THE FINANCING AND ALLOCATION OF RESEARCH: DIRECTIONS, INDICATORS AND INCENTIVES

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Overview

- Motivation
- Conceptual Framework
- Empirical Framework
- Directions, Indications and Incentives
- Next steps

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- Motivation
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Key questions

EDITORIAL

Wanted: Better Benchmarks

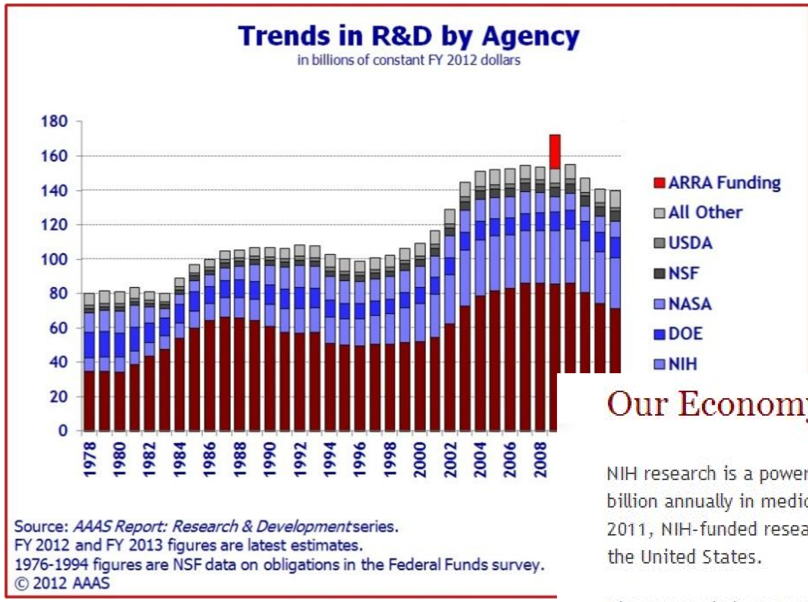
How much should a nation spend on science? What kind of science? How much from private versus public sectors? Does demand for funding by potential science performers imply a shortage of funding or a surfeit of performers?......A new "science of science policy" is emerging, and it may offer more compelling guidance for policy decisions and for more credible advocacy

H

All
as key
greater
produc
most effective in the rapidly changing global environment for science. Here, ideas diverge.

Take the issue of the technical workforce. Sharply differing opinions exist regarding the production of U.S. scientists to meet possible impending shortages.* The differences turn on the interpretation of "benchmark" data regarding the numbers of degree holders produced in the United States and other countries, particularly China and India. In the latter countries, the rates of growth in the numbers of scientists are high, although actual numbers are small relative to those in the United States. Advocates for increased production of U.S. scientists point to our low graduation rates, whereas critics emphasize limited short-term job opportunities for graduates and postdocs. Resolution of this issue requires a broader understanding of socioeconomic factors in a number of nations that would allow us to attach probabilities to different future scenarios. Optimal strategies for large mature economies such as that of the United States will doubtless differ from those for smaller or developing economies. Here, as elsewhere in policy debates,

We spend a lot



Source: *AAAS Report: Research & Development* series.
FY 2012 and FY 2013 figures are latest estimates.
1976-1994 figures are NSF data on obligations in the Federal Funds survey.
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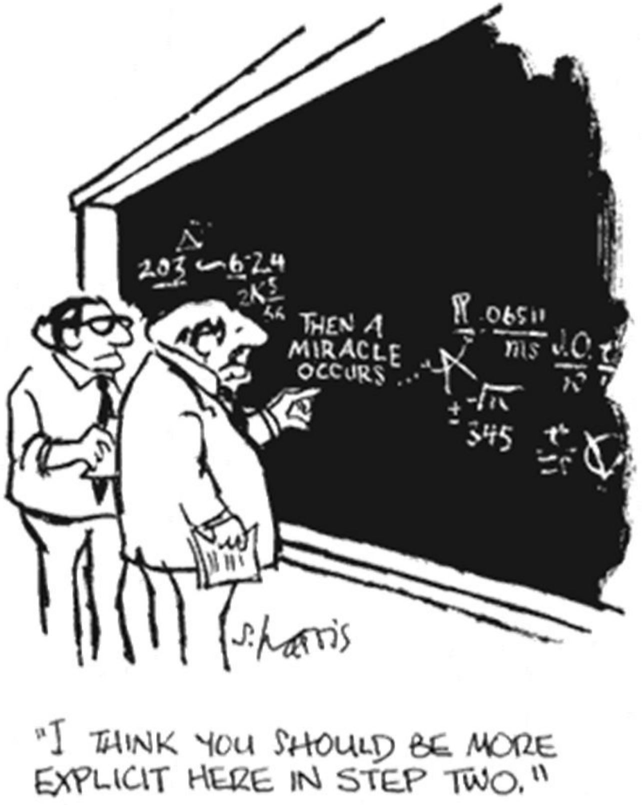
Our Economy

NIH research is a powerful economic engine, investing more than $31 billion annually in medical research for the American people. In fiscal ye 2011, NIH-funded research supported an estimated 432,000 jobs all acro the United States.

The economic impact of NIH does not end there. It has been estimated that every $1 of NIH funding generates about $2.21 in local economic growth. Also, discoveries arising from NIH-funded research serve as a foundation for the entire U.S. biomedical industry. Long considered the world's leader in innovation, that vital sector exports an estimated $90 billion in good and services annually and employs 1 million U.S. citizens with wages totaling an estimated $84 billion.

Consider the economic payoff of just one NIH-supported research initiative: the successful effort to read all the letters in the human DNA instruction book. The U.S. government's $4 billion investment in the Human Genome Project spurred an estimated $796 billion in economic growth from 2000-2010—a 141-fold return on investment, after adjustin for inflation.

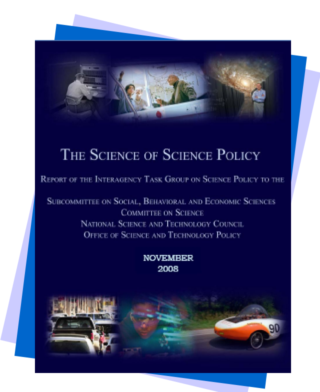


Note…the data don’t exist

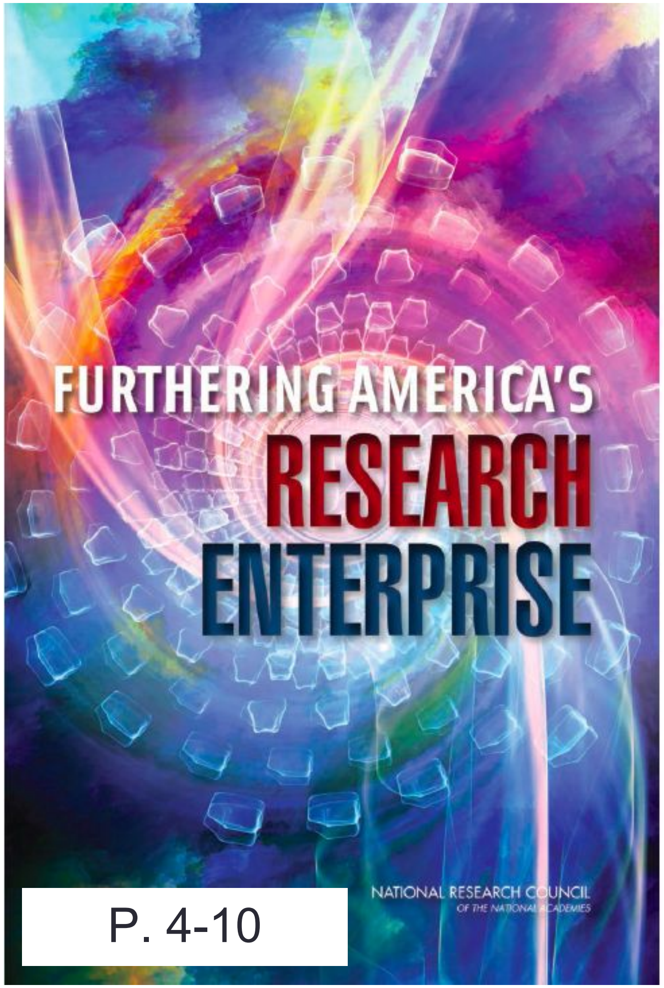
The ITG undertook a literature review to determine the state of the science to date. A questionnaire was also circulated to Federal agencies to ascertain what methods are currently in use for programmatic investment decision making, as well as to ask what tools and resources are needed by Federal agencies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



An Opportunity



P. 4-10

. . . STAR METRICS represents a valuable step toward developing detailed, broadly accessible and nationally representative data that would allow systematic and scientific analysis of the organization, productivity, and at least some of the effects of federally funded research [but] . .

1. . . . STAR METRICS data are largely inacessible . . .
2. . . . data collection could usefully be expanded to include more universities and other performers . . .
3. . . . STAR METRICS data would be more useful if steps were taken to ensure the data can be flexibly linked to other data sources [such as] those maintained by the federal statistical and science agencies . . . as well as proprietary data sources . . . Creating a robust and linkable dataset may require the addition of individual and organizational identifiers.

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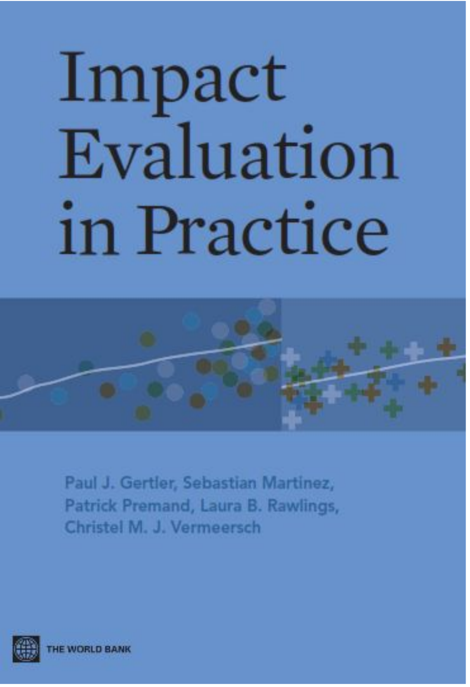
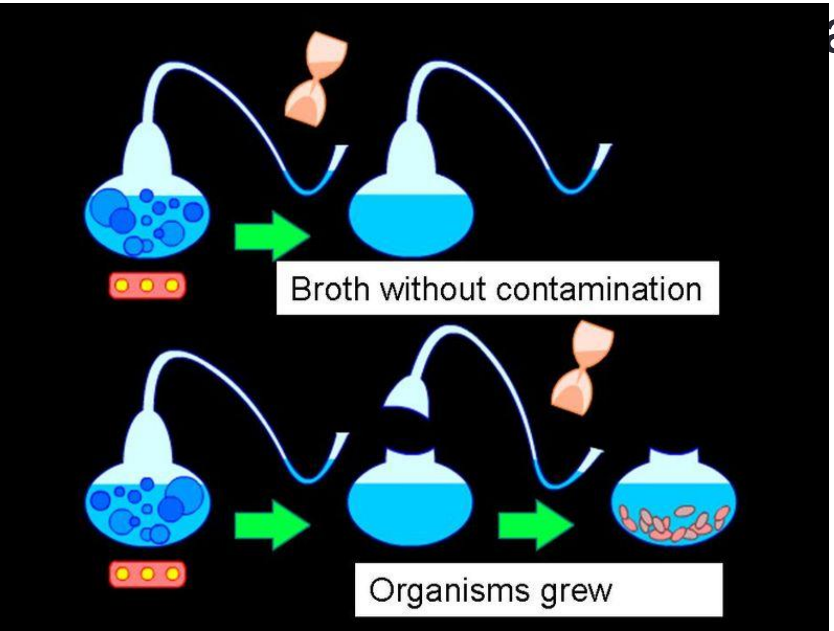


Major use: Evaluation

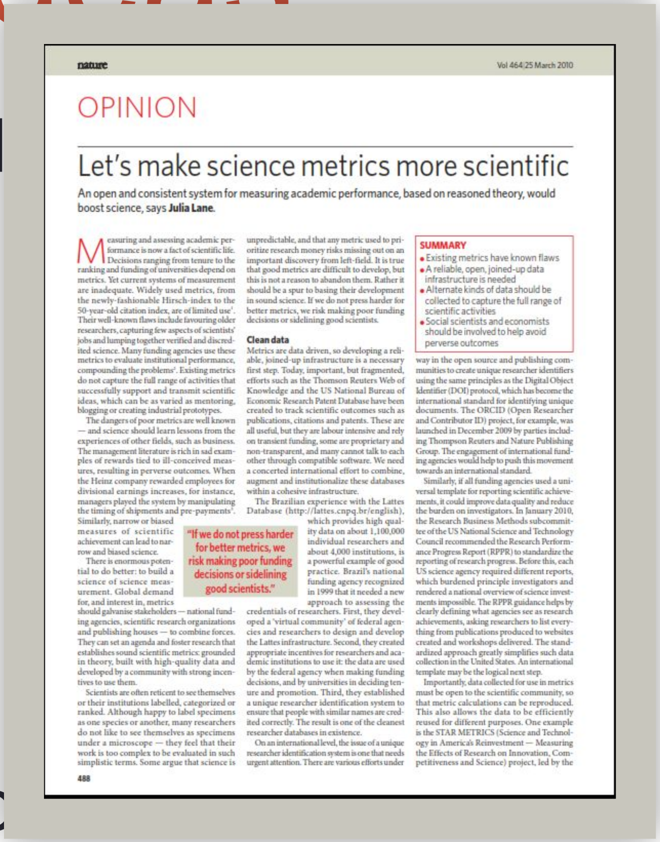
- What is the impact or causal effect of a program on outcome of interest?
- Is a given program effective compared to the absence of the program?
- When a program can be implemented in
ays, which one is the most



A conceptual framework

Core outcome is ideas

- Goal of project/firm: to create and scientific ideas and push for their other scientists, policy-makers or
- Behavioral Framework; Ideas are workers in a variety of potentially ways, and emails
- Behavioral Framework: Social networks/collaboration are a majo whereby ideas are transmitted



nature Vol 464|25 March 2010

OPINION

Let's make science metrics more scientific

An open and consistent system for measuring academic performance, based on reasoned theory, would boost science, says **Julia Lane**.

Measuring and assessing academic performance is now a fact of scientific life. Decisions ranging from tenure to the ranking and funding of universities depend on metrics. Yet current systems of measurement are inadequate. Widely used metrics, from the newly-fashionable Hirsch-index to the 50-year-old citation index, are of limited use[1]. Their well-known flaws include favouring older researchers, capturing few aspects of scientists' jobs and lumping together verified and discredited science. Many funding agencies use these metrics to evaluate institutional performance, compounding the problems[2]. Existing metrics do not capture the full range of activities that successfully support and transmit scientific ideas, which can be as varied as mentoring, blogging or creating industrial prototypes.

The dangers of poor metrics are well known — and science should learn lessons from the experiences of other fields, such as business. The management literature is rich in sad examples of rewards tied to ill-conceived measures, resulting in perverse outcomes. When the Heinz company rewarded employees for divisional earnings increases, for instance, managers played the system by manipulating the timing of shipments and pre-payments[3]. Similarly, narrow or biased measures of scientific achievement can lead to narrow and biased science.

There is enormous potential to do better: to build a science of science measurement. Global demand for, and interest in, metrics should galvanise stakeholders — national funding agencies, scientific research organizations and publishing houses — to combine forces. They can set an agenda and foster research that establishes sound scientific metrics: grounded in theory, built with high-quality data and developed by a community with strong incentives to use them.

Scientists are often reticent to see themselves or their institutions labelled, categorized or ranked. Although happy to label specimens as one species or another, many researchers do not like to see themselves as specimens under a microscope — they feel that their work is too complex to be evaluated in such simplistic terms. Some argue that science is unpredictable, and that any metric used to prioritize research money risks missing out on an important discovery from left-field. It is true that good metrics are difficult to develop, but this is not a reason to abandon them. Rather it should be a spur to basing their development in sound science. If we do not press harder for better metrics, we risk making poor funding decisions or sidelining good scientists.

"If we do not press harder for better metrics, we risk making poor funding decisions or sidelining good scientists."

Clean data

Metrics are data driven, so developing a reliable, joined-up infrastructure is a necessary first step. Today, important, but fragmented, efforts such as the Thomson Reuters Web of Knowledge and the US National Bureau of Economic Research Patent Database have been created to track scientific outcomes such as publications, citations and patents. These are all useful, but they are labour intensive and rely on transient funding, some are proprietary and non-transparent, and many cannot talk to each other through compatible software. We need a concerted international effort to combine, augment and institutionalize these databases within a cohesive infrastructure.

The Brazilian experience with the Lattes Database (http://lattes.cnpq.br/english), which provides high quality data on about 1,100,000 individual researchers and about 4,000 institutions, is a powerful example of good practice. Brazil's national funding agency recognized in 1999 that it needed a new approach to assessing the credentials of researchers. First, they developed a 'virtual community' of federal agencies and researchers to design and develop the Lattes infrastructure. Second, they created appropriate incentives for researchers and academic institutions to use it: the data are used by the federal agency when making funding decisions, and by universities in deciding tenure and promotion. Third, they established a unique researcher identification system to ensure that people with similar names are credited correctly. The result is one of the cleanest researcher databases in existence.

On an international level, the issue of a unique researcher identification system is one that needs urgent attention. There are various efforts under way in the open source and publishing communities to create unique researcher identifiers using the same principles as the Digital Object Identifier (DOI) protocol, which has become the international standard for identifying unique documents. The ORCID (Open Researcher and Contributor ID) project, for example, was launched in December 2009 by parties including Thompson Reuters and Nature Publishing Group. The engagement of international funding agencies would help to push this movement towards an international standard.

Similarly, if all funding agencies used a universal template for reporting scientific achievements, it could improve data quality and reduce the burden on investigators. In January 2010, the Research Business Methods subcommittee of the US National Science and Technology Council recommended the Research Performance Progress Report (RPPR) to standardize the reporting of research progress. Before this, each US science agency required different reports, which burdened principle investigators and rendered a national overview of science investments impossible. The RPPR guidance helps by clearly defining what agencies see as research achievements, asking researchers to list everything from publications produced to websites created and workshops delivered. The standardized approach greatly simplifies such data collection in the United States. An international template may be the logical next step.

Importantly, data collected for use in metrics must be open to the scientific community, so that metric calculations can be reproduced. This also allows the data to be efficiently reused for different purposes. One example is the STAR METRICS (Science and Technology in America's Reinvestment — Measuring the Effects of Research on Innovation, Competitiveness and Science) project, led by the

SUMMARY
- Existing metrics have known flaws
- A reliable, open, joined-up data infrastructure is needed
- Alternate kinds of data should be collected to capture the full range of scientific activities
- Social scientists and economists should be involved to help avoid perverse outcomes

A Conceptual Framework

(1) $Y_{it}^{(1)} = Y_{it}^{(2)}\alpha + X_{it}^{(1)}\lambda + \varepsilon_{it}$

(2) $Y_{it}^{(2)} = Z_{it}\beta + X_{it}^{(2)}\mu + \eta_{it}$,

$Y^{(1)}$ output variables

$Y^{(2)}$team composition variables

Both are determined by a set of control variables $X^{(1)}$ and $X^{(2)}$ that can overlap and be truly exogenous or predetermined, A variable of key interest in Z is funding investment.

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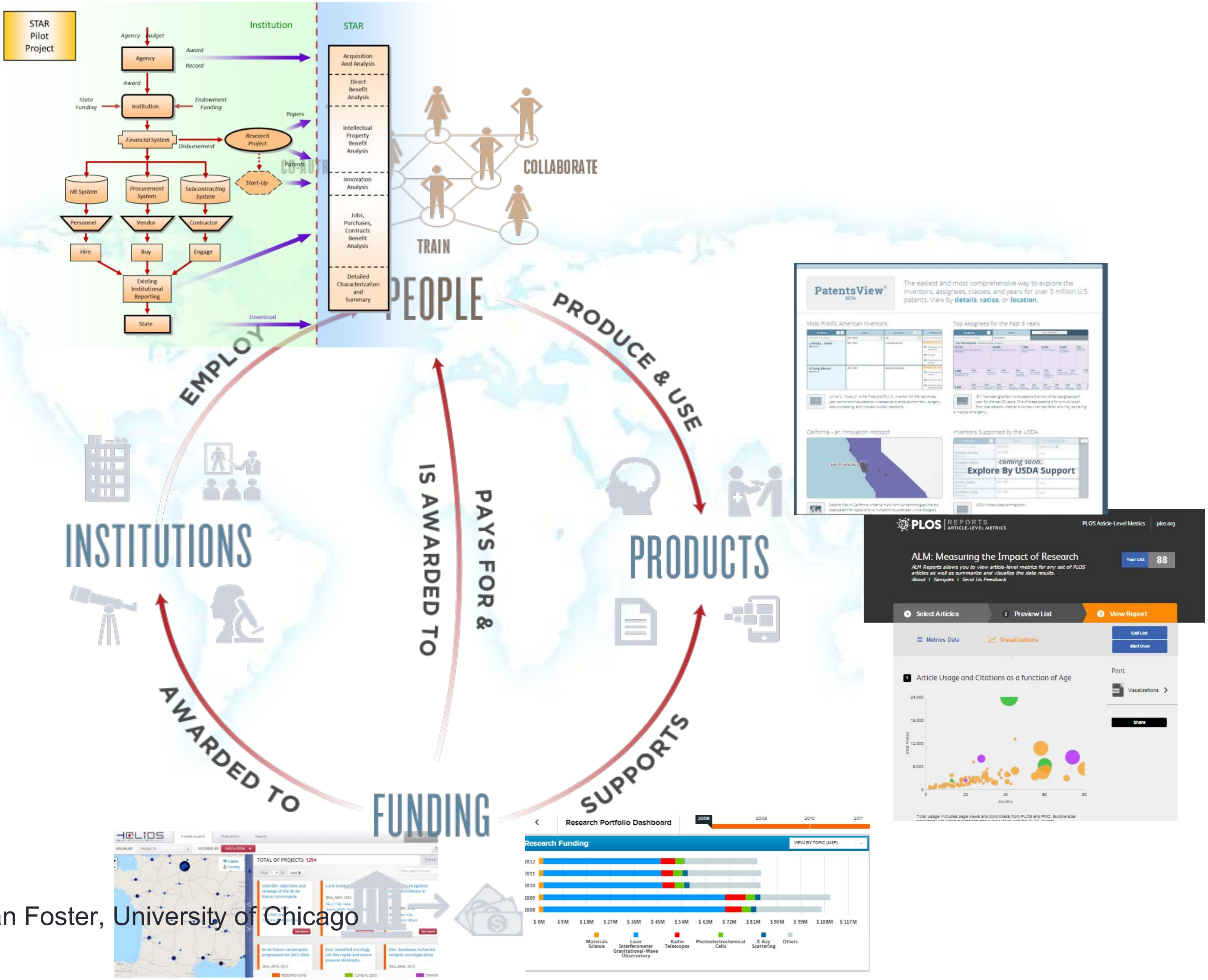
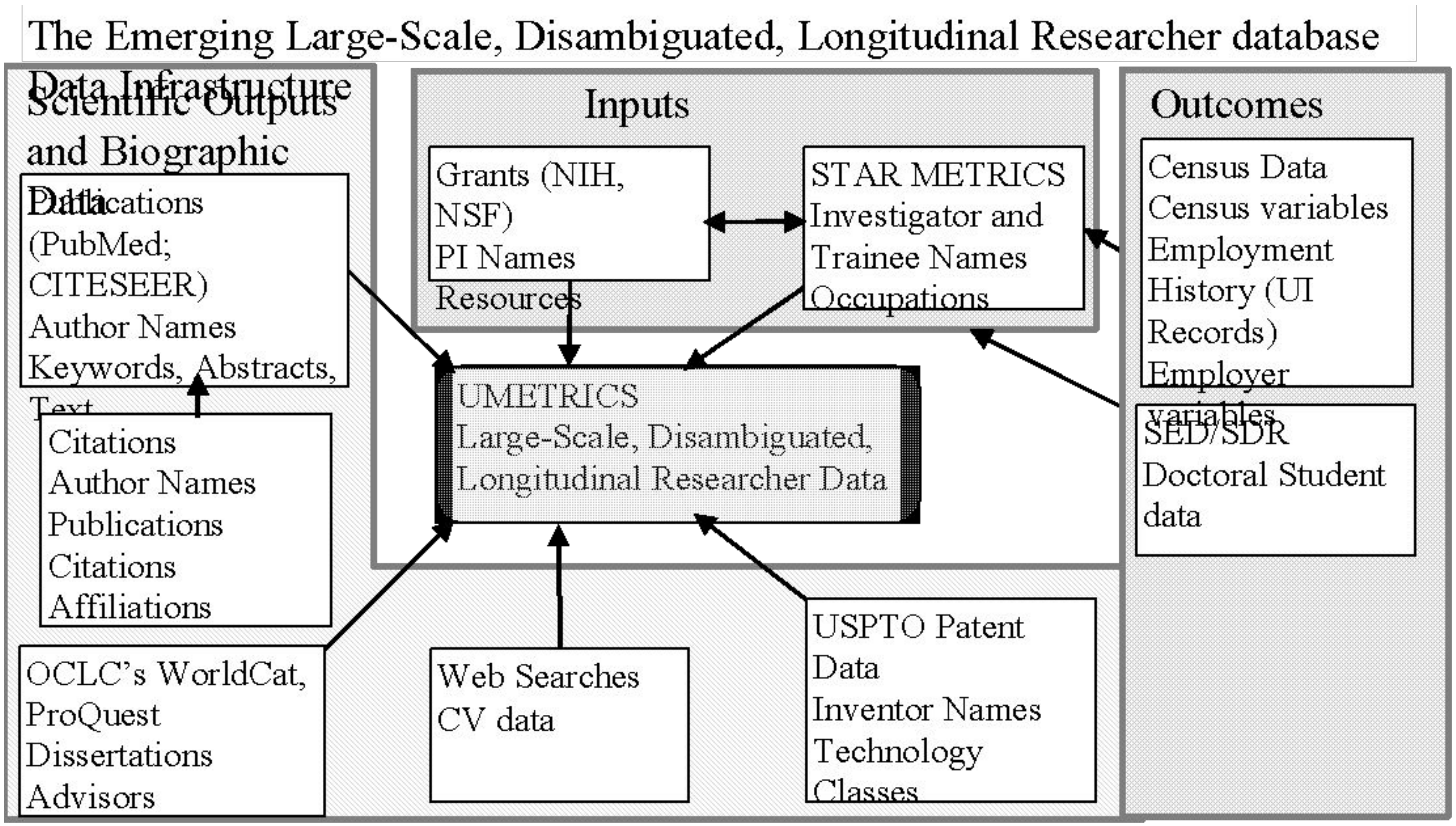
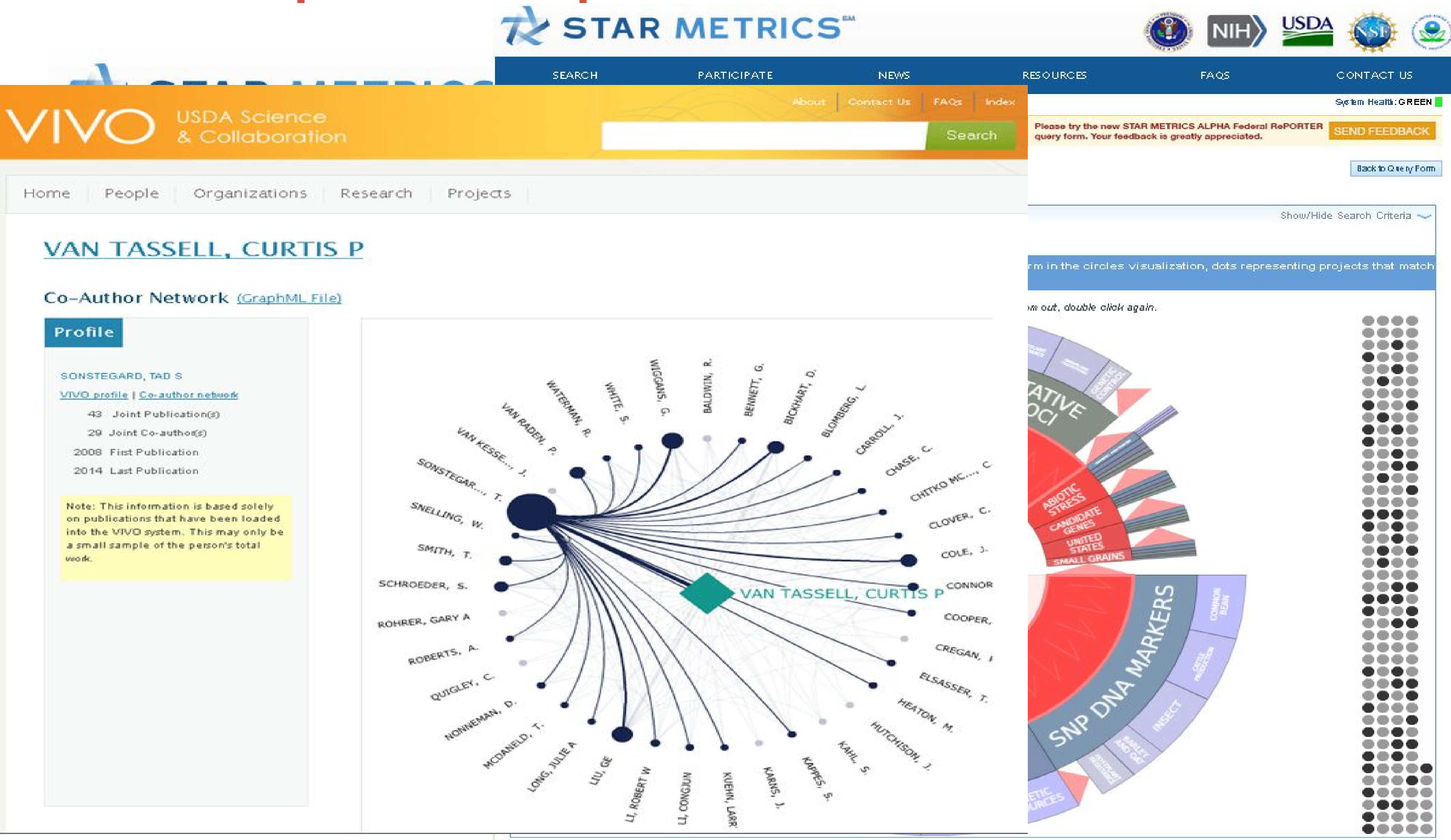
The Empirical Framework



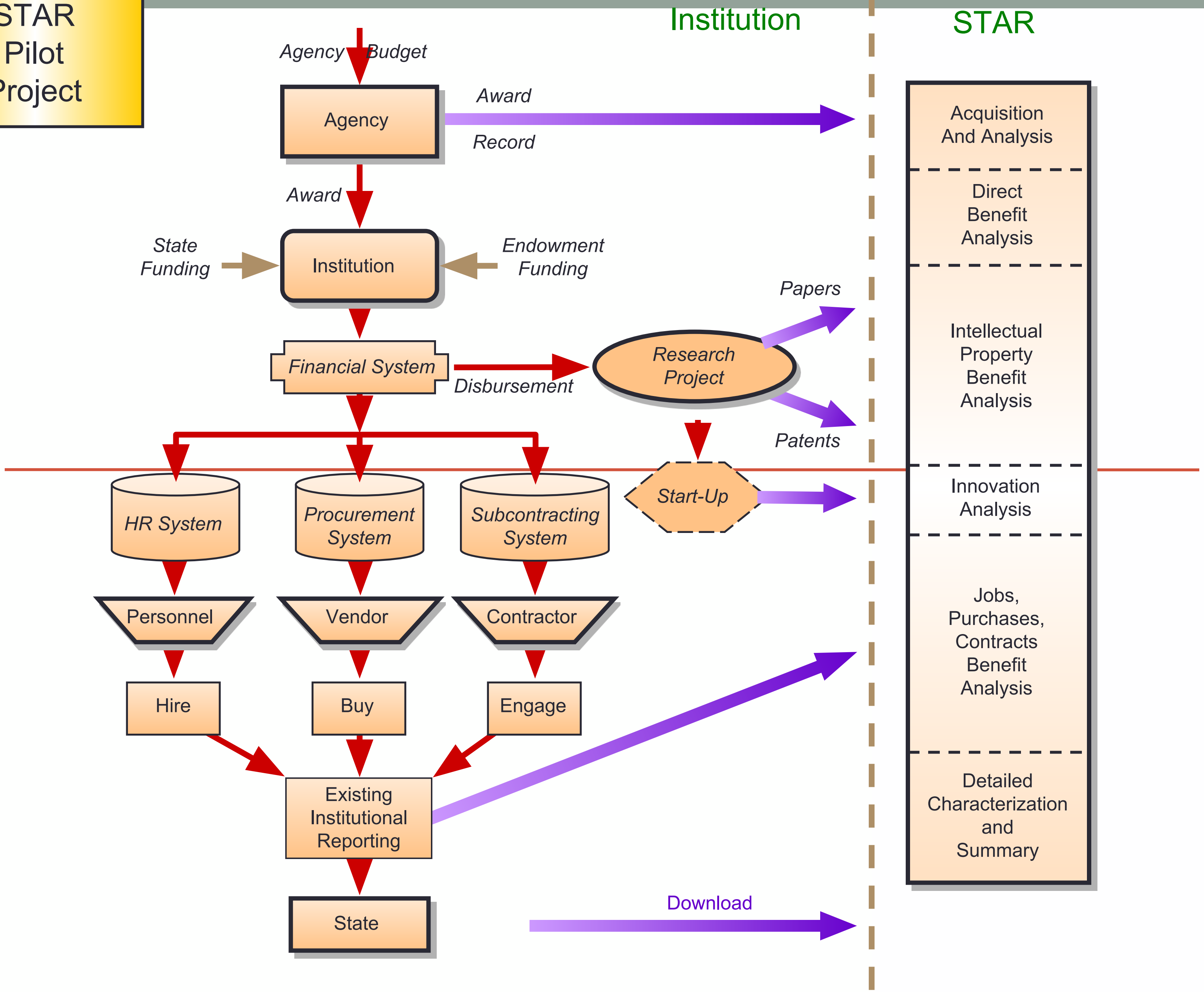
Source: Ian Foster, University of Chicago


The Emerging Large-Scale, Disambiguated, Longitudinal Researcher database
Data Infrastructure
Scientific Outputs and Biographic Data
Publications (PubMed; CITESEER) Author Names Keywords, Abstracts, Text
Citations Author Names Publications Citations Affiliations
OCLC's WorldCat, ProQuest Dissertations Advisors
Inputs
Grants (NIH, NSF) PI Names Resources
STAR METRICS Investigator and Trainee Names Occupations
UMETRICS Large-Scale, Disambiguated, Longitudinal Researcher Data
Web Searches CV data
USPTO Patent Data Inventor Names Technology Classes
Outcomes
Census Data Census variables Employment History (UI Records) Employer variables
SED/SDR Doctoral Student data

Example of input



STAR Pilot Project



Example of Output – Census Data

- Business Register (BR)
  - Universe of U.S. non-agricultural businesses and the source of data from which all other economic data are ultimately created
  - Key data provided: industry classification, geographic data, employment measures
- Longitudinal Business Database (LBD)
  - Universe of employer businesses, unique establishments, the LBD covers all industries and all U.S. States
  - Key data provided: industry classification, geographic data, employment measures, payroll, firm age
- Integrated Longitudinal Business Database (iLBD)
  - Universe of non-employer businesses with links to employer universe
  - iLBD records are identified by either PIKs or EINS
  - Key data provided: industry classification, gross receipts, geographic data

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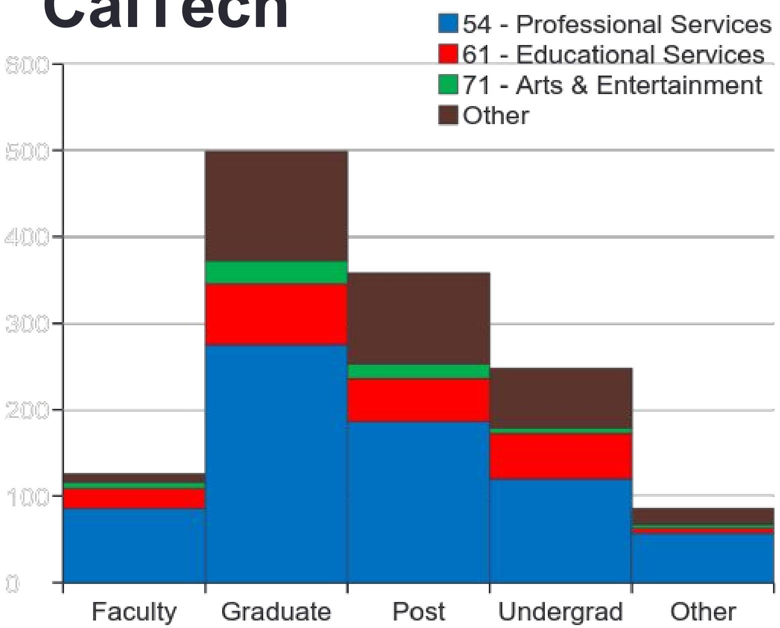
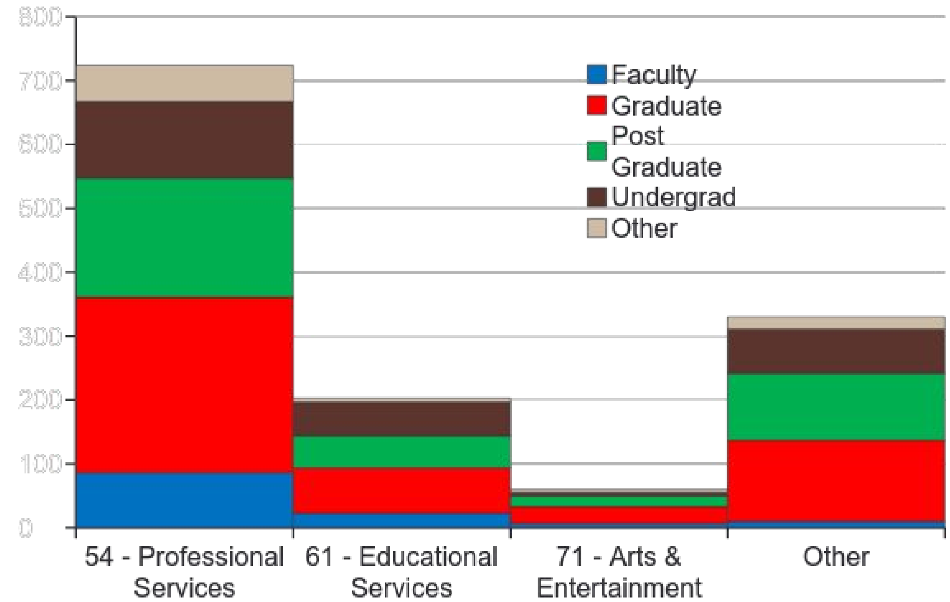
Directions: Some Initial Results

Joint Frequency of NAICS and Last Occupation at CalTech

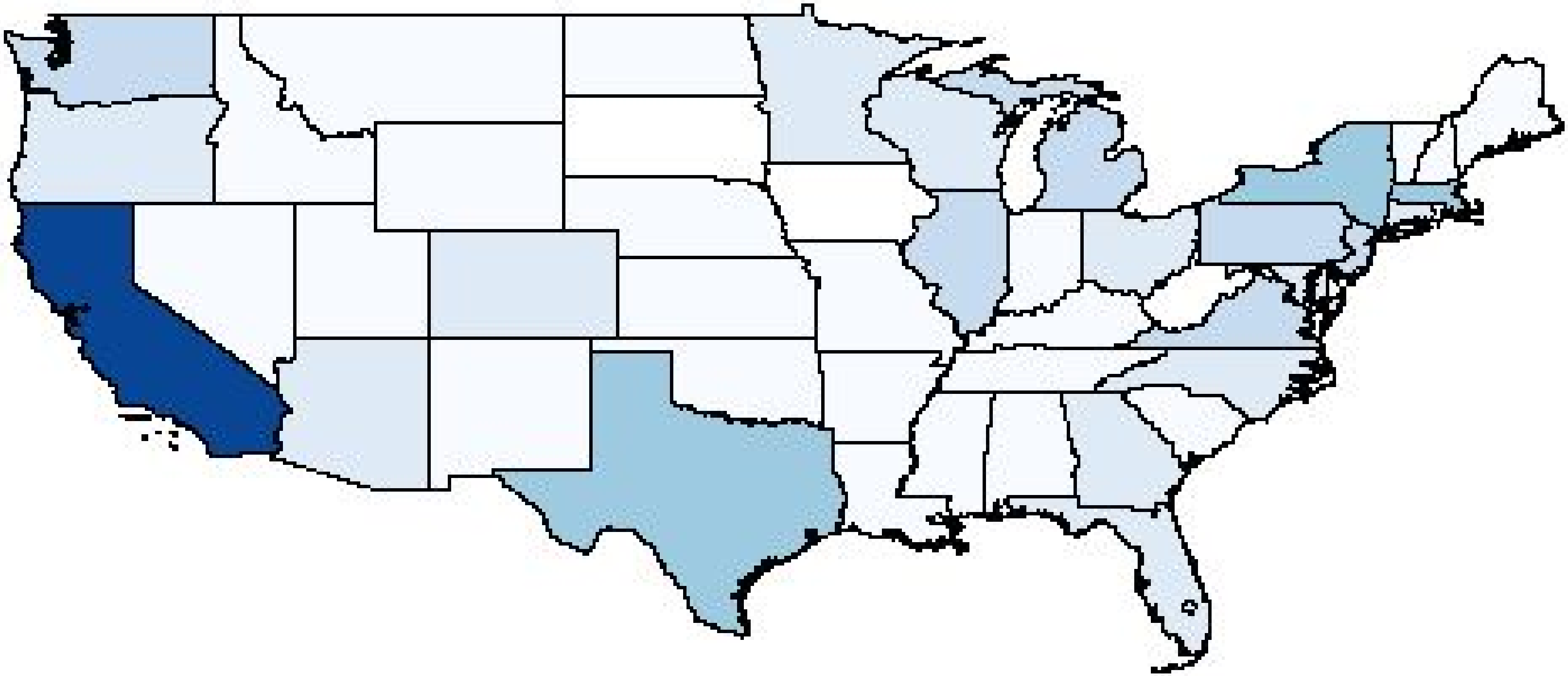




- Majority of Caltech Employees are Graduates and Post Graduates who start Consulting companies

Directions: Some Initial Results

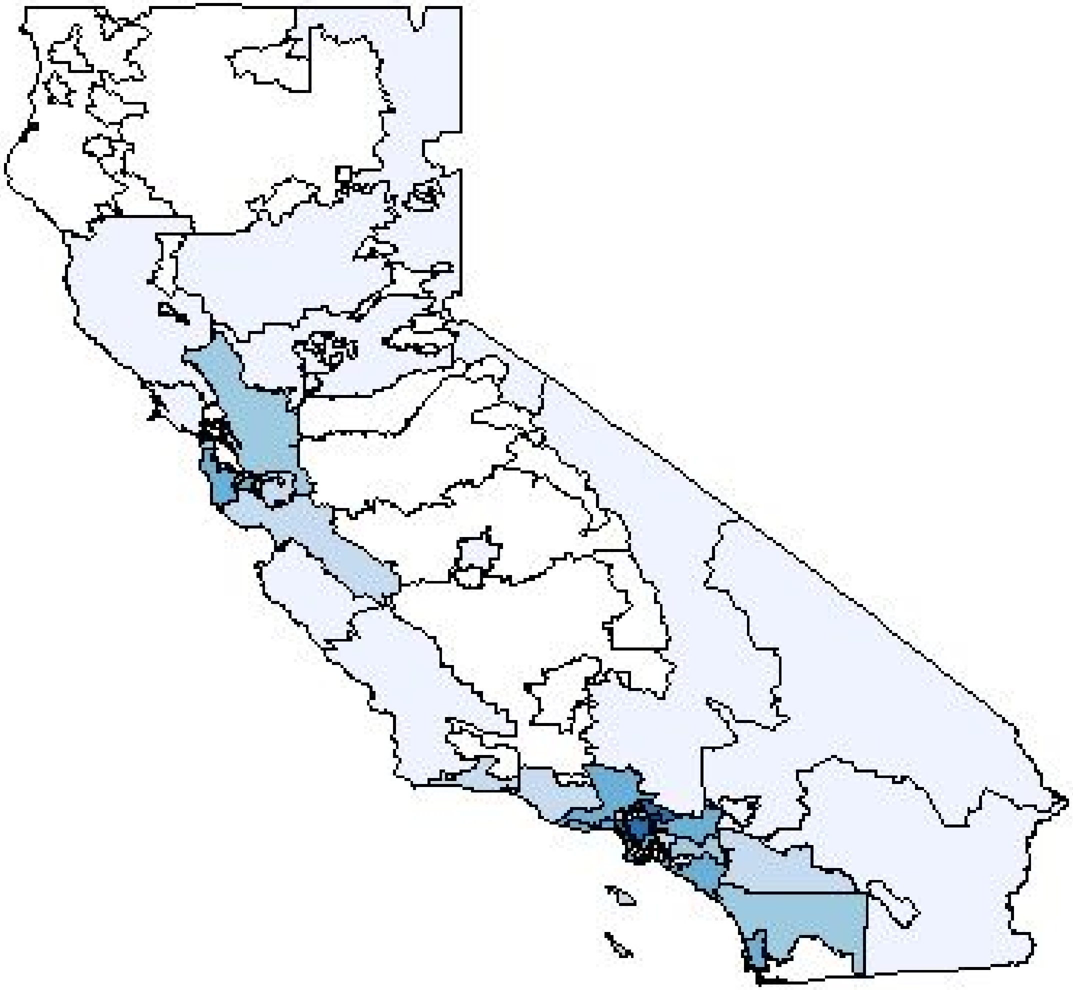
Map of where Caltech employees go by State



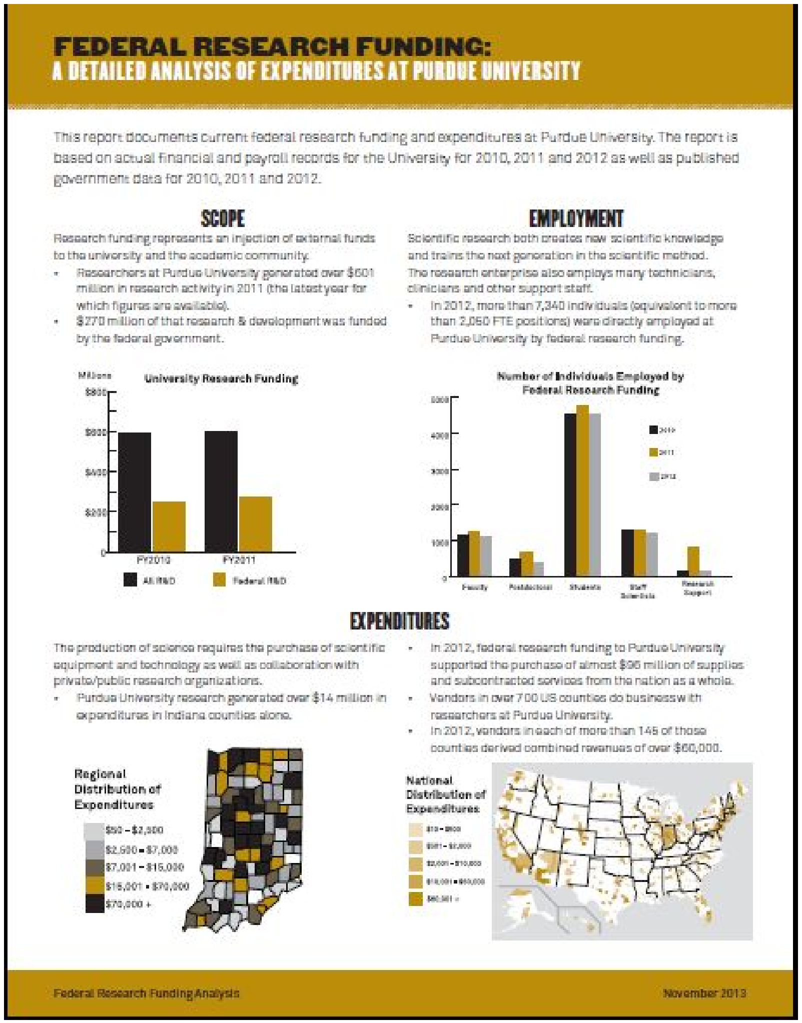
- Most Caltech employees end up staying in California

Directions: Some Initial Results

Caltech employees are concentrated in the Los Angeles/Southern California area and around San Francisco



Indicators: Aggregate information



FEDERAL RESEARCH FUNDING:
A DETAILED ANALYSIS OF EXPENDITURES AT PURDUE UNIVERSITY

This report documents current federal research funding and expenditures at Purdue University. The report is based on actual financial and payroll records for the University for 2010, 2011 and 2012 as well as published government data for 2010, 2011 and 2012.

SCOPE

Research funding represents an injection of external funds to the university and the academic community.

- Researchers at Purdue University generated over $601 million in research activity in 2011 (the latest year for which figures are available).
- $270 million of that research & development was funded by the federal government.

EMPLOYMENT

Scientific research both creates new scientific knowledge and trains the next generation in the scientific method. The research enterprise also employs many technicians, clinicians and other support staff.

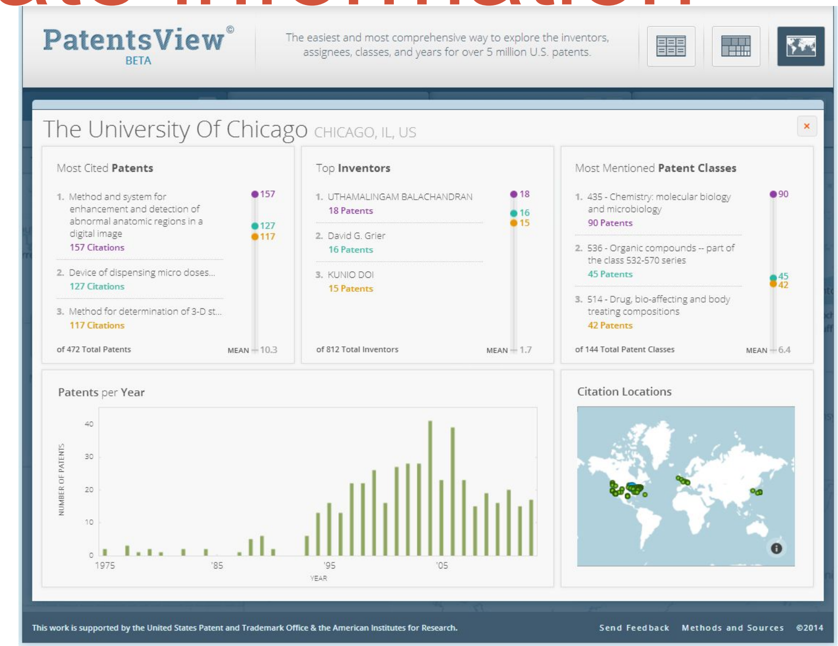
- In 2012, more than 7,340 individuals (equivalent to more than 2,060 FTE positions) were directly employed at Purdue University by federal research funding.

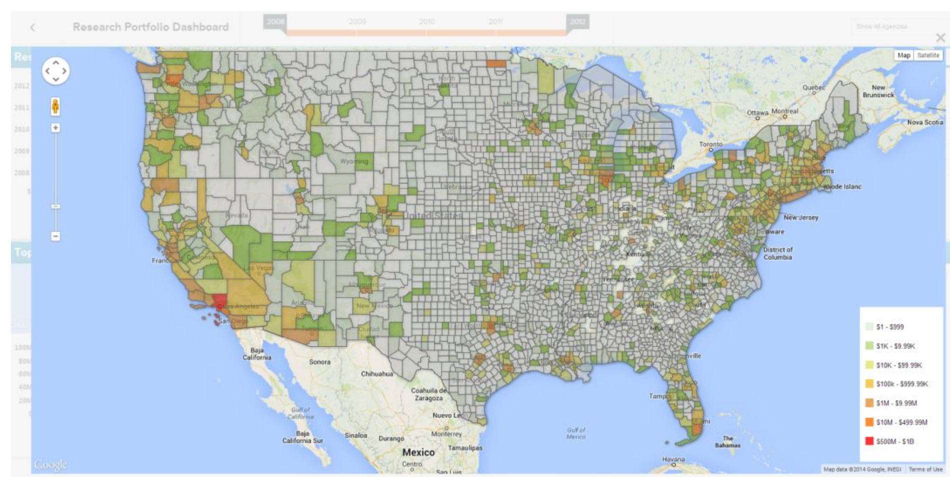
EXPENDITURES

The production of science requires the purchase of scientific equipment and technology as well as collaboration with private/public research organizations.

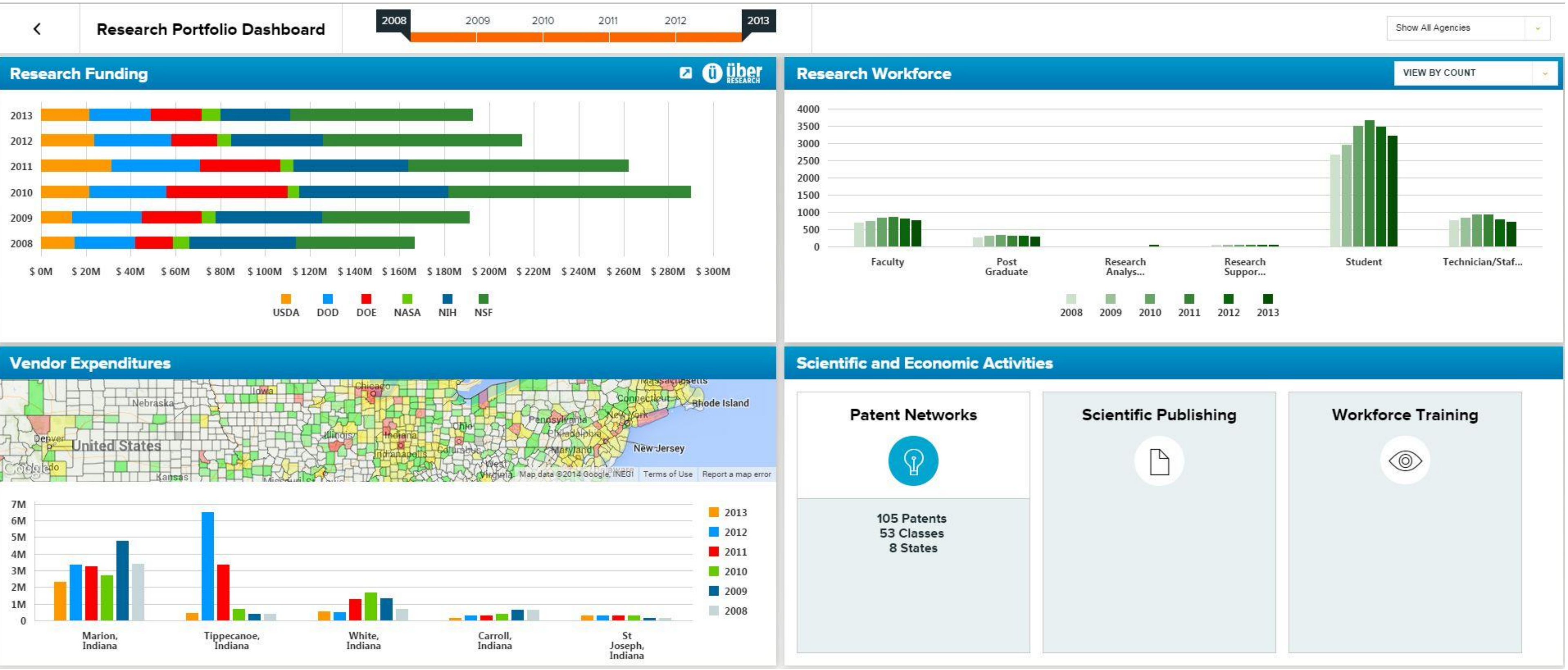
- Purdue University research generated over $14 million in expenditures in Indiana counties alone.
- In 2012, federal research funding to Purdue University supported the purchase of almost $95 million of supplies and subcontracted services from the nation as a whole.
- Vendors in over 700 US counties do business with researchers at Purdue University.
- In 2012, vendors in each of more than 145 of those counties derived combined revenues of over $60,000.

Federal Research Funding Analysis
November 2013



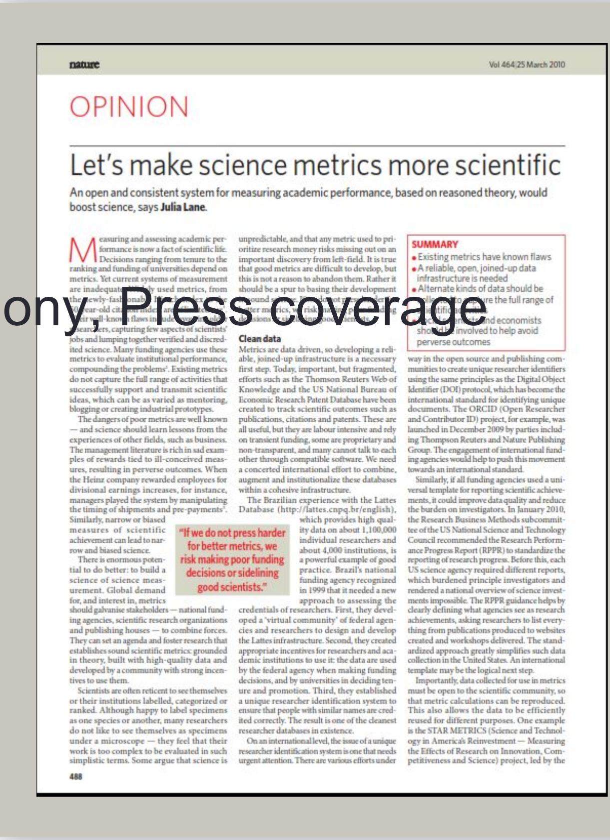


Indicators: Visualizations



Incentives

- People focus => more focus on students
- Reduced Burden => more time on research
- University led => replicable and generalizable
  - 38 researchers have worked with Umetrics data
- Research based => evolving field
  - *Science* Policy Forum, *Research Policy* R&R
  - Economic Reports, Senate Appropriations Testimony, Press coverage
  - 60 Participants in A2 Workshop



nature Vol 464 25 March 2010

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"If we do not press harder for better metrics, we risk making poor funding decisions or sidelining good scientists."

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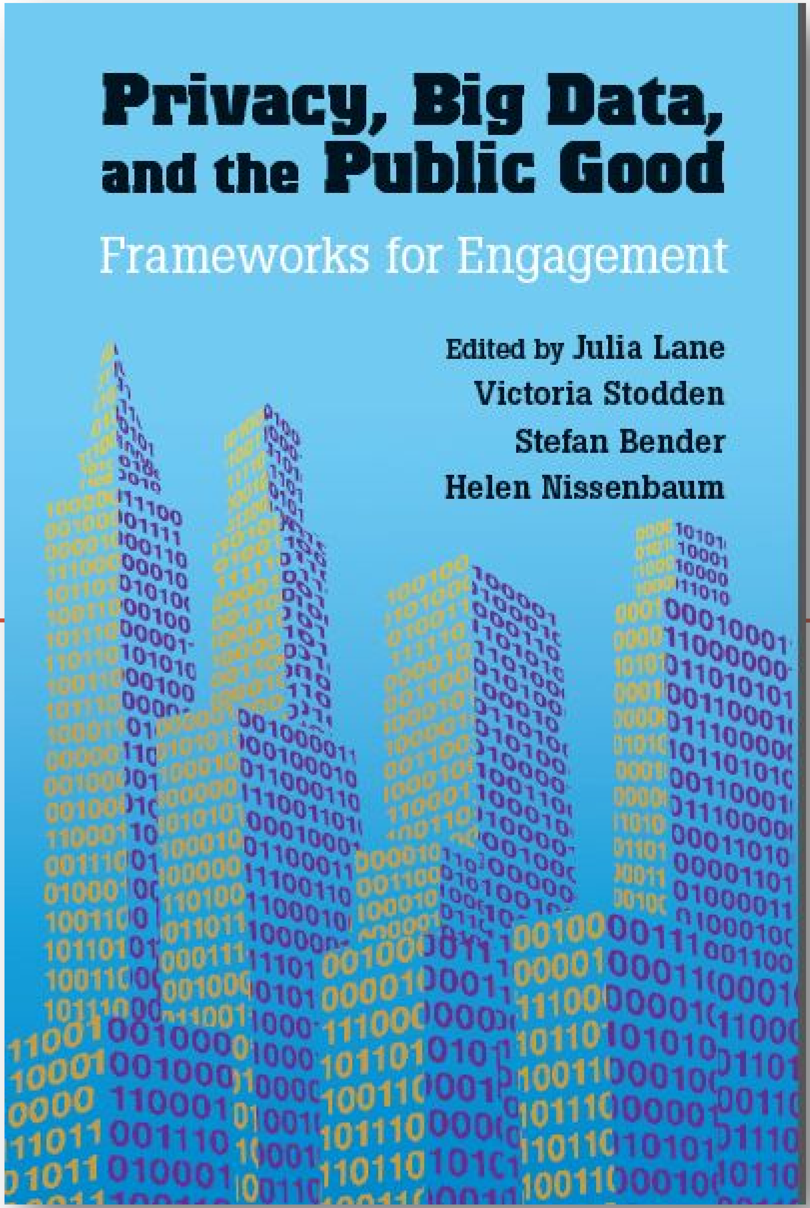
Institute for Research on Innovation and Science

- Federated organization (Core & Nodes) yield:
  - Quick startup that leverages existing resources
  - Synergies at the core facility (Michigan)
  - Expertise, Outreach and Data (AIR/CIC, OSU, CENSUS)
  - Potential to expand the above (Illinois, GA Tech, UMass)
- Stakeholder partnerships yield:
  - Use inspired questions (e.g. CIC VPRs)
  - Data and financial support (CIC, AAU, APLU)

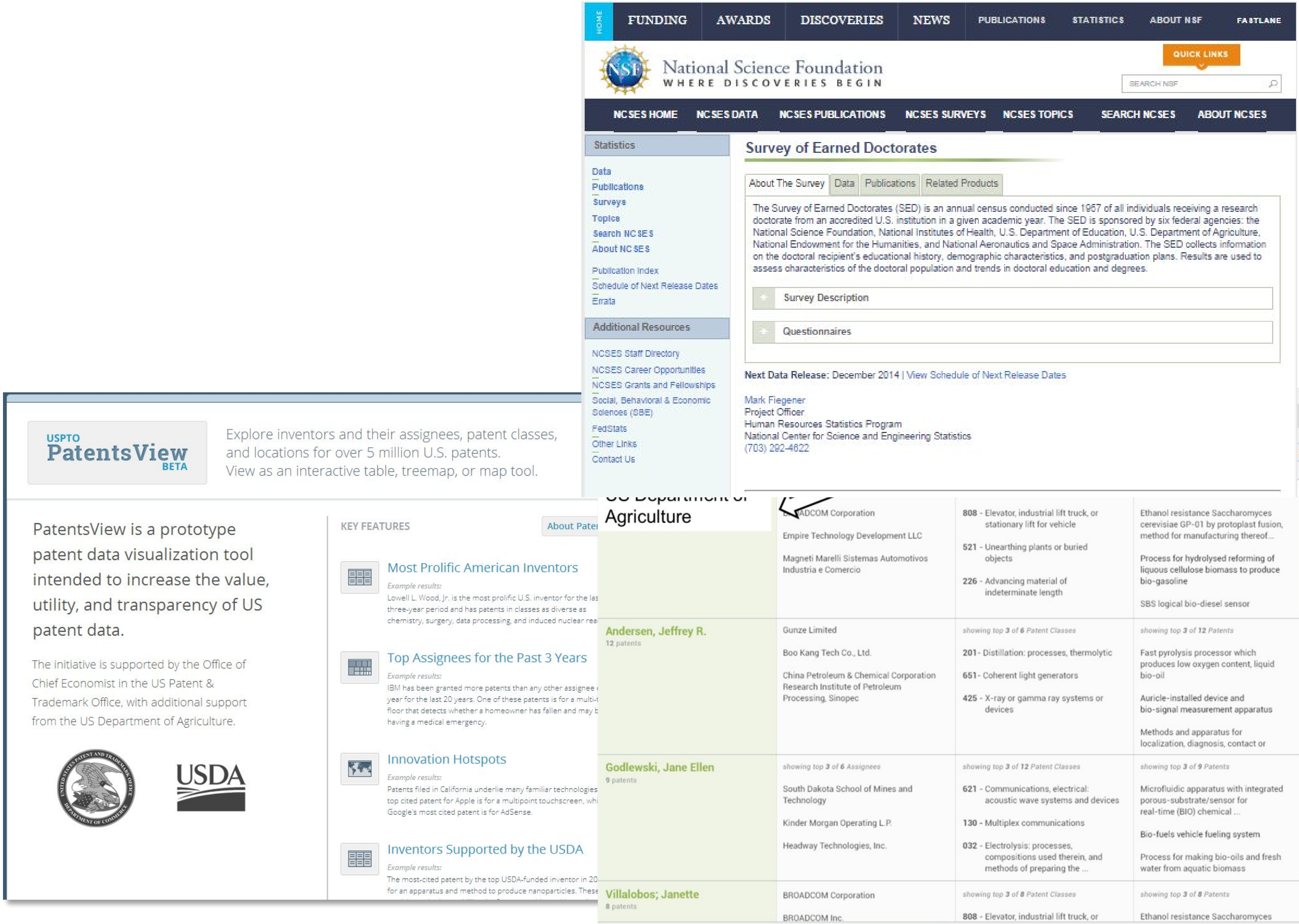


ASA AMERICAN STATISTICAL ASSOCIATION

CUSP CENTER FOR URBAN SCIENCE+PROGRESS

Bundesagentur für Arbeit

Engage with Federal agencies



Engage Internationally

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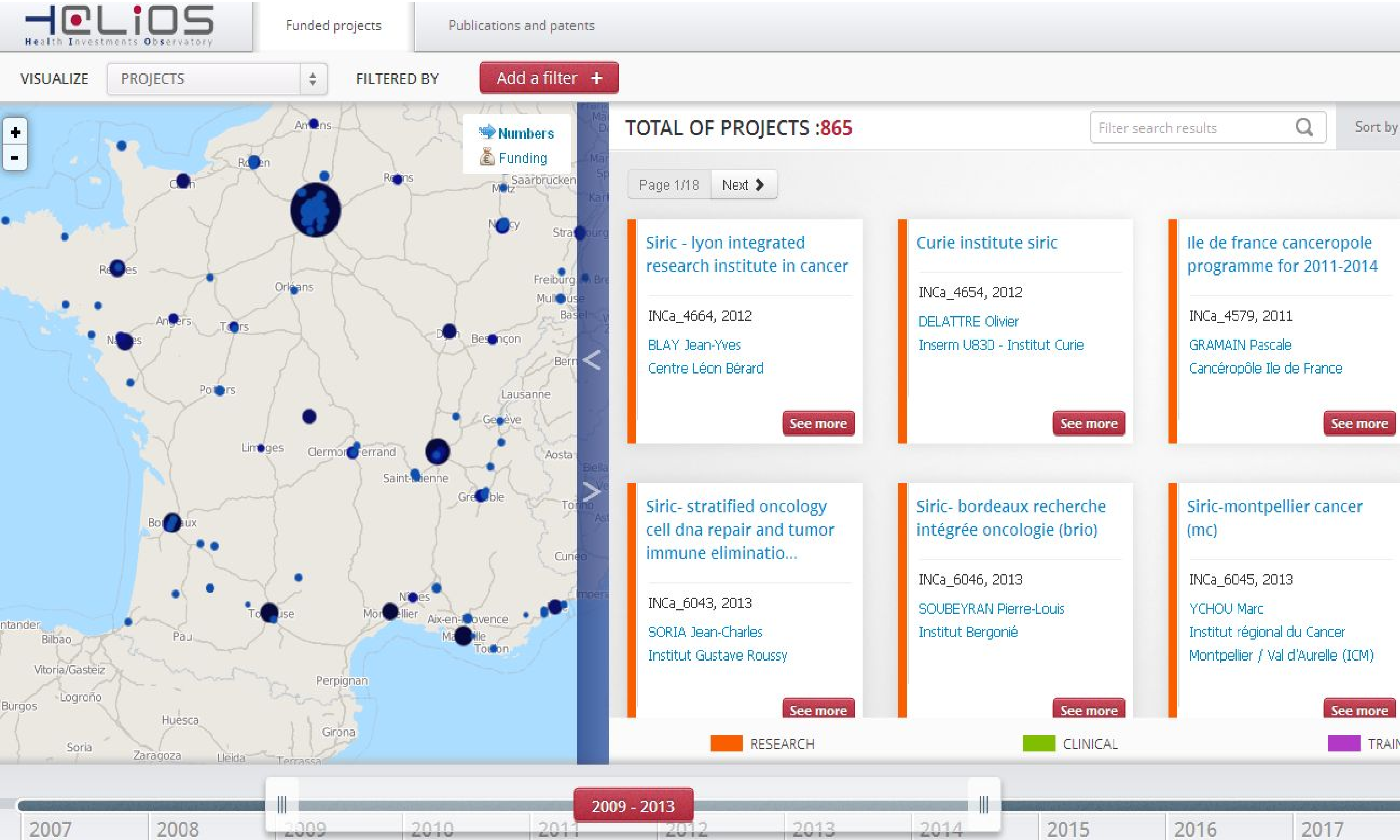

Engage internationally

2013

Empirical Foundations of Science and Innovation Policy

September 16-17, 2013

Ministère de l'Enseignement Supérieur et de la Recherche
25 rue le la Montagne Ste Geneviève
70005 Paris cedex 05

Agenda

September 16, 2013

12:00-12:30	Registration
12:30-1:30	Welcome, Motivation and goals; Introductions - Jacques and Julia
1:30-2:00	Measuring science investments • Overview of the emerging US approach : Bruce Weinberg • Overview of potential ERC approaches Reinhilde Veugelers
2:00-2:30	Initial Findings from STAR METRICS data Presentation by ETOILE team
2:30-3:00	Coffee
3:00-4:00	Group discussion from other teams: • What they are doing (or what they hope to do) • What they found most useful in their approach (or hope to find most useful) Their major challenges (or what they expect to see as their major challenges
4:00-5:00	Describing the results of research: • Output capture (CVs, patents, and people placement) - Markus Perkman, Paul Jensen and Erling Barth
5:15-5:45	Suggestions for practical next steps
5:45-6:30	Drinks
7:00-9:00	Dinner

September 17, 2013

9:00-9:45	Discussion of key issues: • Measuring team structure - Jacques Mairesse and Bruce Weinberg • Topic modeling – Ghislaine Filliatreau and Rebecca Rosen
9:45-10:15	General Discussion
10:15-10:45	Coffee
10:45-11:30	Managing all the data: Research management: the view from three practitioners - David Baker, Laure Haak and Ed Simons
11:30-12:00	General discussion
12:00-12:30	Suggestions for practical next steps
12:30	Adjourn

And a reminder of why

EDITORIAL

Wanted: Better Benchmarks

How much should a nation spend on science? What kind of science? How much from private versus public sectors? Does demand for funding by potential science performers imply a shortage of funding or a surfeit of performers?......A new "science of science policy" is emerging, and it may offer more compelling guidance for policy decisions and for more credible advocacy

H

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most effective in the rapidly changing global environment for science. Here, ideas diverge.

Take the issue of the technical workforce. Sharply differing opinions exist regarding the production of U.S. scientists to meet possible impending shortages.* The differences turn on the interpretation of "benchmark" data regarding the numbers of degree holders produced in the United States and other countries, particularly China and India. In the latter countries, the rates of growth in the numbers of scientists are high, although actual numbers are small relative to those in the United States. Advocates for increased production of U.S. scientists point to our low graduation rates, whereas critics emphasize limited short-term job opportunities for graduates and postdocs. Resolution of this issue requires a broader understanding of socioeconomic factors in a number of nations that would allow us to attach probabilities to different future scenarios. Optimal strategies for large mature economies such as that of the United States will doubtless differ from those for smaller or developing economies. Here, as elsewhere in policy debates, the benchmarks do not speak for themselves.