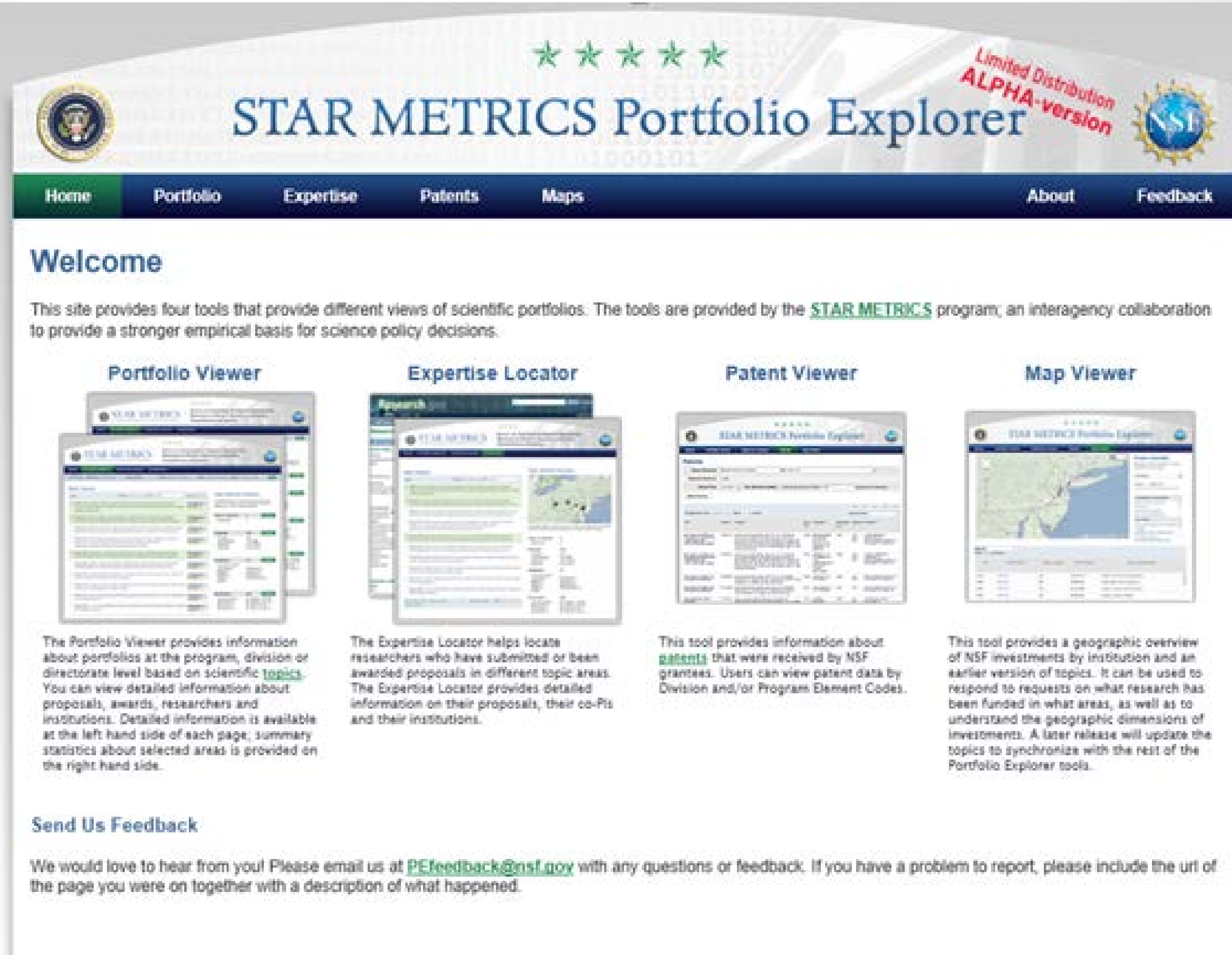
Portfolio Explorer



Source: Ian Foster University of Chicago

Information about grants tells us about portfolio using different lenses

- Divisions
- Programs
- Researchers
- Institutions
- Time
- Geography



STAR METRICS Portfolio Explorer
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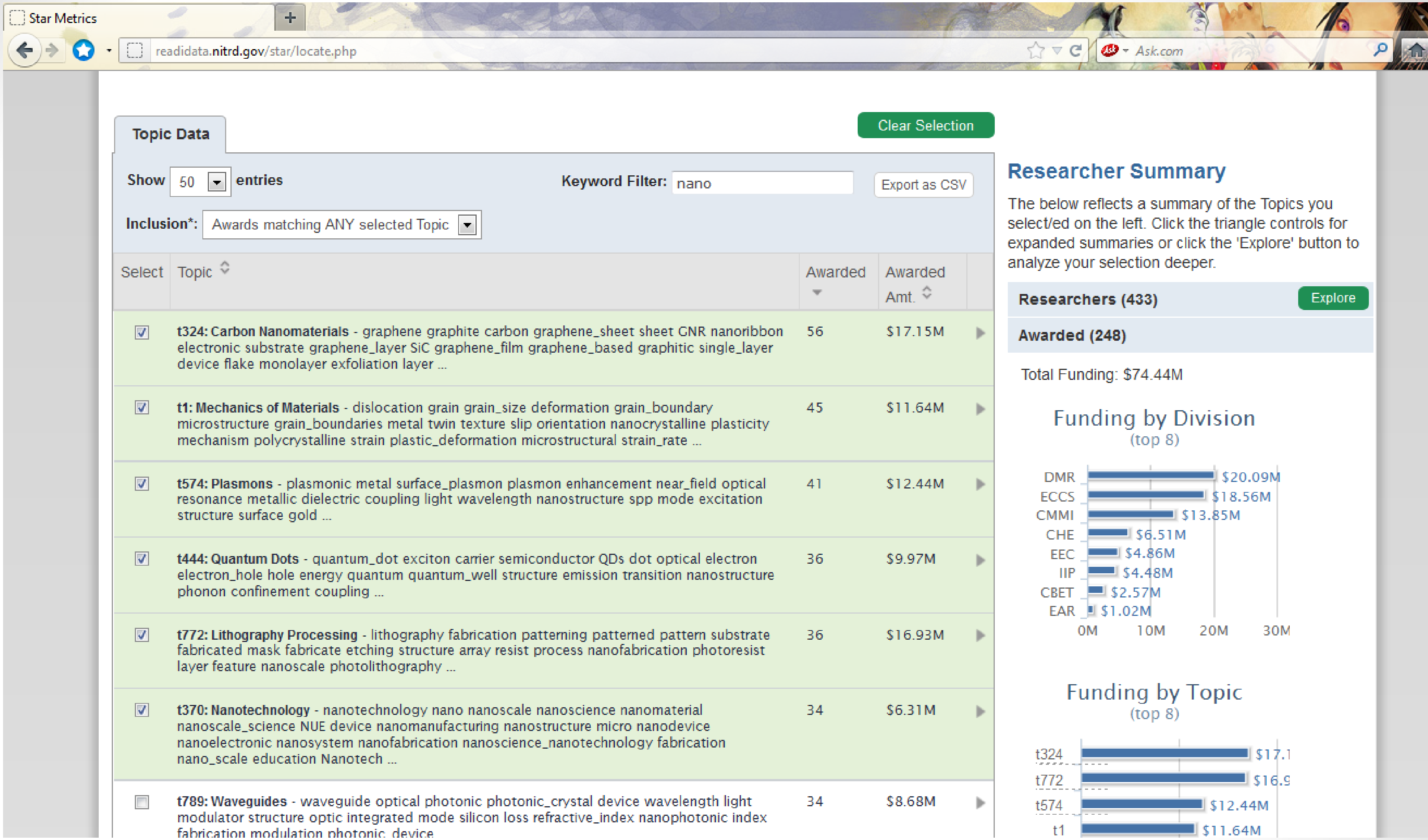
This site provides four tools that provide different views of scientific portfolios. The tools are provided by the STAR METRICS program; an interagency collaboration to provide a stronger empirical basis for science policy decisions.
Portfolio Viewer
The Portfolio Viewer provides information about portfolios at the program, division or directorate level based on scientific topics. You can view detailed information about proposals, awards, researchers and institutions. Detailed information is available at the left hand side of each page; summary statistics about selected areas is provided on the right hand side.
Expertise Locator
The Expertise Locator helps locate researchers who have submitted or been awarded proposals in different topic areas. The Expertise Locator provides detailed information on their proposals, their co-PIs and their institutions.
Patent Viewer
This tool provides information about patents that were received by NSF grantees. Users can view patent data by Division and/or Program Element Codes.
Map Viewer
This tool provides a geographic overview of NSF investments by institution and an earlier version of topics. It can be used to respond to requests on what research has been funded in what areas, as well as to understand the geographic dimensions of investments. A later release will update the topics to synchronize with the rest of the Portfolio Explorer tools.
Send Us Feedback
We would love to hear from you! Please email us at PEfeedback@nsf.gov with any questions or feedback. If you have a problem to report, please include the url of the page you were on together with a description of what happened.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Ask.com
Topic Data
Clear Selection
Show 50 entries
Keyword Filter: nano
Export as CSV
Inclusion*: Awards matching ANY selected Topic
Select
Topic
Awarded
Awarded Amt.
t324: Carbon Nanomaterials - graphene graphite carbon graphene_sheet sheet GNR nanoribbon electronic substrate graphene_layer SiC graphene_film graphene_based graphitic single_layer device flake monolayer exfoliation layer ...
56
$17.15M
t1: Mechanics of Materials - dislocation grain grain_size deformation grain_boundary microstructure grain_boundaries metal twin texture slip orientation nanocrystalline plasticity mechanism polycrystalline strain plastic_deformation microstructural strain_rate ...
45
$11.64M
t574: Plasmons - plasmonic metal surface_plasmon plasmon enhancement near_field optical resonance metallic dielectric coupling light wavelength nanostructure spp mode excitation structure surface gold ...
41
$12.44M
t444: Quantum Dots - quantum_dot exciton carrier semiconductor QDs dot optical electron electron_hole hole energy quantum quantum_well structure emission transition nanostructure phonon confinement coupling ...
36
$9.97M
t772: Lithography Processing - lithography fabrication patterning patterned pattern substrate fabricated mask fabricate etching structure array resist process nanofabrication photoresist layer feature nanoscale photolithography ...
36
$16.93M
t370: Nanotechnology - nanotechnology nano nanoscale nanoscience nanomaterial nanoscale_science NUE device nanomanufacturing nanostructure micro nanodevice nanoelectronic nanosystem nanofabrication nanoscience_nanotechnology fabrication nano_scale education Nanotech ...
34
$6.31M
t789: Waveguides - waveguide optical photonic photonic_crystal device wavelength light modulator structure optic integrated mode silicon loss refractive_index nanophotonic index fabrication modulation photonic device
34
$8.68M
Researcher Summary
The below reflects a summary of the Topics you select/ed on the left. Click the triangle controls for expanded summaries or click the 'Explore' button to analyze your selection deeper.
Researchers (433)
Explore
Awarded (248)
Total Funding: $74.44M
Funding by Division
(top 8)
DMR $20.09M
ECCS $18.56M
CMMI $13.85M
CHE $6.51M
EEC $4.86M
IIP $4.48M
CBET $2.57M
EAR $1.02M
0M
10M
20M
30M
Funding by Topic
(top 8)
t324
t772
t574 $12.44M
t1 $11.64M

Star Metrics

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t1: Mechanics of Materials - dislocation grain grain_size deformation grain_boundary microstructure grain_boundaries metal twin texture slip orientation nanocrystalline plasticity mechanism polycrystalline strain plastic_deformation microstructural strain_rate ... 45 $11.64M

PGE Code (Total:12)	Division	Awarded	Awarded Amt.
p1771:METAL & METALLIC NANOSTRUCTURE	DMR	23	$5.24M
p1630:MECHANICS OF MATERIALS	CMMI	9	$2.73M
p1574:GEOPHYSICS	EAR	2	$0.57M
p1572:TECTONICS	EAR	2	$0.45M
p1467:MATERIALS PROCESSING AND MANFG	CMMI	2	$0.70M
p1594:HIST BLACK COLLEGES AND UNIV	HRD	1	$0.20M

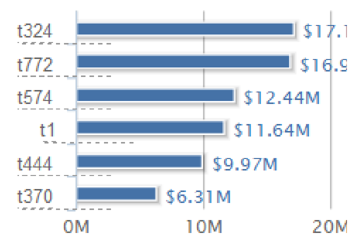
Co-occurring Topics: t1:Mechanics of Materials, t867:Metals, t724:Fracture Mechanics, t192:Molecular Modeling, t710:Mechanics of Materials, t1000:Mechanics of Materials

t574: Plasmons - plasmonic metal surface_plasmon plasmon enhancement near_field optical resonance metallic dielectric coupling light wavelength nanostructure spp mode excitation structure surface gold ... 41 $12.44M

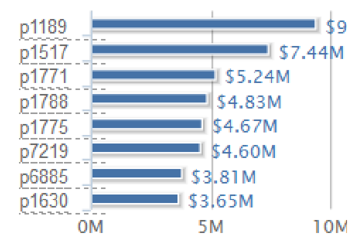
PGE Code (Total:19)	Division	Awarded	Awarded Amt.
p1517:ELECT, PHOTONICS, & MAG DEVICE	ECCS	6	$1.92M
p6885:MACROMOLEC/SUPRAMOLEC/NANO	CHE	5	$1.46M
p7607:ENERGY,POWER,ADAPTIVE SYS	ECCS	4	$1.30M
p1775:ELECTRONIC/PHOTONIC MATERIALS	DMR	4	$1.01M
p6880:CHEMICAL MEASUREMENT & IMAGING	CHE	3	$0.94M
p7909:BIOSENSING	CBET	3	$0.79M

Co-occurring Topics: t574:Plasmons, t835:Biosensors, t789:Waveguides, t39:Metamaterials, t772:Lithography Processing, t250:Instrumentation

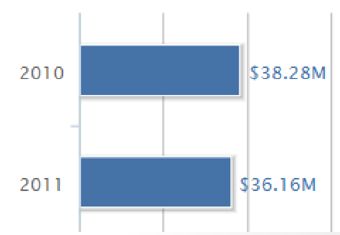
Funding by Topic
(top 8)



Funding by PGE Codes
(top 8)



Funding over Time



Star Metrics

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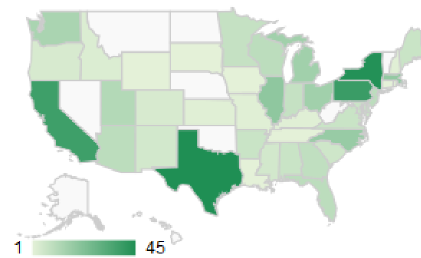
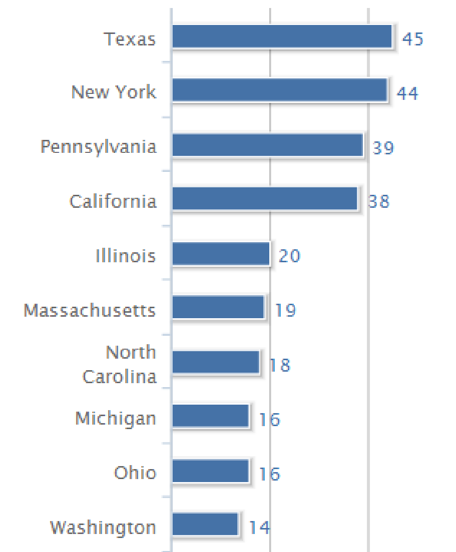
Researchers

Show 50 entries **Keyword Filter:** Export as CSV

Name	Institution	Department	Count*	IDs**	Details
Tony F Heinz	American Physical Society	Education	4	1106210, 1124894, 1106172, 1106225	▶
Rodney S Ruoff	University of Texas at Austin	Mechanical Engineering	3	1130261, 0969106, 1006350	▶
James C Hone	Columbia University	Mechanical Engineering	3	1124894, 1138237, 1122594	▶
Donald K Roper	University of Arkansas	Chemical Engineering	3	1138248, 1006927, 1134222	▶
Teri W Odom	Northwestern University	Chemistry	3	1006380, 1058501, 1069180	▶
Eui-Hyeok Yang	Stevens Institute of Technology	Mechanical Engineering	3	1040007, 1104870, 1138244	▶
Stefan Strauf	Stevens Institute of Technology	Physics and Engineering Physics	3	1040007, 1104870, 1053537	▶
Jan M Yarrison-Rice	Miami University Oxford Campus	Department of Physics	2	1100489, 1105121	▶
Gregory J Salamo	University of Arkansas	Department of Physics	2	1138248, 1008107	▶
Myung S Jhon	Carnegie-Mellon University	Chemical Engineering	2	1020137, 1123627	▶
Pallab K Bhattacharya	University of Michigan Ann Arbor	Electrical Engineering & Computer Sci.	2	1120923, 0968346	▶
Howard E Jackson	University of Cincinnati Main Campus	Department of Physics	2	1100489, 1105362	▶
Thomas R Bieler	Michigan State University	Chemical Engineering and Materials Sci.	2	1006656, 1108211	▶
Leigh M Smith	University of Cincinnati Main Campus	Department of Physics, ML-11	2	1100489, 1105362	▶
Naomi J Halas	William Marsh Rice University	Electrical & Computer Engineering	2	0959343, 1040478	▶
Ronald S Besser	Stevens Institute of Technology	Chemical Engineering and Materials Scien	2	1040007, 1138244	▶

Researchers by State





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Name	Institution	Department	Count*	IDs**	Details
John W Morris	University of California-Berkeley	Material Science and Engineering	1	1105081	
Ronald O Scattergood	North Carolina State University	Materials Science & Engineering	1	1005677	
William W Gerberich	University of Minnesota-Twin Cities	Chemical Engr & Materials Science	1	0946337	

William W Gerberich:

wgerb@umn.edu
6126258548

Chemical Engr & Materials Science
University of Minnesota-Twin Cities

Total: 8
Awarded: 8 ($5.27M)
Date First: 5/1/1984
Date Last: 6/1/2010

Patents: 4

Awarded

Grant: 1000415

Status: Awarded $205,368 on 2010/07/01

Title: Collaborative Research: Hierarchically Structured Polycrystalline Hollow Gold Nanoparticles- A Model System for Integrated Experimental and Multiscale Computational Nanomechanics

NSF Division: Division of Civil, Mechanical, and Manufacturing Innovation (**CMMI**)

Program Element: Biomechanics and Mechanobiology (BMMB) (7479)

Topics: t192: Molecular Modeling, t805: Nanomaterials, t1: Mechanics of Materials, t790: NSF/Minorities

Co-PIs
- Traian Dumitrica

Grant: 0946337

Status: Awarded $264,439 on 2009/12/15

Title: EAGER: Oxide Film Effects on Dislocation Nucleation -- Implications to Structure/Property Relations

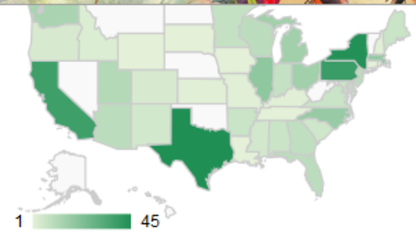
NSF Division: Metals (**DMR**)

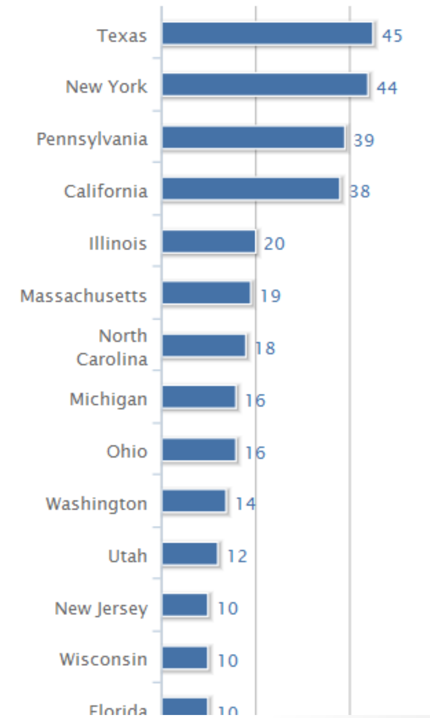
Program Element: Metals and Metallic Nanostructure (1771)

Topics: t1: Mechanics of Materials, t402: Mechanics of Materials, t176: Thin Films, t636: Metal Oxides

Co-PIs
- Christopher Leighton

Name	Institution	Department	Count*	IDs**	Details
Tsu-Wei Chou	University of Delaware	Mechanical Engineering	1	1138182	
Roberto D Merlin	University of Michigan Ann Arbor	Department of Physics	1	1120923	
Scott E Johnson	University of Maine	Earth Sciences	1	1118786	





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John W Morris	University of California-Berkeley	Material Science and Engineering	1	1105081	
Ronald O Scattergood	North Carolina State University	Materials Science & Engineering	1	1005677	
William W Gerberich	University of Minnesota-Twin Cities	Chemical Engr & Materials Science	1	0946337	

- Timothy P Lodge

Grant: 8400015

Status: Awarded $425,900 on 1984/06/01

Title: Electron Channeling Studies of Three-Dimensional Strain Gradients at Fracture Surfaces and Near Crack Tips (Materials Research)

NSF Division: Electronic Materials (**DMR**)

Program Element: Metals, Ceramics, And Electronic Materials (1715)

Topics: t0: Not Machine Readable

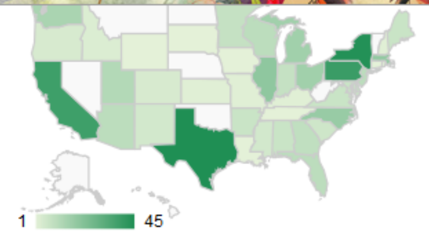
Co-PIs

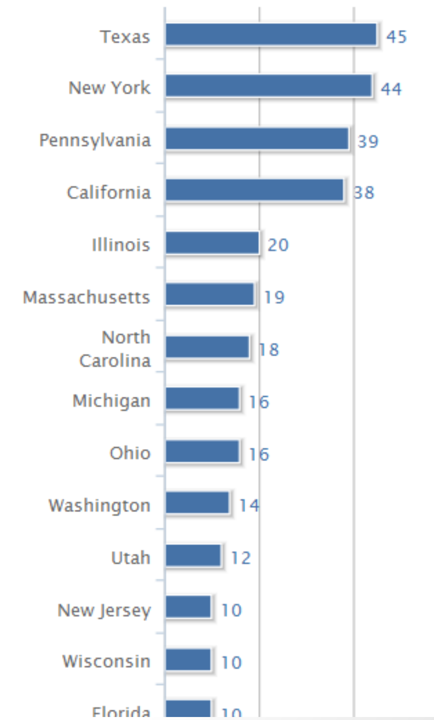
- David L Davidson

Patents:

ID	Title	Application Year	Grant Year	Assignee
5260141		1991	1993	UNIVERSITY OF MINNESOTA THE REGENTS OF
5344551		1993	1994	UNIVERSITY OF MINNESOTA THE REGENTS OF
5696327		1994	1997	UNIVERSITY OF MINNESOTA THE REGENTS OF
6924004	Apparatus and method for synthesizing films and coatings by focused particle beam deposition	2001	2005	REGENTS OF THE UNIVERSITY OF MINNESOTA

Name	Institution	Department	Count*	IDs**	Details
Tsu-Wei Chou	University of Delaware	Mechanical Engineering	1	1138182	
Roberto D Merlin	University of Michigan Ann Arbor	Department of Physics	1	1120923	
Scott E Johnson	University of Maine	Earth Sciences	1	1118786	





PATENTS

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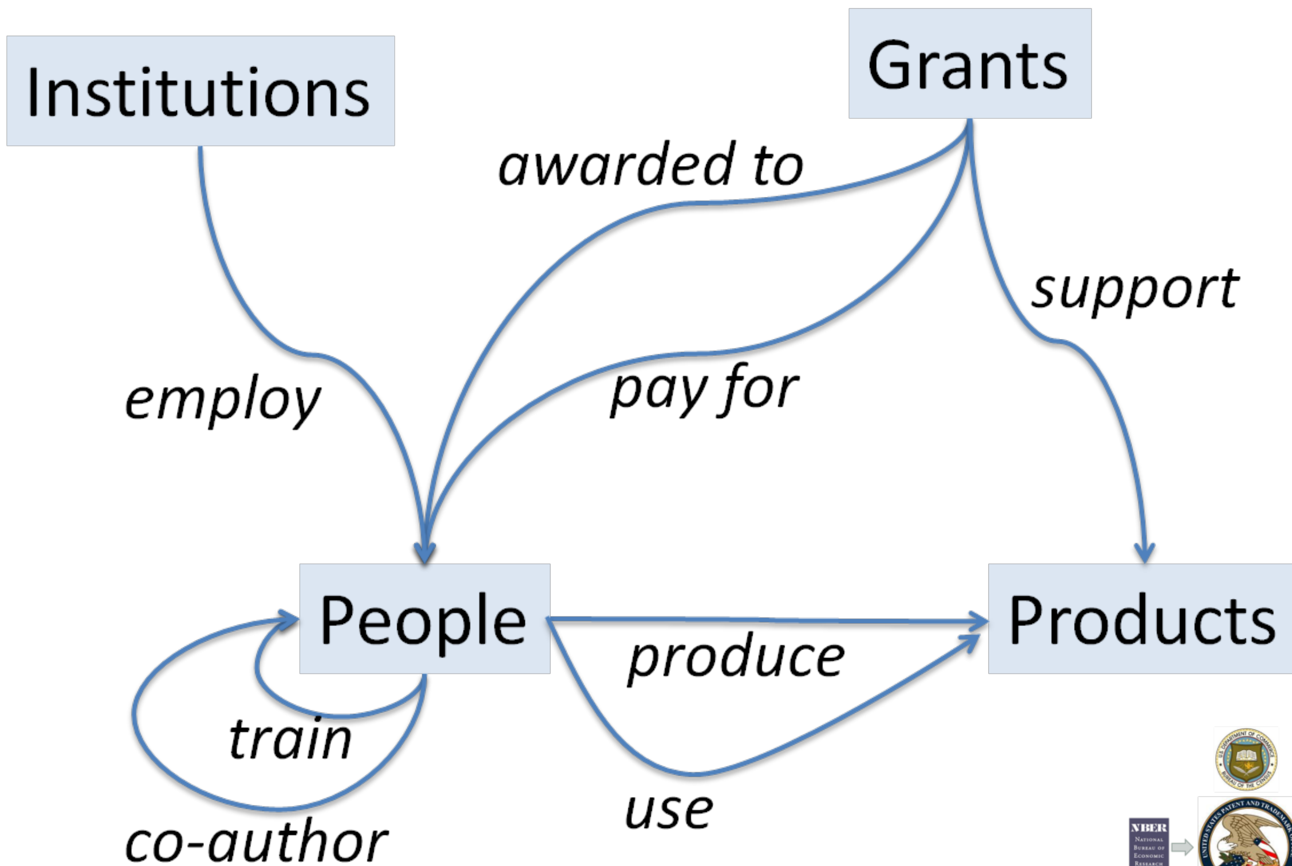
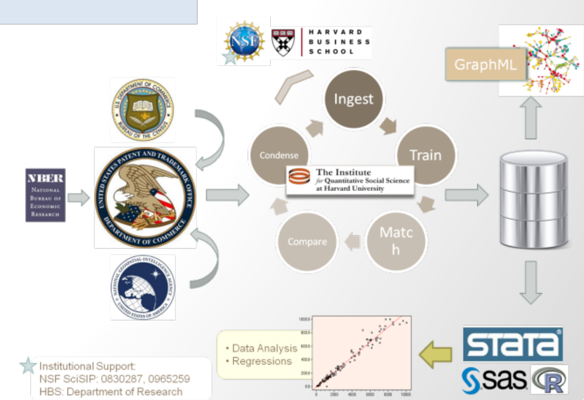
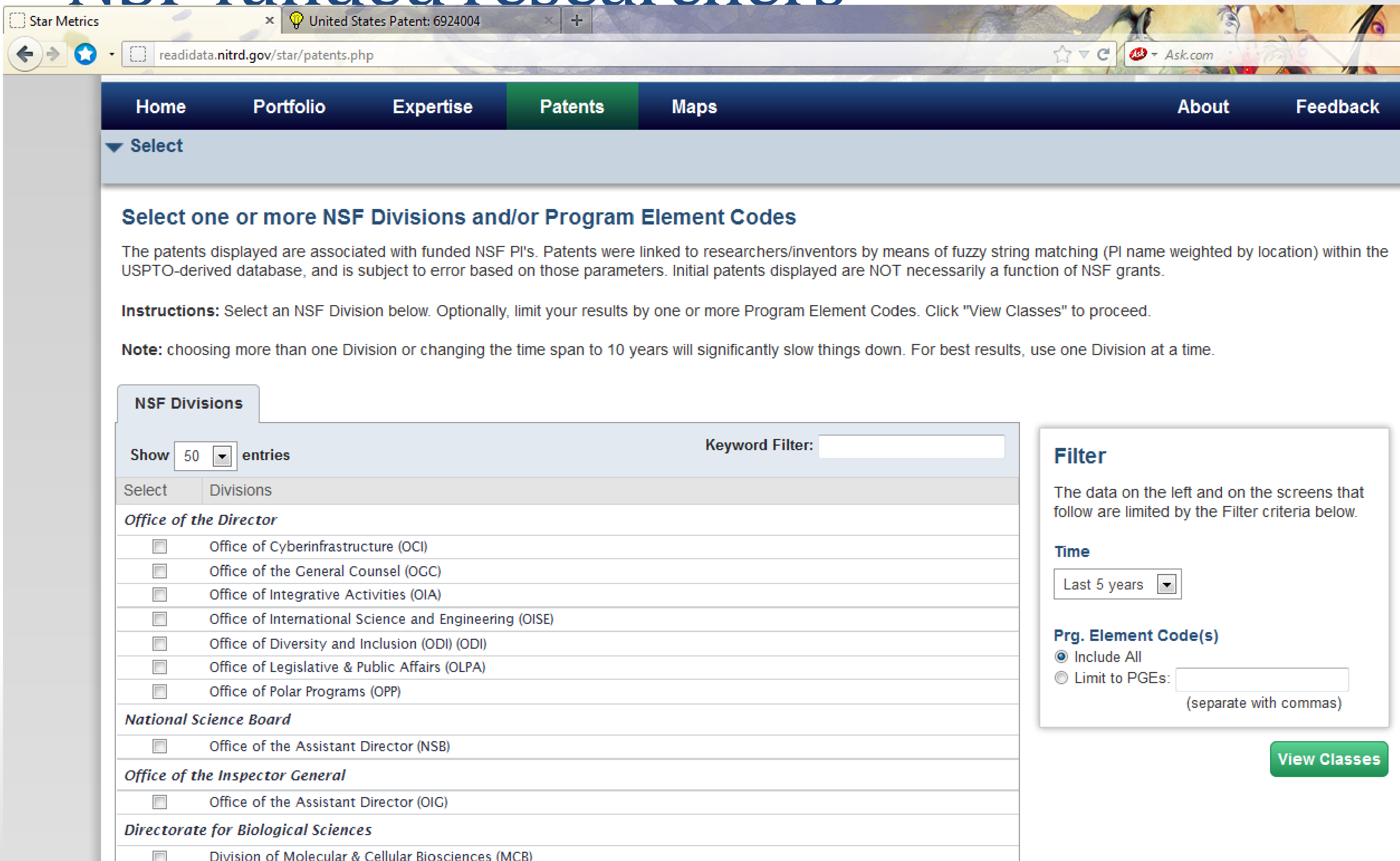


e.g. Patent Databa



Source: Ian Foster University of Chicago

What patents have been granted to NSF funded researchers



Star Metrics | United States Patent: 6924004

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Classes
Filter

Include patents for selected Classes. Use the Summary sidebar to explore your selection.

Classes — Clear Selection

Show 50 entries — Keyword Filter:

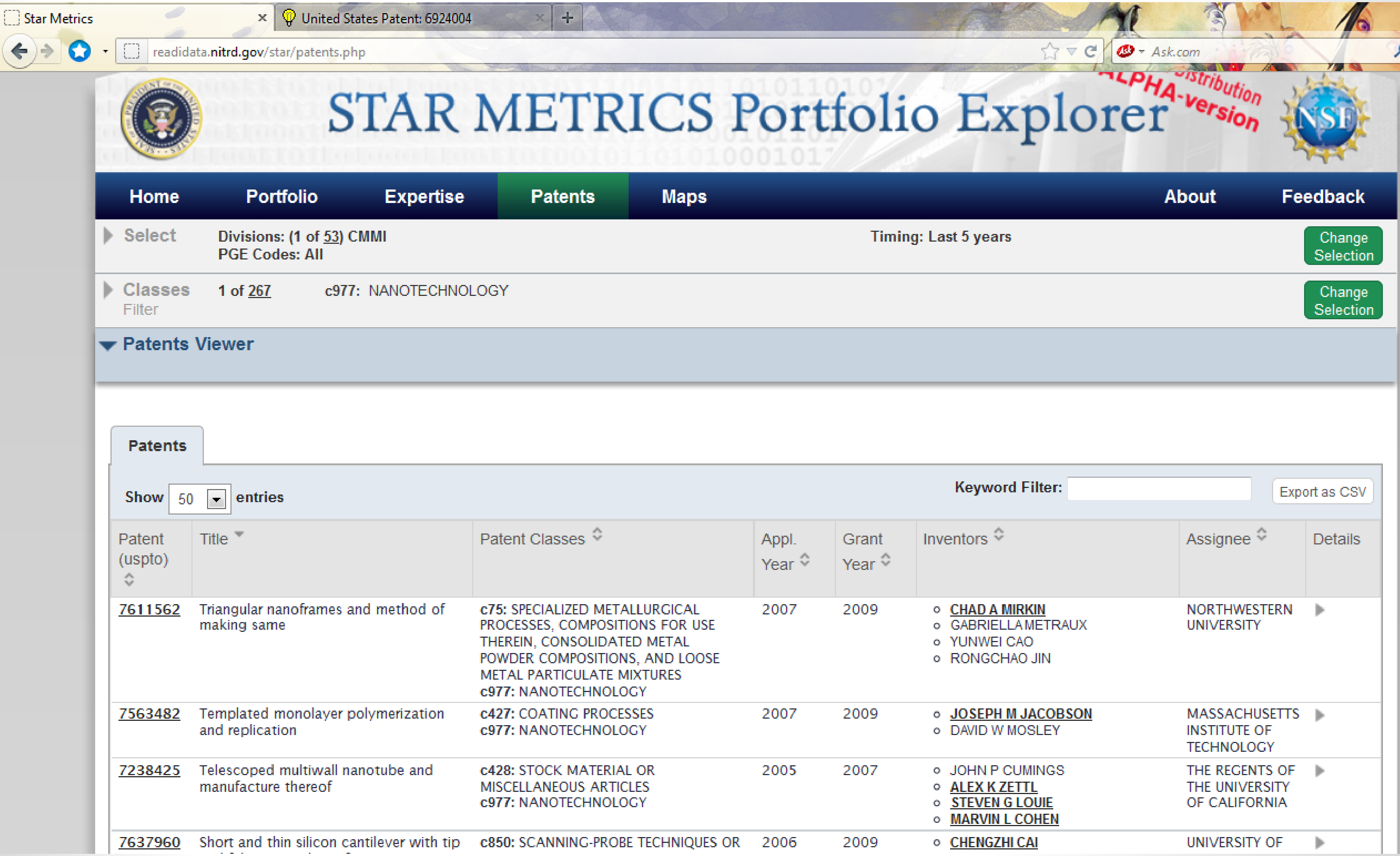
Select	USPTO Class ID	Patent Class Description	Patents by NSF PIs
☐	c257	ACTIVE SOLID-STATE DEVICES (E.G., TRANSISTORS, SOLID-STATE DIODES)	114
☐	c73	MEASURING AND TESTING	91
☐	c438	SEMICONDUCTOR DEVICE MANUFACTURING: PROCESS	86
☐	c428	STOCK MATERIAL OR MISCELLANEOUS ARTICLES	78
☐	c250	RADIANT ENERGY	65
☐	c385	OPTICAL WAVEGUIDES	60
☐	c435	CHEMISTRY: MOLECULAR BIOLOGY AND MICROBIOLOGY	52
☐	c977	NANOTECHNOLOGY	44
☐	c356	OPTICS: MEASURING AND TESTING	43
☐	c359	OPTICAL: SYSTEMS AND ELEMENTS	43
☐	c423	CHEMISTRY OF INORGANIC COMPOUNDS	42
☐	c324	ELECTRICITY: MEASURING AND TESTING	40
☐	c427	COATING PROCESSES	36

Patents Summary

The below reflects a summary of the Classes you select/ed on the left. Click the 'Explore' button to analyze your selection deeper.

Patents () — Explore

Drilling down into details



Star Metrics | United States Patent: 6924004

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Classes Filter — 1 of 267 — c977: NANOTECHNOLOGY — Change Selection

Patents Viewer

Patents

Show 50 entries — Keyword Filter: — Export as CSV

Patent (uspto)	Title	Patent Classes	Appl. Year	Grant Year	Inventors	Assignee	Details
7611562	Triangular nanoframes and method of making same	**c75:** SPECIALIZED METALLURGICAL PROCESSES, COMPOSITIONS FOR USE THEREIN, CONSOLIDATED METAL POWDER COMPOSITIONS, AND LOOSE METAL PARTICULATE MIXTURES **c977:** NANOTECHNOLOGY	2007	2009	CHAD A MIRKIN GABRIELLA METRAUX YUNWEI CAO RONGCHAO JIN	NORTHWESTERN UNIVERSITY	▶
7563482	Templated monolayer polymerization and replication	**c427:** COATING PROCESSES **c977:** NANOTECHNOLOGY	2007	2009	JOSEPH M JACOBSON DAVID W MOSLEY	MASSACHUSETTS INSTITUTE OF TECHNOLOGY	▶
7238425	Telescoped multiwall nanotube and manufacture thereof	**c428:** STOCK MATERIAL OR MISCELLANEOUS ARTICLES **c977:** NANOTECHNOLOGY	2005	2007	JOHN P CUMINGS ALEX K ZETTL STEVEN G LOUIE MARVIN L COHEN	THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	▶
7637960	Short and thin silicon cantilever with tip	**c850:** SCANNING-PROBE TECHNIQUES OR	2006	2009	CHENGZHI CAI	UNIVERSITY OF	▶

Star Metrics | United States Patent: 7611562 | United States Patent: 6924004

patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND

United States Patent
Mirkin , et al.

Triangular nanoframes and method of making same

Abstract

The present invention provides nanoprisms etched to generate triangular framework structures. These triangular nanoframes possess no strong surface plasmon bands in the ultraviolet or visible regions of spectrum. By adding a mild reducing agent, metal ions remaining in solution can be reduced, resulting in metal plating and reformation of nanoprisms. The extent of the backfilling process can be controlled formation of novel nanoprisms with nanopores. This back-filling process is accompanied by a regeneration of the surface plasmon bands in the UV-visible spectrum.

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Related U.S. Patent Documents

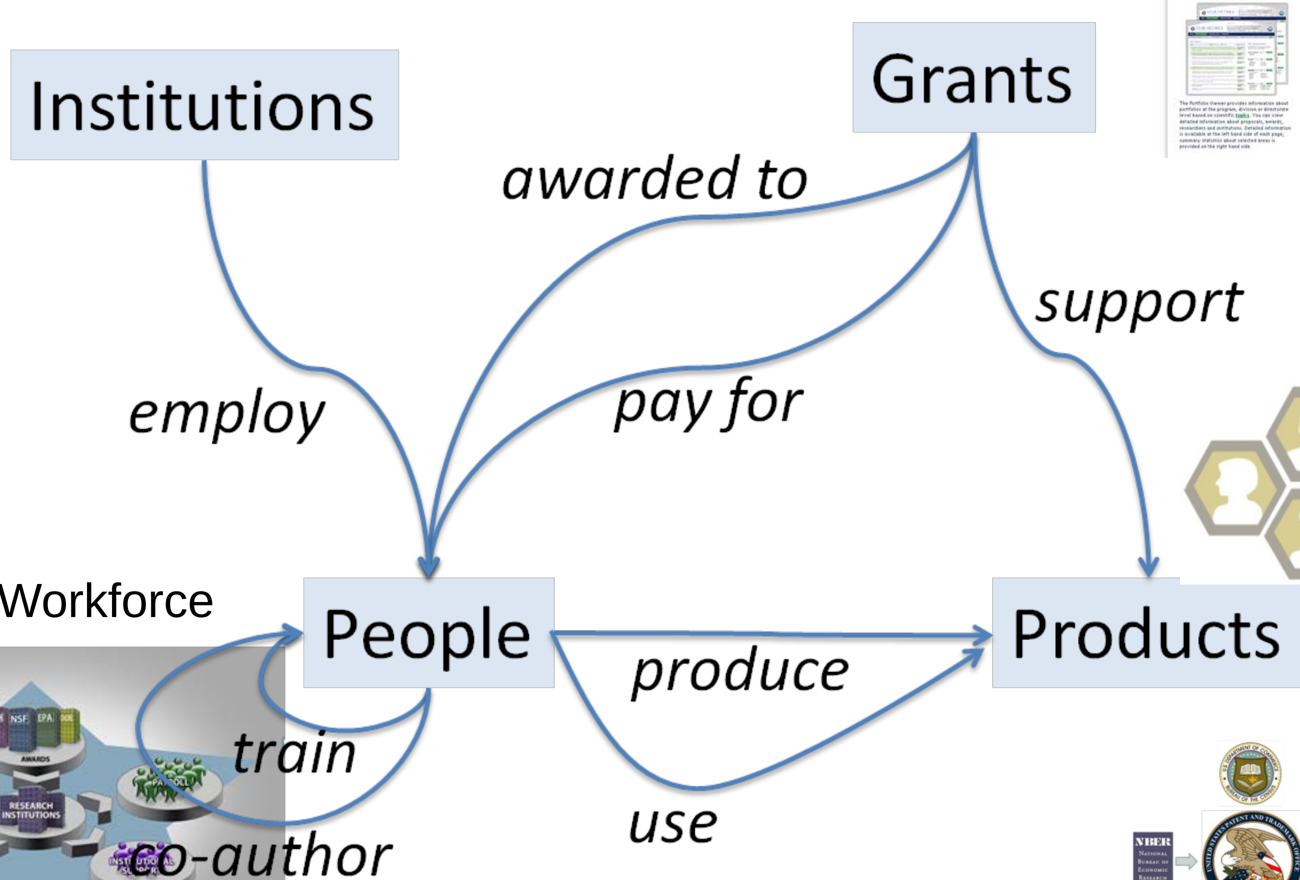
Application Number	Filing Date	Patent Number	Issue
10801976	Mar., 2004	7252698	
60454552	Mar., 2003		

Basic Approach

- Focus: Build coherent data infrastructure (not shiny tools) leverage existing systems – and minimize manual input
- Unit of Analysis: Individual - Senior personnel
- Incentives: Create value for all stakeholders to ensure capture of right measures and data quality

Approach: automatically capture data about the conduct of science – inputs, outputs and the connections between the two

Portfolio Explorer



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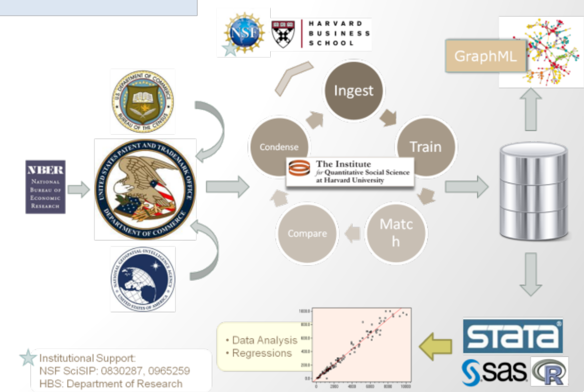

Source: Ian Foster University of Chicago

Supporting automated reporting using Auto-population

Auto-population is possible when existing information is accessible, or is made available by those who need it.

An auto-populated report infrastructure will consist of a **set of rules** that will extract and synthesize information from a variety of sources.

A provenance framework for data interpretation and synthe

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A solution (for report auto-population) will include a mix of the following methods

Synthesis of *authoritative and non-authoritative* sources

Extraction of data from ***authoritative databases*** *(HR systems, other)*

Extraction of data from ***non-authoritative* sources** (publications, patents, etc)

Participant incentives to share data

Review and revision by the Principal Investigator (or other authorized individuals

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Ultimate Goals

- Fully fledged academic field
- Fully fledged analytical tool set in government
  - Science policy in same analytical tier as tax policy
- Common empirical infrastructure available to all universities and science agencies to quickly respond to State, Congressional and OMB requests
- Common scientific infrastructure for researchers to develop and study science policy

Thank you

- Comments and questions?