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.

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• The data infrastructure is inadequate for decision-making.



#### THE SCIENCE OF SCIENCE POLICY: A FEDERAL RESEARCH ROADMAP

## 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



## Automated capture of scientific topics

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t6. conflict violence war international military ... t7. model method data estimation variables ... t8. parameter method point local estimates ... t9. optimization uncertainty optimal stochastic ... t10. surface surfaces interfaces interface ... t11. speech sound acoustic recognition human ... t12. museum public exhibit center informal outreach t13. particles particle colloidal granular material ... t14. ocean marine scientist oceanography ...

**NSF** proposal

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Topic Model:
- Use words from
(all) text
- Learn T topics

David Newman - UC Irvir

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Topic tags for each and every proposal

### Automated capture of economic outcomes



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



# 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

**Distribution of Employment on Nanotech awards** 



# Where did Nanotech award expenditures get spent?

DISTRIBUTION OF SUB-AWARD AND VENDOR JOBS BY INDUSTRY:	Rolling 12 months	thru 9/2011	
	Subawards/		
Industry	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%



## Information about grants tells us about portfolio using different lenses

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



#### Welcome

This site provides four tools that provide different views of scientific portfolios. The tools are provided by the <u>STAR METRICS</u> 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 patients 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 Portfolic Explorer tools.

#### Send Us Feedback

We would love to hear from you! Please email us at <u>PEfeedback@nsf.gov</u> 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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	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	•
<	<b>t772: Lithography Processing</b> - 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	Þ

#### **Researcher Summary**

Ask.com

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.

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<b>V</b>	t1: Mechanics of Materials - dislocation grain grain, microstructure grain_boundaries metal twin textur mechanism polycrystalline strain plastic deformat	_size deform re slip orienta ion microstru	ation grain_b Ition nanocry	oundary rstalline plasticity rate	45	\$11.64M	Funding by Topic (top 8)
_	PGE Code (Total:12)	Division	Awarded	Awarded Amt.			t324 \$17.1 t772 \$16.9
	p1771:METAL & METALLIC NANOSTRUCTURE	DMR	23	\$5.24M			t574 \$12.44M
	p1630:MECHANICS OF MATERIALS	СММІ	9	\$2.73M			t444 \$9.97M
	p1574:GEOPHYSICS	EAR	2	\$0.57M			t370 \$6.31M
	p1572:TECTONICS	EAR	2	\$0.45M			0M 10M 20M
	p1467:MATERIALS PROCESSING AND MANFG	СММІ	2	\$0.70M			
	p1594:HIST BLACK COLLEGES AND UNIV	HRD	1	\$0.20M			Funding by PGE Codes
	Co-occurring Topics: t1:Mechanics of Materials, t867 t192:Molecular Modeling, t710:Mechanics of Materia	7:Metals, t724: Is, t1000:Mecl	Fracture Mech nanics of Mate	nanics, rials			p1189 p1517 \$9 \$7.44M
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	PGE Code (Total:19)	Division	Awarded	Awarded Amt.			p1630 \$3,81M
	p1517:ELECT, PHOTONICS, & MAG DEVICE	ECCS	6	\$1.92M			
	p6885:MACROMOLEC/SUPRAMOLEC/NANO	CHE	5	\$1.46M			Funding over Time
	p7607:ENERGY,POWER,ADAPTIVE SYS	ECCS	4	\$1.30M			Funding over time
	p1775:ELECTRONIC/PHOTONIC MATERIALS	DMR	4	\$1.01M			
	p6880:CHEMICAL MEASUREMENT & IMAGING	CHE	3	\$0.94M			2010 \$38.28M

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Tony F Heinz	American Physical Society	Education	4	<u>1106210, 112</u> 1106172, 110	4894, <b>b</b> 6225
Rodney S Ruoff	University of Texas at Austin	Mechanical Engineering	3	<u>1130261, 0969</u> 1006350	<u>9106,</u>
James C Hone	Columbia University	Mechanical Engineering	3	<u>1124894, 113</u> 1122594	<u>8237,</u>
Donald K Roper	University of Arkansas	Chemical Engineering	3	<u>1138248, 100</u> <u>1134222</u>	<u>6927,</u>
Teri W Odom	Northwestern University	Chemistry	3	<u>1006380, 105</u> 1069180	<u>8501,</u>
Eui-Hyeok Yang	Stevens Institute of Technology	Mechanical Engineering	3	<u>1040007, 1104</u> 1138244	<u>4870,</u>
Stefan Strauf	Stevens Institute of Technology	Physics and Engineering Physics	3	<u>1040007, 1104</u> 1053537	<u>4870,</u>
Jan M Yarrison-Rice	Miami University Oxford Campus	Department of Physics	2	<u>1100489, 110</u>	<u>5121</u>
Gregory J Salamo	University of Arkansas	Department of Physics	2	<u>1138248, 100</u>	<u>8107</u>
Myung S Jhon	Carnegie-Mellon University	Chemical Engineering	2	<u>1020137, 112</u>	3627
Pallab K Bhattacharya	University of Michigan Ann Arbor	Electrical Engineering & Computer Sci.	2	<u>1120923, 096</u>	8346
Howard E Jackson	University of Cincinnati Main Campus	Department of Physics	2	<u>1100489, 110</u>	5362
Thomas R Bieler	Michigan State University	Chemical Engineering and Materials Sci.	2	<u>1006656, 110</u>	<u>8211</u>
Leigh M Smith	University of Cincinnati Main Campus	Department of Physics, ML-11	2	<u>1100489, 110</u>	5362
Naomi J Halas	William Marsh Rice University	Electrical & Computer Engineering	2	<u>0959343, 104</u>	0478
Ronald S Besser	Stevens Institute of Technology	Chemical Engineering and Materials Scien	2	<u>1040007, 113</u>	<u>8244</u>
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Researchers by State

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John	W Morris	University of California-Berkeley	Material Science and Engineering	1	<u>1105081</u>	•				
Rona Scatt	ld O tergood	North Carolina State University	Materials Science & Engineering	1	<u>1005677</u>	•				
Willia Gerb	m W erich	University of Minnesota-Twin Cities	Chemical Engr & Materials Science	1	<u>0946337</u>	Ψ	in the second se			
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							. New Jersey	10		
Tsu-V	Vei Chou	University of Delaware	Mechanical Engineering	1	<u>1138182</u>	•	Wisconsin	10		
Robe	rto D Merlin	University of Michigan Ann Arbor	Department of Physics	1	<u>1120923</u>	▶				
Scott	t E Jonnson	University of Maine	Earth Sciences	1	1118/86	P	- Florida	10		

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John W Morr	ris I	University of California-Berkeley	Material Scien	ce and Engineer	ing	1	1105081	•				
Ronald O Scattergood	l E	North Carolina State University	Materials Scie	nce & Engineerin	ıg	1	<u>1005677</u>	•				
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Approach: automatically capture data about the conduct of science – inputs, outputs and the connections between the two



## What patents have been granted to <u>NSF funded researchers</u>

National Science Board

Office of the Inspector General

Directorate for Biological Sciences

Office of the Assistant Director (NSB)

Office of the Assistant Director (OIG)

Division of Molecular & Cellular Biosciences (MCB)

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## Drilling down into details

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Mirkin, et al.				
Triangular nano	oframes 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.				
Inventors:	Mirkin; Chad A. (Wilmette, IL), Metraux; Gabriella (Evanston, IL), Cao; Yunwei (Gainesville, FL), Jin; Rongchao (Evanston, IL)			
Assignee:	Northwestern University (Chicago, IL)			
Appl. No.:	11/786,172			
Filed:	April 11, 2007			
	Related U.S. Patent Documents			
	Application Number	Filing Date	Patent Num	ıber <u>Issue</u>
	10801976	Mar., 2004	7252698	3
	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



## 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







## **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?