

MEASURES FOR INNOVATION AND COMPETITIVENESS

STEM

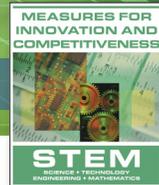
Science | Technology | Engineering | Mathematics

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Table of Contents

Workshop Charter	3
Workshop Program	4
Speaker Bios	6
STEM Workshop Planning Committee	16
With Special Thanks to Our Sponsors	17
Introduction	18
Opening of Workshop	
Presented by Dr. Martin M. Sokoloski, Chair, IEEE-USA Research & Development Policy Committee	20
Keynote Address: STEM Engineering?	
Presented by Professor John Marburger III, University Professor of Physics and Electrical Engineering, Stony Brook University, Stony Brook, New York	21
Measuring and Evaluating the STEM Enterprise: Perspectives from the Obama Administration	
Presented by Mr. Kei Koizumi, Assistant Director for Federal R&D, Office of Science and Technology Policy, Executive Office of the President, Washington, D.C.	25
STEM: Individual, Local, and Global Flows and Activity Patterns	
Presented by Prof. Katy Börner, Victor H. Yngve Professor of Information Science and Director of the Information Visualization Lab & Cyberinfrastructure for Network Science Center, School of Library and Information Science Indiana University	34
Powerful Numbers or a Short Reflection on Influential Analyses in the History of Science of Science Policy	
Presented by Dr. Diana Hicks	68
Measuring and Evaluating the STEM Enterprise Outcomes and Productivity	
Presented by Dr. James Hosek, Director, Forces and Resources Policy Center RAND National Security Research Division ...	81
R&D Activities in the U.S. Department of Defense & Technology Priorities	
Presented by Mr. Robert W. Baker, Deputy Director, Plans & Programs Office of the Director, Defense Research and Engineering	98
The Census Bureau’s New American Community Survey Enables Major Improvements in the Coverage, Content, Timeliness, and Accessibility of STEM Workforce Data	
Presented by Mr. Richard Ellis, Ellis Research Services.....	119
Towards Data Driven STEM Policymaking	
Presented by Dr. Ron Hira, Associate Professor of Public Policy Rochester Institute of Technology	124
An Overview of Federal Government Innovation Metrics Initiatives & Related Efforts: Why They Matter	
Presented by Mr. Robert S. Boege, J.D., Executive Director, The Alliance for Science & Technology Research in America (ASTRA).....	136
Citation Metrics: Using Citation Analysis of Journal Data to Measure Research Productivity and Impact	
Presented by Ms. Ann Kushmerick, Manager, Research Evaluation and Bibliometric Data, Global Sales Support, Healthcare & Science Business of Thomson Reuters	149
Experiencing Innovation in College Curricula	
Presented by Dr. Ralph W. Wyndrum, President, IEEE-USA Innovation Institute	177
Bring Them In: Improving STEM Recruiting by Working with High School Teachers	
Presented by Dr. David Alan Grier, Associate Professor of International Science and Technology Policy; Associate Dean of International Affairs, George Washington University	189
Workshop Conclusion	192



Workshop Charter

2009 IEEE-USA Workshop on Science, Technology, Engineering and Mathematics Enterprise (STEM): Economics Measures and Indicators

The U.S. science, technology, engineering and mathematics (STEM) enterprise represents the collective research & development (R&D) activities accomplished by the federal, academic and private sectors, and tends to be global in nature. It is the driving force for worldwide economic and social advancement. Policies should be derived from basic incorruptible data and measures to best plan for a healthy and productive enterprise, future economic growth and rapid innovation.

The economic health of the STEM enterprise is based on a number of factors, the first being the workforce. How many STEM workers do we have and what is their unemployment rate? Another factor is where and how much money is put into R&D. For example, should earmarks in any federal agency allotment be counted as part of the R&D budget? What is the true amount within reasonable error margins of the industrial input to the R&D budget? What is the industrial sector's contribution to basic & applied research?

The input for the R&D enterprise is generally considered to be the budget, but what is the output and, more importantly, the outcome? Is bibliometric data reasonable in measuring output, both quantity and quality, or are new data sources needed to quantify output? What data exists to follow interactions among the three STEM enterprise sectors: federal, academic and private, and among different collaborating country sectors? What is the outcome or impact of the R&D investment on society and quality of life? How can we measure and assess the outcome?

Finally, is there or can there be a U.S. entity – federal, for-profit, non-profit, academic – that, empowered to employ the products mentioned above, can create unbiased reports and recommendations for STEM enterprise policy?

The IEEE-USA STEM workshop will be constructed and organized to address and answer these important questions and bring about viable solutions. We believe STEM policy should be based on arguments fully supported by concrete data and proven algorithms.

IEEE-USA advances the public good and promotes the careers and public policy interests of more than 210,000 engineers, scientists and allied professionals who are U.S. members of IEEE. IEEE-USA is part of IEEE, the world's largest technical professional society with 375,000 members in 160 countries. See www.ieeeusa.org.

Workshop Program

- 8:00 AM -9:00 AM** **Registration and Continental Breakfast**
- 9:00 AM-9:10 AM** **Opening of Workshop**
Dr. Martin M. Sokoloski
Chair, IEEE-USA Research & Development Policy Committee
- 9:10 AM-9:40 AM** **Keynote Address: *STEM Engineering?***
Professor Jack Marburger III
University Professor of physics & Electrical Engineering
Stony Brook University
- 9:40 AM-10:10 AM** ***Measuring and Evaluating the STEM Enterprise: Perspectives from the Obama Administration***
Mr. Kei Koizumi
Assistant Director for Federal R&D
Office of Science and Technology Policy
Executive Office of the President
Washington, D.C.
- 10:10 AM -10:40 AM** **Break/Coffee**
- 10:40 AM-11:10 AM** ***STEM: Individual, Local, and Global Flows and Activity Patterns***
Prof. Katy Börner
Victor H. Yngve Professor of Information Science and Director of the Information
Visualization Lab & Cyberinfrastructure for Network Science Center
School of Library and Information Science
Indiana University
- 11:10 AM-11:40 AM** ***Powerful Numbers***
Dr. Diana Hicks
Chair, School of Public Policy
Georgia Institute of Technology
- 11:40 AM-12:10 PM** ***Measuring STEM Enterprise Outcomes and Productivity***
Dr. James Hosek
Director, Forces and Resources Policy Center
RAND National Security Research Division
- 12:10 PM-1:30 PM** **Lunch: *R&D Activities in the U.S. Department of Defense & Technology Priorities***

Mr. Robert W. Baker
Deputy Director, Plans & Programs
Office of the Director
Defense Research and Engineering

- 1:30 PM-2:00 PM** ***The Census Bureau's New American Community Survey Enables Major Improvements in the Coverage, Content, Timeliness, and Accessibility of STEM Workforce Data***
Mr. Richard Ellis
Ellis Research Services
- 2:00 PM-2:30 PM** ***Towards Data Driven STEM Policymaking***
Dr. Ron Hira
Associate Professor of Public Policy
Rochester Institute of Technology
- 2:30 PM-3:00 PM** ***An Overview of Federal Government Innovation Metrics Initiatives & Related Efforts: Why They Matter***
Mr. Robert S. Boege, J.D.
Executive Director, ASTRA, The Alliance for Science &
Technology Research in America
- 3:00 PM-3:30 PM** **Break/Beverages**
- 3:30 PM- 4:00 PM** ***Citation Metrics: Using Citation Analysis of Journal Data to Measure Research Productivity and Impact***
Ms. Ann Kushmerick
Manager, Research Evaluation and Bibliometric Data
Global Sales Support
Healthcare & Science Business of Thomson Reuters
- 4:00 PM-4:30 PM** ***Experiencing Innovation in College Curricula***
Dr. Ralph W. Wyndrum
President, IEEE-USA Innovation Institute
- 4:30 PM-5:00 PM** ***Bring Them In: Improving STEM Recruiting by Working with High School Teachers***

Dr. David Alan Grier
Associate Professor of International Science & Technology Policy; Associate Dean of
International Affairs, Elliott School of International Affairs

George Washington University
- 5:00 PM-5:30 PM** **Conclusion**
- 5:45pm** **Adjourn**

Speaker Bios

MARTIN M. SOKOLOSKI

Dr. Martin M. Sokoloski obtained his B.S. and M.S. degrees from Bucknell University in physics and mathematics, and a Ph.D. in physics from The Catholic University of America. He served an IEEE-USA congressional fellowship in Rep. Rush Holt's office in 2004 and established the Congressional Research & Development Caucus. Prior to that he consulted for the Department of Energy and NASA and was an associate senior scientist for Science and Technology Corp.



Sokoloski managed NASA's Remote Sensing R&D program, encompassing electro-optics, superconducting devices, imaging technology and low-temperature physics, and was a visiting research professor at Drexel University. He managed the Army's Harry Diamond Laboratories basic R&D programs in solid-state physics, electro-optics and microwave pulse power and laser research. He has also conducted research in plasma physics, disordered materials, magnetic bubble devices and radiation effects on electronic devices.

Sokoloski is chair of IEEE-USA's Research & Development Policy Committee, former chair of the Committee on Transportation and Aerospace Policy, and a member of the Career & Workforce Policy Committee and the IEEE Committee on Earth Observations. He is a former associate editor of the IEEE Intelligent Transportations Systems Journal.

Sokoloski is a member of IEEE, the American Association for the Advancement of Science and the American Physical Society.

JOHN H. MARBURGER, III

John H. Marburger, III, university professor in the departments of Physics and Electrical Engineering at the State University of New York at Stony Brook, served as science advisor to the president and director of the Office of Science and Technology Policy during the George W. Bush Administration (2001-09). Prior to his federal service, he was Director of Brookhaven National Laboratory from 1998, and the third president of Stony Brook University (1980-94). His prior career at the University of Southern California included professor of Physics and Electrical Engineering, Physics Department chairman and dean of the College of Letters, Arts and Sciences.



Marburger's tenure as the president's science advisor – the longest in history – began immediately following the terrorist attacks of September 11, 2001 and included major policy initiatives associated with the establishment of the Department of Homeland Security, re-orientation of the nation's space policy following the crash of the Columbia space shuttle in 2003, the U.S. re-entry in the international nuclear fusion program ITER, and the American Competitiveness Initiative that aimed to double federal funding for the physical sciences and engineering. Serving during a time of deep political and ideological divisions, especially regarding climate change and human embryonic stem cell research, Marburger brought high standards of fairness and objectivity to the science policy process, and launched a movement to strengthen the "science of science policy" that achieved international recognition.

While at the University of Southern California, Marburger contributed as a theoretical physicist to the rapidly growing fields of nonlinear optics and quantum optics. He was a co-founder of the University's Center for Laser Studies, a consultant at Lawrence Livermore Laboratory on high-power laser phenomena, and a frequent public speaker on science, hosting a series of educational programs called "Frontiers of Electronics" on CBS TV.

Marburger's presidency at Stony Brook coincided with the opening and growth of University Hospital and the development of the biological sciences as a major strength of the university. During that time, Marburger served on numerous boards and committees, including chairmanship of the governor's commission on the Shoreham Nuclear Power facility, and chairmanship of the 80 campus "Universities Research Association" which operates Fermi National Accelerator Laboratory near Chicago and operated the Superconducting Super Collider Laboratory during its lifetime.

Marburger was the first president of Brookhaven Science Associates, a partnership of the State University Research Foundation and Battelle Memorial Institute that successfully bid to operate Brookhaven National Laboratory under contract with the U.S. Department of Energy (1997). Under Marburger's directorship, the laboratory commissioned the Relativistic Heavy Ion Collider (RHIC), achieved ISO14001 certification of the laboratory's environmental management system, and significantly improved support for the laboratory by the surrounding community.

Marburger was born on Staten Island, N.Y., and attended Princeton University (A.B. Physics 1962) and Stanford University (Ph.D. Applied Physics 1967).

KEI KOIZUMI

Kei Koizumi is assistant director for Federal Research and Development at the White House Office of Science and Technology Policy (OSTP). Koizumi joined OSTP in mid-February after having served on the Obama transition team as part of the Technology, Innovation & Government Reform Policy Working Group.



Before joining OSTP, Koizumi served as the longtime director of the R&D Budget and Policy Program at the American Association for the Advancement of Science (AAAS). While at AAAS, he became known as a leading authority on federal science and technology funding and budget issues and was a frequent speaker to public groups and the media. He was the principal budget analyst, editor and writer for AAAS reports on federal R&D.

Koizumi received his M.A. from the Center for International Science, Technology and Public Policy program at George Washington University, and received his B.A. in political science and economics from Boston University.

KATY BÖRNER

Katy Börner is the Victor H. Yngve Professor of Information Science at the School of Library and Information Science, adjunct professor in the School of Informatics, core faculty of Cognitive Science, research affiliate of the Biocomplexity Institute, Fellow of the Center for Research on Learning and Technology, member of the Advanced Visualization Laboratory, and founding director of the Cyberinfrastructure for Network Science Center (<http://cns.slis.indiana.edu>) at Indiana University.



Börner is a curator of the Places & Spaces: Mapping Science exhibit (<http://scimaps.org>). Her research focuses on the development of data analysis and visualization techniques for information access, understanding and management. She is particularly interested in the study of the structure and evolution of scientific disciplines, the analysis and visualization of online activity and the development of cyber infrastructures for large-scale scientific collaboration and computation. She is the co-editor of the Springer book on Visual Interfaces to Digital Libraries and of a special issue of PNAS on Mapping Knowledge Domains (2004). Her new book, *Atlas of Science: Guiding the Navigation and Management of Scholarly Knowledge*, published by MIT Press, will become available in 2010.

Börner holds a M.S. in electrical engineering from the University of Technology in Leipzig, 1991, and a Ph.D. in Computer Science from the University of Kaiserslautern, 1997.

DIANA HICKS

D.Phil, SPRU, University of Sussex, Science and Technology Policy, M.Sc., SPRU, University of Sussex, in Science, Technology and Industrialization
B.A, Grinnell College, Physics



Diana Hicks is Professor and Chair of the School of Public Policy, Georgia Institute of Technology. She was previously the Senior Policy Analyst at CHI Research, Inc. In addition, Hicks was on the faculty of SPRU, University of Sussex in the U.K. Her work has appeared in such journals as: *Policy Sciences, Social Studies of Science, Nature, Research Policy, Science and Public Policy, Research Evaluation, Research Technology Management, R&D Management, Scientometrics, Revue Economique Industrielle, Science Technology and Human Values, Industrial and Corporate Change, Japan Journal for Science, Technology and Society.*

Her work has been supported by and has informed policy makers on three continents. She has conducted quantitative assessments and served as a consultant for the Advanced Technology Program of the National Institute of Standards and Technology, the American Cancer Society, the Council for Chemical Research, the Department of Energy, the heads of the UK Research Councils, the Japanese National Institute for Science and Technology Policy, the National Science Foundation, the Small Business Administration, and The Royal Society in the UK. Prof. Hicks has taught at the Haas School of Business at the University of California, Berkeley and worked at the National Institute of Science and Technology Policy (NISTEP) in Tokyo. She is an honorary fellow of the Science Policy Research Unit, University of Sussex, UK and on the Academic Advisory Board for Center for Science, Policy and Outcomes, Washington D.C.

JAMES HOSEK

James Hosek's recent work has been on U.S. competitiveness in science and technology and the U.S. science and engineering workforce. He directs the Forces and Resources Policy Center of the National Defense Research Institute at RAND and has published studies in defense manpower in the areas of recruiting, retention, compensation and personnel quality.



Hosek is editor-in-chief of The RAND Journal of Economics, a leading peer-reviewed journal on industrial organization and microeconomics, and professor of economics at the Pardee RAND Graduate School. He has served as RAND corporate research manager in Human Capital and chair of the Economics and Statistics Department. He was chair of the Economic Advisory Council of the California Institute, a nonprofit organization informing California's congressional delegation on policy matters.

Hosek received his Ph.D. in economics from The University of Chicago.

RICHARD ELLIS

Richard Ellis is an independent consulting social scientist who has been designing, directing and publishing public interest research for more than 40 years. Since 1985, he has specialized in work on scientific and technical professions. Operating as Ellis Research Services in Carlisle, Pa., he is currently engaged in projects for the American Chemical Society (ACS) and the Commission on Professionals in Science and Technology (CPST). He also serves as a consulting member of IEEE-USA's Career and Workforce Policy Committee.



Ellis served CPST as designer and principal analyst for the Alfred P. Sloan Foundation-funded IT and STEM Workforce Data Projects. The STEM project, which includes nine reports, white papers and links to detailed statistical tabulations, resulted in demographic information on more than 50 STEM occupations. He was lead author on six of the reports between June 2004 and October 2007, including the most recent, *Is U.S. Science and Technology Adrift?* He is currently assembling new STEM workforce statistics for the U.S. Department of Energy, using the Census Bureau's American Community Survey. This statistical source did not exist before the current century. It supports major improvements in the coverage, content, timeliness and accessibility of data on scientific and technical professionals.

Ellis served for more than a decade as the director of research for the Engineering Workforce Commission of the American Association of Engineering Societies, where he was responsible for that organization's annual program of comprehensive data collection and commentary on engineering careers. His earlier experience includes direction of national and cross-national research projects for the U.S. Agency for International Development, the World Bank and the Organisation for Economic Cooperation and Development; national program evaluations and other policy research for a broad range of U.S. federal agencies; research for local, regional and national libraries; and a wide variety of work for other clients, including corporations, school systems and religious organizations.

Ellis developed the original versions of IEEE-USA's online Salary Calculator and ACS' Salary Comparator, pioneering the use of regression modeling to provide multi-variable compensation benchmarking for individual technical professionals. His most recent assignment for IEEE-USA was to produce graphic displays of 21st century workforce trends. His longtime work was recognized by IEEE-USA earlier this year when he was honored with an Award for Distinguished Literary Contributions Furthering Engineering Professionalism.

Ellis was a Stouffer Fellow at the National Opinion Research Center at the University of Chicago, where he received his master's degree in sociology.

RON HIRA, PH.D., P.E.

Dr. Ron Hira is an associate professor of Public Policy at the Rochester Institute of Technology, where he specializes in engineering workforce issues, high-skill immigration and innovation policy. He is also a research associate with the Economic Policy Institute.



Hira is co-author of the book, *Outsourcing America* (AMACOM 2005; 2nd edition 2008), which was a finalist for best business book in the Independent Book Publishers Association Benjamin Franklin Awards. *The Boston Globe* called *Outsourcing America* an “honest, disturbing look at outsourcing.” *The Washington Post* described it as a “thorough and easy to grasp primer on the wrenching outsourcing debate.”

Hira is an expert on offshore outsourcing, testifying before Congress twice on its implications. He is frequently quoted and interviewed in many major media outlets, including *The New York Times*, *Wall Street Journal*, *Financial Times*, *BusinessWeek*, *Fortune*, NPR, CNN, CNBC, *NBC Nightly News*, *Time* and *Newsweek*.

In 2007, Hira served as a consultant to the U.S. House of Representatives’ Committee on Science & Technology, helping to organize a series of hearings on the Globalization of Innovation & R&D.

A licensed professional engineer, Hira has worked as a control systems engineer and program manager with Sensytech, NIST and George Mason University. He has been a consultant to the U.S. Department of Treasury, Rand Corporation, Commission on Professionals in Science & Technology, National Research Council, Enterprise Integration Inc. and Deloitte & Touche.

Hira participated on the Council on Foreign Relations’ “Research Roundtable on Technology, Innovation and America’s Primacy” and the Council on Competitiveness’ “National Innovation Initiative.” He was IEEE-USA’s vice president for Career Activities. He is a past chair of IEEE-USA’s R&D Policy Committee and a member of the organization’s Career & Workforce Policy Committee.

Hira completed his post-doctoral Fellowship at Columbia University’s Center for Science, Policy and Outcomes. He holds a Ph.D. in public policy from George Mason, an M.S. in electrical engineering from the school and a B.S. in electrical engineering from Carnegie-Mellon University.

ROBERT S. BOEGE

Robert Spurrier Boege (“Bur—ga”) has served as executive director of ASTRA, the Alliance for Science & Technology Research in America, since December 2000. ASTRA is a collaboration of more than 127 companies, academic institutions, professional and trade associations focused on increasing federal research support for the physical sciences, mathematics and engineering. To accomplish its mission, ASTRA has developed a facts-driven, research-focused education and advocacy program that includes innovation and competitiveness studies, early-stage capital formation and other data products to make a case for a transformed national STEM policy structure.



Boege attended Georgetown University and the Université de Fribourg, Switzerland as an undergraduate. An honors graduate of the Georgetown University Law School, Boege has served in various positions within the government, nonprofit sector and industry. He has published extensively in the areas of nonprofit taxation and antitrust law. Boege created the publication Association Law & Policy and served as its editor for 11 years.

Following jobs in the Congressional Research Service and Sperry Corporation, Boege became the chief lobbyist for the American Society of Association Executives (ASAE) and began that organization’s government affairs outreach program in 1982.

Boege was business liaison for the 1984 Presidential Campaign and the Presidential Inaugural Committee in 1985. He was subsequently appointed associate director of the White House Conference on Small Business, and then held a series of positions in the Small Business Administration and Department of Energy.

From 1999–2000 Boege served in the Technology Administration at the Department of Commerce, where he specialized in issues related to the “new” economy, workforce development and technology policy.

Boege edits the annual State R&D Fact Sheets and State STEM ED Report Cards for ASTRA. He has served as co-principal investigator on a variety of federal research projects, including ASTRA’s Innovation Vital Signs effort during 2007–08. A native of Davenport, Iowa, Boege lives in Martinsburg, W.V., where he is active in civic affairs and historic preservation activities.

ANN KUSHMERICK

Ann Kushmerick is manager in Thomson Reuters’ Global Sales Support group. Her specialty is research evaluation and bibliometric data. The Healthcare and Science Business of Thomson Reuters provides innovative information, platforms, analytical tools and solutions that enable success for professionals working in research and development. Thomson Reuters provides the largest citation index, Web of Science.



Kushmerick holds an M.S. in science communication from Drexel University and a B.A. in English and philosophy from the University of Scranton. She also studied at University of Oxford. Since joining Thomson Reuters in 2006, she has specialized in delivering customized solutions for research evaluation and citation analysis. She speaks about the applications of citation data for informed decision making at industry conferences related to information technology and scholarly research.

RALPH W. WYNDRUM, JR.

Dr. Ralph W. Wyndrum Jr. is an IEEE Fellow who has worked as an engineer for more than 40 years. He currently leads Executive Engineering Consultants in areas of R&D resource allocation and decision sciences targeted at new products and services. He also teaches strategic leadership/ decision quality at Rutgers University. Prior to assuming these positions, he had a long and successful career at Bell Labs and AT&T Labs, beginning in thin film and solid state circuit R&D, and retiring as technology vice president and then program planning and management vice president.



During his 36 years at Bell Labs and AT&T, Wyndrum was a technical staff member, supervisor of IC development, head of several R&D departments, director of Systems Analysis and of Quality, Engineering, Software and Technologies. In 2000 he was an AT&T executive consultant involved in a wide variety of business-related projects and development of a graduate-level Internet protocol curriculum for AT&T's technical staff. In the 1970s and 1980s, Wyndrum served as the AT&T's ITU delegate in Geneva, Switzerland for local transmission systems. He led the manufacturing development of several digital subscriber loop carrier systems – which now serves millions of customers – and of the early prototype TouchTone telephones. He also taught graduate electrical engineering courses at Stevens Institute as an adjunct professor from 1981-88, and has advised masters and doctoral thesis students at the New Jersey Institute of Technology and Rutgers.

Wyndrum served as IEEE vice president of technology activities in 2004 and has served on the IEEE Executive Committee and Board of Directors for five years. In 2003, he was IEEE-USA's vice president for technology policy. He has served on the boards of the IEEE Communications Society and the IEEE Components, Packaging & Manufacturing Technology Society, and was the president of CPMT. He has also served as IEEE Publications vice president and on the Technical Activities Board, the U.S. Activities Board, and as an ABET evaluator.

As 2006 IEEE-USA president, Wyndrum advanced programs aimed at mid-career education and at K-12 science and mathematics education. In January 2007, Wyndrum's was appointed CEO and president of the newly formed IEEE-USA Innovation Institute. He is currently leading four Innovation Forums per year at various locations throughout the United States.

Wyndrum was voted chair-elect of the American Association of Engineering Societies (AAES) for 2008, and is serving as chair this year.

Wyndrum holds B.S. and M.S. degrees in electrical engineering and an executive MBA from Columbia University, as well as a doctorate (Eng.Sc.D.) from New York University. He has published more than 40 papers, articles and reviews and is a contributing author to texts published by Wiley and McGraw Hill. He is frequently invited to speak at international conferences and workshops and holds six patents in integrated circuit applications, VF receiver design and voice/data transmission.

DAVID ALAN GRIER

Dr. David Alan Grier is associate professor of International Science and Technology Policy and International Affairs at George Washington University, where he also serves as associate dean of academic programs. He specializes in globalization and international standardization, scientific institutions and the history of science



Grier has published extensively on the development of computation and the institutions that support it. He writes across a wide variety of genres, including general news pieces for The Washington Post, children's articles and academic pieces for *American Mathematical Monthly* and the *Communications of the ACM*. He has been the Joseph Henry Lecturer at the Washington Philosophical Society.

Grier writes the column, *In Our Time*, for the IEEE Computer Society's *Computer* magazine and served for four years as editor-in-chief of the *IEEE Annals of the History of Computing* (www.computer.org/annals/). His 2005 book, *When Computers Were Human*, (Princeton University Press) won favorable reviews on NPR's *Marketplace* and in *Nature* and *Discover*. His most recent book, *Too Soon to Tell*, was published in February by John Wiley.

Grier received his B.A. in mathematics from Middlebury College and his Ph.D. in statistical computation at the University of Washington.

ROBERT W. BAKER

Bob Baker is deputy director of Plans & Programs for the Director of Defense Research & Engineering (DDR&E) within the Office of the Secretary of Defense (OSD). In this position he provides planning oversight of the \$11.5 billion Department of Defense (DoD) Science & Technology program. He also provides OSD oversight for the preparation of the DoD Research & Engineering Strategy, coordinating with the Joint Staff on issues concerning development of the Joint Warfighting Science & Technology Plan, and focusing technology development to support priority joint warfighting needs.



Bob retired from active duty as a Colonel in the United States Air Force in January, 1995, after serving in numerous science and technology-related assignments including: special assistant to the deputy DDR&E in the Pentagon from 1991-95; executive officer to the deputy chief of staff for Science & Technology from 1988-91 and chief, Aeromechanics Technology Division from 1986-8888, at Air Force Systems Command; deputy director of the Turbine Engine Division from 1983-86, and chief of the Turbine Engine Assessment Branch in 1982-8383 at the U.S. Air Force Wright Aeronautical Laboratory.

Baker also served on active duty for 12 years with the United States Army as an assistant professor of engineering mechanics at the United States Military Academy at West Point, N.Y., from 1977-82; as a mechanical engineer at the U.S. Army Harry Diamond Laboratory from 1974-77; and as a nuclear weapons maintenance officer, U.S. Army Europe, from 1970-74.

Baker earned a master of science and bachelor of science degrees in mechanical engineering from the University of Rhode Island. He is also a graduate of the Air War College and Air Command & Staff College. He is the recipient of the Exceptional Civilian Service Award, the Office of the Secretary of Defense Award for Excellence and the Defense Superior Service Medal.

A native of Warwick, R.I., Baker is married to Norma Catherine (Szarek) Baker, a registered nurse. They have two sons: Kevin, a West Virginia University graduate who works as a database analyst in San Francisco; and Russell, a Tufts University graduate and anesthesiologist in New York.

STEM Workshop Planning Committee

Chair

Dr. Martin (Marty) M. Sokoloski
5526 Phelps Luck Drive
Columbia, MD 21045
H: (410) 997-2575
Email: mmsokoloski@ieee.org

Co-Chair

Mr. James (Jim) M. Bielefeld
Principal Professional Staff
Johns Hopkins APL
Johns Hopkins Road
Laurel, MD 20723-6099
O: (240) 228-6969; (443) 778-6969
E-mail: jim.bielefeld@jhuapl.edu

Members

Dr. Jack Cederquist
General Dynamics
Advanced Information Systems
1200 Joe Hall Drive
P.O. Box 990
Ypsilanti, MI 48197
O: (734) 480-5073/5252
E-mail: jack.cederquist@gd-ais.com

Prof. Robert (Bob) W. Newcomb
University of Maryland
Dept. of Electrical & Computer
Engineering
College Park, MD 20742-0001
O: (301) 405-3662
E-mail: newcomb@eng.umd.edu

Mr. Edward (Ed) G. Perkins
8224 SW Shenandoah Way
Tualatin, OR 97062-9370
O: (503) 612-9397
E-mail: e.perkins@ieee.org

Treasurer

Dr. Clifford (Cliff) Lau
Institute for Defense Analyses
4850 Mark Center Drive, Room
7610
Alexandria, VA 22311-1882
O: (703) 933-6525
E-mail: clau@ida.org

Financial Officer

Mr. James (Jim) T. Barbera, Sr.
13513 Crispin Way
Rockville, MD 20853
O: (301) 460-4347
E-mail: j.barbera@ieee.org

IEEE-USA Publicity

Chris McManes
Public Relations Manager
IEEE-USA
2001 L Street, NW, Ste. 700
Washington, DC 20036
O: (202) 530-8356
F: (202) 785-0835
E-mail: c.mcmanes@ieee.org

IEEE-USA Web Design

Greg Hill
Electronic Communications
Manager
IEEE-USA
2001 L Street, NW, Ste. 700
O: (202) 530-8335
E-mail: g.hill@ieee.org

IEEE-USA Staff

Bill Williams
Senior Legislative Representative
IEEE-USA
2001 L Street, NW, Ste. 700
Washington, DC 20036
O: (202) 530-8331
F: (202) 785-0835
E-mail: bill.williams@ieee.org

Deborah Rudolph
Technology Policy Manager
IEEE-USA
2001 L Street, NW, Ste. 700
Washington, DC 20036
O: (202) 530-8332
E-mail: d.rudolph@ieee.org

Vin O'Neill
Senior Legislative Representative
Career Policy Activities
IEEE-USA
2001 L Street, NW, Ste. 700
Washington, D.C. 20036
O: (202) 530-8327
E-mail: v.oneill@ieee.org

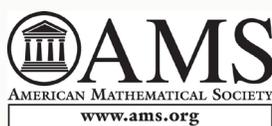
Bernadette Concepcion
Staff Assistant
IEEE-USA
1828 L Street, NW, Ste. 1202
Washington, DC 20036
O: (202) 530-8365
F: (202) 785-0835
E-mail: b.concepcion@ieee.org

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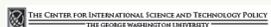
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The American Association of Engineering Societies (AAES) is a multidisciplinary organization of engineering societies dedicated to advancing the knowledge, understanding, and practice of engineering. AAES member societies represent the mainstream of U.S. engineering engineers in industry, government, and academia.

Introduction

This E-Book provides a transcript of the Workshop on Science, Technology, Engineering and Mathematics (STEM) Enterprise: Measures for Innovation & Competitiveness. The one-day workshop was sponsored by IEEE-USA and the IEEE-USA Innovation Institute, AAES, AMS, ASME, ASTRA, the Rand Corporation, Thomson Reuters, and the Center for International Science and Technology Policy at the George Washington University and took place on Wednesday, 21 October 2009, at George Washington University, Washington D.C.¹

The workshop was founded on the premise that STEM are the driving forces for the US and worldwide economical and social advancements. The workshop had the goal of bringing together leaders to discuss important questions facing STEM and to develop policy positions based on concrete data and proven algorithms.

Input to the STEM research and development (R&D) enterprise is generally considered to be the funding that includes federal, state, industry, and academics. But what are the outputs, and more importantly the outcomes, from that investment? Is bibliometric data reasonable in measuring output, both quantity and quality, or are new data sources needed to quantify output? What data exists to follow interactions among the STEM enterprise sectors: federal, state, academic, and private industry? What is the outcome or impact of the R&D investment on society and quality of life? How can we measure and assess the outcomes? The workshop successfully provided a forum to discuss these issues to come up with policy positions and recommendations.

The workshop sessions focused on:

Input/Funding

What are the National Expenditures on R&D both in the public and private sectors with the research portion broken down by basic and applied research? What is the breakout among federal, industry, and academia and by mission, physics chemistry, and engineering?

Work Force

This area incorporates such data as S&T employment, un-employment, under-employment, education level of population, and breakout among the STEM enterprise by sector; federal, industry, and academia.

Output/Measures

This area covers data such as scientific publication, patents awarded and other public and private data banks. Data mining from such sources as: Information Science Institute, ISI now know as Thompson Scientific, Rand's RaDIUS Data Base, American Association for the Advancement of Science data on the S&E federal budget, the National Science Foundation's Science and Technology Indicators, and databases from the Department of Commerce, the Department of Labor Statistics, the Patent Offices and the Organization for Economic Co-operation and Development.

¹ Additional information, including a detailed workshop program, on the Workshop on Science, Technology, Engineering and Mathematics Enterprise can be found at <http://www.ieeeusa.org/calendar/conferences/stem/default.asp>.

Outcomes/Productivity

This area covers citations, such as how the top one percent of citations measuring high quality and high impact and/or influence, and rankings and prizes. Given the output and measures, how do we measure productivity?

This E-Book provides a transcript of the Workshop on STEM Enterprise. An effort was made to preserve the original dialogue as it was presented by the workshop's speakers. In the event that PowerPoint slides and visuals were available for transcription, relevant slides and images have been inserted into the text to help the reader follow along. It is hoped that after reading the following content, the reader will have gained the same knowledge as if he/she were physically present at the workshop.

Opening of Workshop

Presented by Dr. Martin M. Sokoloski, Chair, IEEE-USA Research & Development Policy Committee

MARTY SOKOLOSKI: This workshop has to do with the STEM enterprise which is a huge embodiment of people all over the spectrum of the federal laboratories, industrial laboratories, academia, spilling over national borders. And one of the axioms I tend to look at is that the STEM Enterprise is the basis for all innovation, not only in our country but globally. And I happened to be reading the *Post* on Sunday and saw this unique quote saying that “If the cash flow is blood of the global economy, and spending and investments are its main arteries, then innovation is the heart that does the pumping” (see Figure 1). I thought that’s a great anthropomorphic rendition of the STEM Enterprise.




AXIOMS*

- The STEM Enterprise is the basis for all R&D & subsequent innovation.
- *“If cash flow is the blood of the global economy and spending and investments are its main arteries, then innovation is the heart that does the pumping” ... D.M. Harris, *Can Innovation Save the Economy*, Washington Post, pg G1, 10/18/2009.*
- Then how can we judge the health of the heart, namely the STEM enterprise, and how can we measure & characterize it?

* axiom or postulate is a proposition that is not proved or demonstrated but considered to be either self-evident, or subject to necessary decision.

Figure 1

Our quest here is actually to see how we can measure the health of the STEM Enterprise. What does it look like today? What did it look like in the past? Where is it possibly going in the future? How to do this? And this particular topic has not gotten much attention in the U.S. In other countries such discussions have been going on for the last two decades, much to our chagrin. So hopefully we can perhaps step into this new regime as U.S. people and see if we can answer some of these. It is a big task, but nonetheless let us begin.

The first speaker is probably known to everybody, but has been out of the country for a decade. John Marburger was the director of the Office of Science and Technology under the Bush administration for the last two presidential regimes. He has since left, and he has gone back to the State University of New York where he is now professor in Physics. It is certainly a great privilege to have John speak to us today.

Keynote Address: STEM Engineering?

Presented by Professor John Marburger III, University Professor of Physics and Electrical Engineering, Stony Brook University, Stony Brook, New York

DR. JOHN H. MARBURGER III: I thank the sponsors and organizers of this workshop for assembling an outstanding group of speakers and participants to discuss a topic of continuing importance and some controversy. And I particularly thank IEEE's Martin Sokoloski for twisting my arm to speak this morning. It didn't take much twisting because this is a topic in which I have had a great interest during much of my career.

My graduate degree in Applied Physics led to academic appointments in both physics and electrical engineering – subjects that are normally taught in two different schools within universities: engineering schools and schools of arts and sciences. From my earliest experiences as an Assistant Professor in these two worlds, I noticed differences in culture and behavior. The engineers were more conservative than the physicists; more of them received their research support from Defense Department agencies, fewer from the National Science Foundation; they did more consulting with private companies and had more contact with the industrial world. The science students focused more intensely on their research topics, were more conscious of the history of their fields, but were less clear about the relation of their work to anything else. I also noticed that engineering enrollments, or more accurately the applications for admission, seemed to rise and fall in cycles. I assumed they were related to business cycles that were linked somehow to employer demand, but whatever the reasons, the student market in engineering education seemed to be more volatile than the market for physical or biological sciences. Numbers of applications from students expressing an interest in science showed trends, but the time scale was longer than for engineering. Not all engineering departments were equally affected, but the larger ones, particularly mechanical and electrical engineering, seemed to have the largest cyclical movements.

Generalizing from direct experience is tricky, as I have learned from direct experience. Universities and engineering schools and national regions are very different among themselves, and generalizing even from good data is dangerous if it averages over this diversity. But those early impressions stayed with me as I moved from Southern California to New York to Washington through a sequence of jobs that made me aware of larger and larger communities of scientists and engineers. These communities are complex, and the experiences of their members, comprehensible and familiar to each one, differed widely from place to place. The lesson I learned early was not that the whole STEM enterprise is chaotic, but that it is very complex. Its structure is not like a fractal where the large pattern is repeated at smaller and smaller scales. It breaks up into a large set of linked activities. The ultimate centers of activity – the atomic building blocks of the whole enterprise – are individual men and women. My message at the outset of today's workshop is that understanding this complex ecology of innovation and competitiveness is a huge task, but not necessarily an impossible one, and we need to keep trying.

Until 2001 I had no intention of trying to understand this complex machinery. I was an advocate for my own STEM fields, *i.e.* more money, more students, more recognition for their importance to society. I was an advocate for the institutions I served, and I acted to solve institutional problems. But in 2001 I found myself in a position from which I could influence policy over a much broader domain. As a policy advisor I had to ask myself "How many new students? How much more money? Which fields? How do we know?" STEM is dynamic and complex, and if its link to Innovation and Competitiveness is obvious from the inside looking out, it is deeply obscure from the outside looking in. Most STEM professionals have personal experience with education, training, and real-world

problem solving, so they are aware of how all these are related in their own particular case. But the cases are by no means all the same, so when an economist, for example, tries to sort out what educational and research inputs lead to given societal outputs, such as productivity in a certain industrial area, then the clarity of individual cases disappears. This contrast between the clarity – you might even say the *linearity* – of personal experience on the one hand, and on the other hand the obscurity of causal relationships in society, is an eternal burden of the social sciences. Everyone is an expert in their own personal behavior (or we think we are), which creates an almost irresistible conviction that we are experts in everyone else's behavior too. Every data display in this field is like a Rorschach test – we see it through a personal experience that inevitably omits alternative interpretations.

I began thinking about this problem seriously about a year after I arrived in Washington. In June 2002 the National Science Board's Task Force on *National Workforce Policies for Science and Engineering* invited me to address them on the topic "Impact of Security Policies on the Science and Engineering Workforce." This struck me as a loaded question. How could the impact be other than negative? Only a few months before I had declared to a AAAS conference on the same theme that, "this administration is determined not to let terrorism deflect America from its trajectory of world leadership in science ... Having produced the means for great strides in science, and in accompanying technologies for improved health care, economic competitiveness, and quality of life, it would be foolish to turn aside now from the course of discovery while we engage the monster of terrorism ... I expect that science in America and the world will forge ahead relatively unaffected by the war against terrorism.... Science has its own intrinsic imperative and this nation will continue to pursue it." That's the kind of rhetoric that people seem to expect from politically appointed science advisors, and I thought I was on reasonably solid ground with my reassurances. The National Science Board, however, was a smaller, more sophisticated audience than a public meeting of the American Association for the Advancement of Science, and I thought they deserved a deeper response. But what more could I offer? Here's what I actually said:

"The fact is, I do not know what the impact of security policies will be on the science and engineering workforce. Part of the reason for this – the least important part – is that the security policies are in a state of flux. Another part is that the impact will be psychological as well as instrumental, and psychology is not part of our predictive model. The most important factor, however, is that there is no reliable predictive model for workforce response to any particular driving force such as a change in policy affecting student visas."

"If there are such models, they seem to be implicit in the types of data we collect and the manner we choose to portray them. When I see graphs and tables relating to workforce, I have the impression they are answers to questions whose significance is either so well known to experts that no further discussion is required, or so completely buried in history that no further discussion is possible. I understand the need to collect the same data year after year so comparisons can be made and changes depicted accurately in the course of time. But I am not at all confident that the right questions are being asked or answered to provide guidance for action. We have workforce data that I do not understand how to use, and we have workforce questions whose answers would seem to require more than merely data."

My idea at the time was that the National Science Board, which oversees the production of the important *Science and Engineering Indicators* reports, should consider the task of building a new workforce model that might make it possible to answer questions like the one they asked me: "What do we expect from a technical workforce model?" I asked the Board.

“I know what I expect from a model. I expect it to give policy guidance. I want to be able to assess the impact of a change of policy on the technical workforce. ... What is the impact of a student loan forgiveness program? Of a scholarship program? Of a change in the compensation structure for researchers, faculty members, technical staff? Of an increase in sponsored research funds in some field? Of a change in graduation rates in certain fields among certain sociological groups?” Ask all these questions with respect to each area of technical skill, and with respect to each nation in which the changes are postulated to occur. – it must be a global model, because the workforce we are speaking of has global mobility. It must take into account the effect of incentives, and the correlation of this effect with sociological parameters.”

“Above all, the model cannot be simply an extrapolation based on historical time-series data. The technical workforce is responding to factors that are changing too rapidly to be captured by historical data. And yet the model does not have to predict everything with perfect accuracy. What we need is the ability to estimate specific effects from specific causes under reasonable assumptions about the future. ... Does it make sense for us to launch a project to model the global workforce with the aim of producing policy guidance? We need an action-oriented *workforce project* that seeks to define the technical workforce problem in a broad way, and to exploit the power of modern information technology to produce tools for policy guidance.”

I knew at the time this was not a task the National Science Board was prepared to undertake, but I wanted to signal my concern about an issue that threatens the credibility of all policy advice. How can we ask the public to support multi-billion dollar programs to produce more engineers or computer scientists without any real evidence they will work? Or even that they are needed? All we have to go on are anecdotes and intuitions and data disconnected from all but the most primitive interpretive frameworks. If we think empirically based research is essential for learning about nature, or making useful products, then why shouldn't we be encouraging research to build empirically validated foundations for effective science policy?

In 2005 I began speaking and writing to encourage the development of the field I call “the science of science policy.” This is not a new subject. Many economists and social scientists have been writing about science policy for nearly a century, and struggling to identify appropriate input data and output measures to answer questions like the ones I mentioned above. Their community has been small and not very visible to policy makers. It is time to make it larger and more visible. There are three reasons why it is important to do this now.

First, the dramatic influence of information technology on almost every aspect of daily life, from entertainment to global trade, has made it very clear that technical issues will be an important dimension of nearly all future economies. In this context, science and technology policy acquires an unprecedented significance. Post World War II science policy focused on Cold War issues until the late 1980's. The 1990's were a transition decade. Since the turn of the century all science policy eyes have been on technology-based innovation and how to sustain it. Studies of government science investment strategies have a long history, but the increased demand for economic effectiveness creates a dynamic in which new approaches to science policy studies will flourish.

Second, in the face of rapid global change, old correlations do not have predictive value. The technical workforce today is highly mobile, and information technology has not only dramatically altered the working conditions for technical labor, but has also transformed and even eradicated the functions of entire categories of technical personnel. Distributed manufacturing, supply chain management, and outsourcing of ancillary functions have undermined the usefulness of old taxonomies classifying work. The conduct of scientific research and engineering

practice has been transformed, with extensive laboratory automation, digital design and simulation, internet communication and publication, and massive computational and data processing power. We simply must have better tools that do not rely on historical data series. They do not work anymore. Microeconomic reality has inundated macroeconomic tradition with a flood of new behaviors.

Third, the same rapidly advancing technologies that created these new conditions also bring new tools that are particularly empowering for the social sciences. Large databases and complex models are inherent in social science research. The vast articulation of internet applications makes possible the gathering of socio-economically relevant data with unprecedented speed and affordability, and access to massive inexpensive computing power makes it possible to process and visualize data in ways unimagined twenty years ago. New capabilities for direct visualization of large data sets in multiple dimensions may render traditional statistical methods obsolete. A growing community of scientists from many different fields are inventing data mining and data visualization techniques that I believe will transform traditional approaches to analysis and model-building. These new tools and opportunities can be an invigorating stimulus for all the social sciences, including the social science of science policy.

I made similar remarks to an OECD planning conference three years ago, before the Great Recession. They remain valid today, and the need for sharper tools to guide federal resource allocations will be greater than ever in the budget-constrained post-recession era. I am delighted that the current policy guidance from OSTP and the Office of Management and Budget encourages federal agencies to “develop ‘science of science policy’ tools that can improve management of their research and development portfolios and better assess the impact of their science and technology investments.”

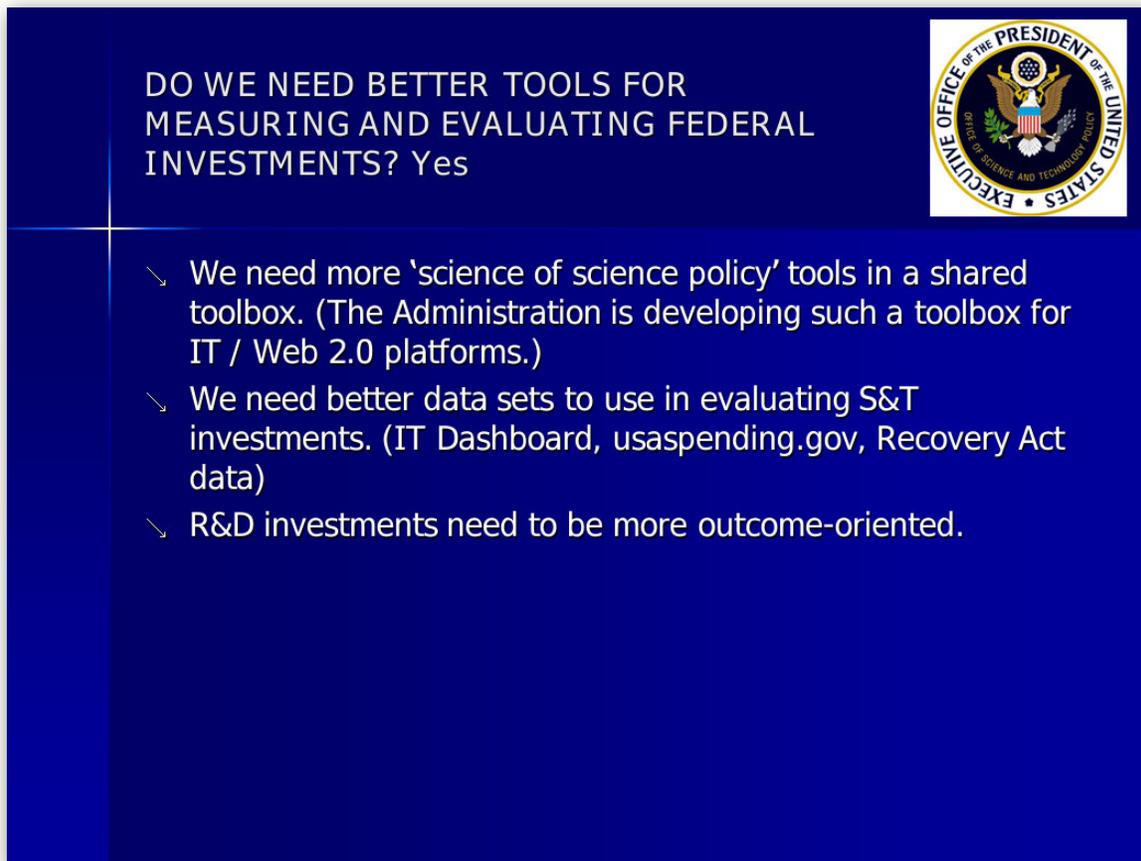
The title of my talk is “STEM Engineering?” with a question mark. The question is whether we can ever create tools for understanding the complex ecology of Innovation and Competitiveness strong enough and complete enough to transform STEM policy-making from a black art to something approaching a professional discipline like engineering. I am not advocating rule by technocrats, but rather the creation of a much larger community of empirically oriented policy researchers who will seize the opportunities presented by modern technology to strengthen the basis for STEM policy-making.

This workshop is a good example of an activity that needs to be replicated for the many different dimensions of vast ecology of Innovation and Competitiveness, and I am grateful to be part of it. Thank you again for inviting me.

Measuring and Evaluating the STEM Enterprise: Perspectives from the Obama Administration

Presented by Mr. Kei Koizumi, Assistant Director for Federal R&D, Office of Science and Technology Policy, Executive Office of the President, Washington, D.C.

MR. KEI KOIZUMI: Today I want to say a few words about the Enterprise, measuring and evaluating STEM, especially for innovation and competitiveness impacts. I guess it doesn't require me to say this is more important than ever as we are dealing with the economic crisis and the recession. In order to get out of this, we do have to worry a great deal about policies that impact innovation and competitiveness. So I want to give a couple of perspectives on that.



DO WE NEED BETTER TOOLS FOR
MEASURING AND EVALUATING FEDERAL
INVESTMENTS? Yes



- ↘ We need more 'science of science policy' tools in a shared toolbox. (The Administration is developing such a toolbox for IT / Web 2.0 platforms.)
- ↘ We need better data sets to use in evaluating S&T investments. (IT Dashboard, usaspending.gov, Recovery Act data)
- ↘ R&D investments need to be more outcome-oriented.

Figure 2

First, I'll start out with the basic questions (see Figure 2): Do we need better tools for measuring and evaluating federal investments? As always, the answer is yes. So I wanted to talk first, to follow on what Dr. Marburger was saying in terms of the great work that he initiated with science of science policy programs, which of course

continue in this administration. And it is something that we support strongly because we do recognize the need for interagency working groups and funded research on science of science policy tools to continue because agencies and federal policy makers need more than ever some kind of a toolbox of measures and proven metrics that enable us to evaluate the results for federal R&D investments.

We find the administration is already creating such a toolbox for web 2.0 IT platforms. There is actually a website where agencies can look at the toolbox to see what kind of web 2.0 interactive tools they can get off the shelf that they can use, preapproved.

So the innovation we have is, if we have something like that the agency evaluators could turn to when they have questions about effectiveness of their R&D programs then that would be an ideal we'd try to work toward. We also need better datasets to use in evaluating S&T investments. Dr. Marburger is very correct to note that we have these new social science datasets. Advances in IT have created probably too much data for us to handle at the moment, and more data are coming online all the time. I'll talk about that in a bit.

We also know that R&D investments need to be more outcomes oriented. That's always been true. I just want to reaffirm that. Ultimately these R&D investments have to be justified in terms of their progress toward national goals and a very important national goal these days is innovation and competitiveness.

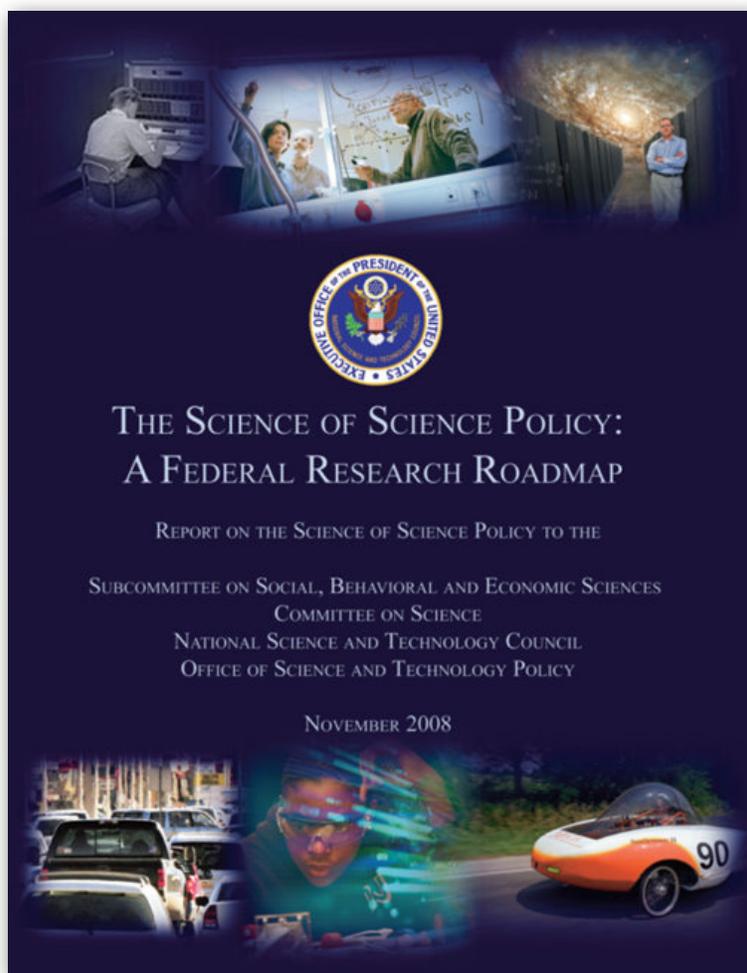


Figure 3

I wanted to first highlight what's happened over the last and this administration. The science of science policy working group has set a research roadmap for science of science policy tools, and it encompasses many of the policy measures that we are talking about today (see Figure 3). It deals with input and output measures and also tries to get at what is the state of the art in outcome measures for R&D investments, toward innovation, economic outcome measures. You should not be surprised to hear that we find that in the input side those measures are relatively well-developed.

Based on many years of working on them, I can say those input measures have their challenges but are fairly easy to understand, collect and evaluate because many input measures deal with dollars, which are easy to count as opposed to engineers, scientists engaged in R&D and some of the other inputs into the process, i.e. education as an input. But there are still some challenges on the input side, so there are a number of initiatives underway to improve input data collections so we have better R&D data and data on human resources.

What is more of a challenge is some of these output measures such as bibliometrics and citations we'll talk about today. Those data exist and are getting more refined and more granular all the time. The question is how to apply to some of these output indicators toward program level analysis. What publications would a specific program in a specific agency create? If we know the publication and citation output, how do we make sense of those data within the context of what to do next with that program? That's not quite where we need it to be, and can be important to use as anecdotes, Certain Program X produces well-cited papers. But how to connect that with the future of the program, to adjust that program, is still unclear.

As for outcome measures, there are lots of potential metrics and measures out there, but the research roadmap has most of the 'more work needs to be done' labels attached to the outcome measures because it is still unclear how policy makers can use some of the data that are out there to make outcome decisions.

The usefulness of this research roadmap that came out late last year and is in implementation phase since then is to identify where we need to do the research. There is a section that's fairly easy to see and understand, color-coded with boxes and green and red lights, so we can see where the most work needs to be and where we are relatively all right.

Those are some of the marching orders for what we need to do to have this better toolbox, and that will be useful for us.



Figure 4

Another model we're looking at for some indicators is the IT dashboard (see Figure 4). So far, this administration's OMB has established the IT dashboard which is supposed to be interactive, very comprehensive and user-friendly to understand all the input data collected for the IT world of government spending. That is possible because already, through various paperwork requirements, federal agencies have been collecting mountains of data on IT. I look at it from the R&D perspective and am envious because agencies are required to submit voluminous documentation of their IT investments in ways that are not required for R&D investments so far.

It is useful for the public to actually slice and dice the data anyway you want for IT investments. One example, DoD, you can see how the DoD invests their IT data. Perhaps more importantly, you can actually look at performance and outcomes. For each IT project you have data on how it is progressing, where it is in the process, and some assessment of the outcomes, how this project has improved a certain variable or certain aspect of an agency's mission in IT performance. It has been a useful tool because it has already had some real-time results as in Department of Veterans Affairs. VA has used this very detailed outcome and output data to rebalance their IT

portfolio and make some program cuts, some program resource shifts, and to expand into new areas where this inventory has shown they are not doing enough. The vision is to be able to do that with R&D investments that are geared toward innovation competitiveness so we can see if we have something resembling an R&D dashboard that we can look at the federal research investment and slice and dice it in ways interesting to us. For example, to try to evaluate effectiveness of various research programs toward a goal such as competitiveness, and then to make some adjustments based on how they rank up.

So one thing we're working on is to create just such an R&D dashboard, and we're somewhat hampered by the fact that federal agencies do not collect volumes of data they collect in IT routinely. All data are out there, but not standardized, because they are not required to be in an annual submission. That is more of a medium-term challenge. So my hope is sometime maybe at next year's conference I'll be able to show the R&D dashboard. We are trying to integrate these roadmap measures, trying to improve them, and trying to apply those measures to the R&D portfolio ways we can see them. That is the vision we are working toward.



Figure 5

Another opportunity is the Recovery Act, the Stimulus Bill signed February 2009, and as you know its reason for being is economic recovery, competitiveness, and innovation. So we have this discreet investment, very large, but unusual in that this is one-time and separately tagged, so it is as close as we come in federal budgeting terms to a control experiment. It is a laboratory of sorts, and it is a control experiment in which the prime purpose is an economic outcome. That is ultimately how the Recovery Act is going to be judged.

So there's been a lot of attention paid toward things like the Recovery.Gov; that is similar to the IT dashboard, a way for everyone to track exactly what is happening to the Recovery Act money (see Figure 5). Right now it is on the input side, you can see exactly where the inputs, the dollars, are going.

So for example, this is actually NSF who got \$3.0 billion in Recovery Act money, and you can see through the dots where the money NSF has awarded so far, about 80 percent of the total, is going. That's an improvement in the input data.

The second challenge is demonstrating some of the outputs and outcomes because one key output the administration is very concerned about is jobs. You've heard recently from news accounts that the first jobs report based on actual data was released and at the moment, based on Recovery Act dollars spent, the initial estimate is 30,000 jobs, and those data will be added to and refined over the coming years because for the first time last week we had actual data from respondents, the recipients of Recovery money. At the moment those jobs data are self-reporting, so each recipient of Recovery Act funds goes around and counts how many jobs were retained or created through the RA money, and it doesn't include all the recipients' RA money because they are having problems getting the state pass-through monies and job estimates for that. But it is one attempt to get an output measure. Notable of course is that a lot of this RA money is R&D money, so NSF, NIH money goes into universities, and over the next few quarterly reports we'll get more data from the recipients, that is university researchers, about how many jobs they have retained or saved.

So that is an attempt and also something of a new frontier, in that this is a new burden, yes, for recipients. But it also provides us with new data. A challenge is to translate that into more reliable standardized measures because at the moment we recognize there are some methodological questions associated with asking 10,000 professors to just look around their labs and count how many jobs, because that's not a standardized way.

At the same time, through the science of science policy programs of various funding agencies we're also funding research to use this RA opportunity to come up with better, more reliable methods to count jobs and also to do some research on using the RA money to come up with outcome measures that is more than just immediate jobs created but rather the broader economic impacts of these RA investments.

So we are letting no crisis go to waste, in that this crisis and the response to it does provide this laboratory. It provides this framework of this purpose on economic outcomes, and that's a great opportunity for the research community to demonstrate and work on getting better tools for evaluating outcomes of R&D past investments that are part of the RA.

Again, if we have this conference next year or year after that, it is my hope I'll get to show a lot more screen captures from Recovery.Gov than just what dollars went toward as a result of S&T investments. Ideally, I'll be able to show also the jobs and some of the broader economic impacts, and they might take the form, of course, of new companies starting or local economic development or how the research investment compares with, let's say, transportation investments.

Those are some visions we are working toward, and we'll see how that goes.

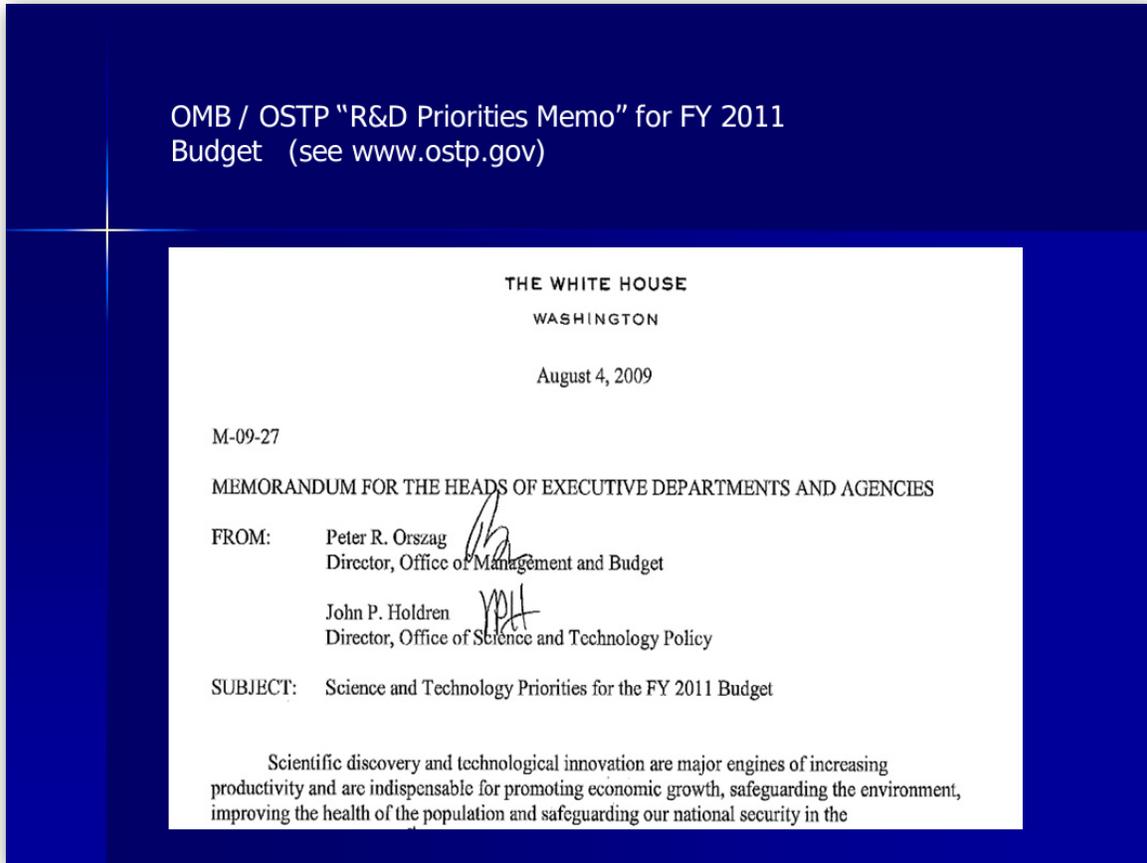


Figure 6

As Dr. Marburger said, for the annual budget process right now inside the Executive Branch we are working on formulating the 2011 federal budget, which will be released next February. But as part of that, OSTP and the Office of Management and Budget collaborate each year in setting forth R&D priorities for the overall federal investment (see Figure 6). Included in that are some of these key sections that relate to what we are talking about today; that is, the outcome measures and this is just to give a flavor of the fact that these evaluations and outcome measures will be very important especially in this budget because it is going to be a very difficult budget with the deficit where it is and the administration's commitment to get that deficit down significantly over the next few years. R&D investments, along with other investments, will need to be justified, explained, linked to outcomes to a greater degree than before.

In order to give some common framework for agencies to think about these required investments, here are some things we want to emphasize. Of course it is the datasets, it is research to relate R&D investments to outcomes, it is outcome-oriented goals, and also the Science of Science Policy tools to help measuring these outcomes.

OMB / OSTP "R&D Priorities Memo" for FY 2011 Budget



- ↙ "Agencies should describe the expected outcomes from their research in relation to... practical challenges and cross-cutting areas, providing quantitative metrics where possible."
- ↙ "Federal agencies... should develop datasets to better document Federal science and technology investments and to make these data open to the public in accessible, useful formats."
- ↙ "Agencies should develop outcome-oriented goals for their science and technology activities, establish procedures and timelines for evaluating the performance of these activities..."
- ↙ "Agencies should develop 'science of science policy' tools that can improve management of their [R&D] portfolios and better assess the impact of their [S&T] investments."

Figure 7

In addition to that, each agency is developing a set of high priority performance goals (see Figure 7) and I can't actually tell you all of what they are coming up with but I can say that many of the science agencies, as performance goals, are setting some fairly aggressive performance goals on these measurement tools because they recognize that if they are ever going to meet these they have to put a greater emphasis on developing, testing, and then using performance measures.

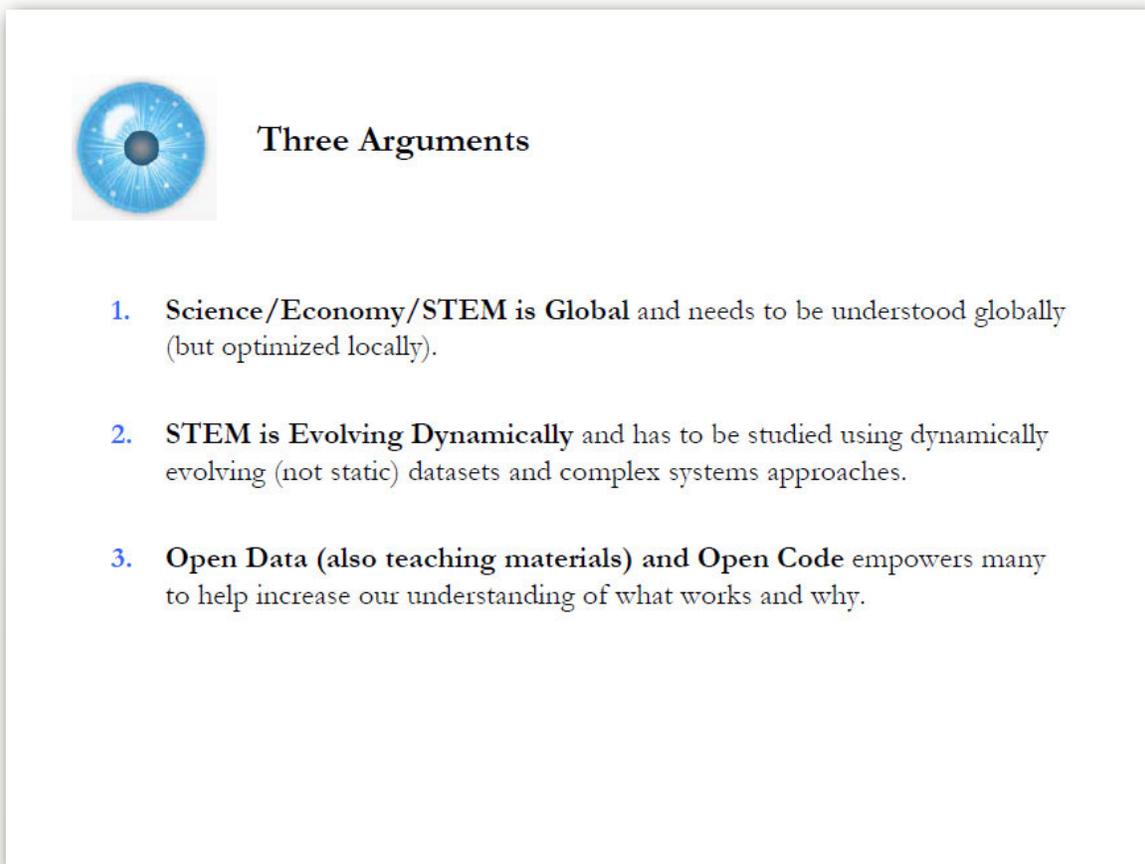
As you might expect, many agencies are choosing performance measures that relate to economic outputs that come out of their research as well as the STEM education outputs and outcomes of their research investments.

So I wanted to give that a quick overview of the things on OSTP's mind and the administration's mind as we go forward in this project of trying to have a very effective R&D investment. We need to demonstrate that the R&D investment is not only effective in terms of these goals' narrow terms such as incremental advances in energy or disease related health goals, but also these broader more diffuse goals such as overall economic innovation competitiveness. I also wanted to lay out some challenges and data opportunities. At this point, having gone over some of the things we're working on, I'd like to hear what's on your minds, some questions you might have as we go forward on this workshop. Thank you.

STEM: Individual, Local, and Global Flows and Activity Patterns

Presented by Prof. Katy Börner, Victor H. Yngve Professor of Information Science and Director of the Information Visualization Lab & Cyberinfrastructure for Network Science Center, School of Library and Information Science Indiana University

PROF. KATY BORNER:² I applaud you for arranging this workshop. It is very important to consider not only funding inputs and publication outputs when evaluating science but to also look at data relevant for education and the training of the next generation of scientists.



Three Arguments

1. **Science/Economy/STEM is Global** and needs to be understood globally (but optimized locally).
2. **STEM is Evolving Dynamically** and has to be studied using dynamically evolving (not static) datasets and complex systems approaches.
3. **Open Data (also teaching materials) and Open Code** empowers many to help increase our understanding of what works and why.

Figure 8

Slide 2 (see Figure 8):

In this talk, I would like to make three major arguments. Firstly, just like science and the economy, STEM is global. Hence, we need global data covering all areas of science as people are often trained in one area of the world in one specific discipline of science but later they might work in a completely different area.

The second argument I'd like to make is that STEM is evolving dynamically. It is not static. Therefore, we need to study it using dynamically evolving data streams. Much data that is used to inform STEM decision making today is based on data that is one or more years old. Imagine you would try to regulate the temperature in a room based on one or more year old data.

The third piece I'd leave you with is the importance of having open data and open code, not to use "black box" tools on proprietary datasets as it is oftentimes done today. Reproducibility of results is a hallmark of science and we now have the data, algorithms and computational power to study STEM and inform STEM relevant decision making in a scientific way.

Next, I'd like to show you a number of examples which might inspire you to do similar devices, setups, approaches for the study of STEM education data.



(1) Science/Economy/STEM is Global

Illuminated Diagram Display

W. Bradford Peley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007) Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007, San Diego, CA.

W. Bradford Peley
Scientific Mapmaker
Digital Image Design Incorporated
Dept. of Computer Science, Columbia University

Figure 9

Slide 3 (see Figure 9):

The setup you see here is part of the Mapping Science exhibit. Sample maps from the exhibit are hung in the back of this room. This particular setup is called “Illuminated Diagram Display.” As you can see, there are two large-scale, printed maps. One shows the map of the world and the other a map of all of science. Using a touch panel display, one can click on any place on the world map to see in the map of science what kind of research is being conducted at this geolocation. Analogously, one can select any node in the Map of Science, to highlight on the map of the world who’s conducting this kind of research on, let’s say, chemistry.

The displays combine 300dpi large scale printed maps and low resolution projectors to illuminate different areas on the maps. Alternatively, the maps can be printed on semi-transparent material and back-illuminated using, e.g., Best Buy TVs.

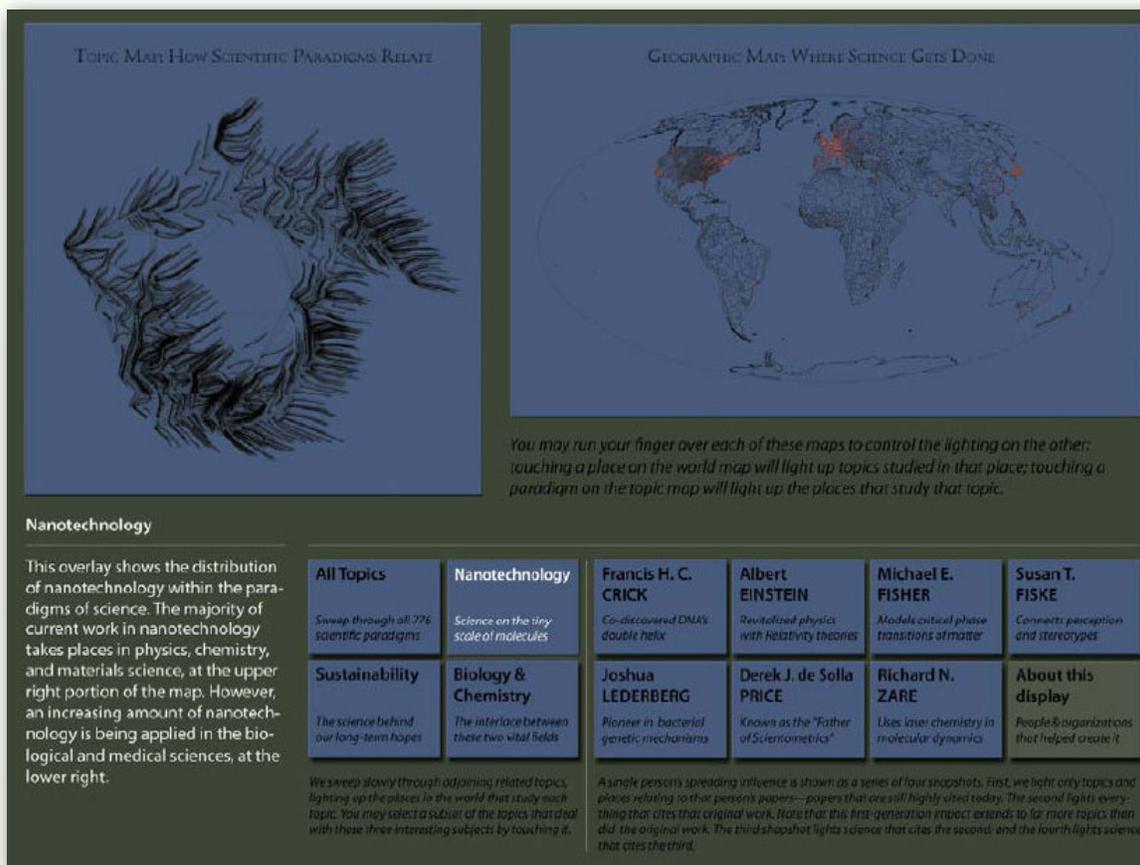


Figure 10

Slide 4 (see Figure 10):

This is the interface to the set-up, so you see a map of science and map of the world. There are also buttons for

more interdisciplinary areas of science and for people. For example, nanotechnology would need many different fingers to actually pin down all those areas of science which are involved in nanotechnology. The same applies for sustainability research.

Currently the display renders publication data in a visual form. Wouldn't it be nice to also know who is training the students who are going to work in these areas?

On the right-hand side are the so-called people buttons. Here you could click on Albert Einstein and you'd see where he published his work, located on the map of the world and also on the map of sciences. In the second time slice, you'd see all the works which cite Einstein. And in the third time slice you'd see who is citing the cited works. The combined three time slide animation shows the spreading of his ideas spatially and within scientific space. The display could be used to render the diffusion of educational material, students, post-docs, etc. given appropriate data.

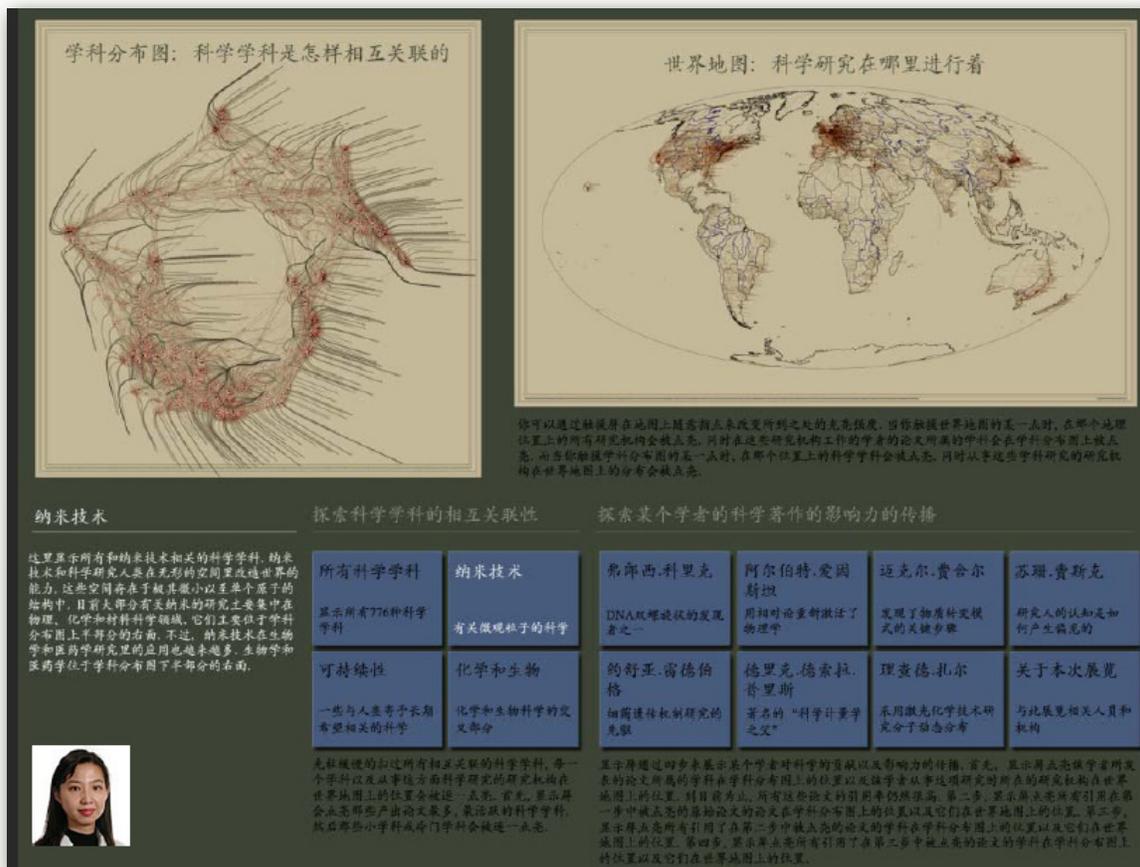


Figure 11

Slide 5 (see Figure 11):

The interface can be provided in different languages. This is the interface for a setup at the Chinese Academy of Science. DNA is the only word I can read.

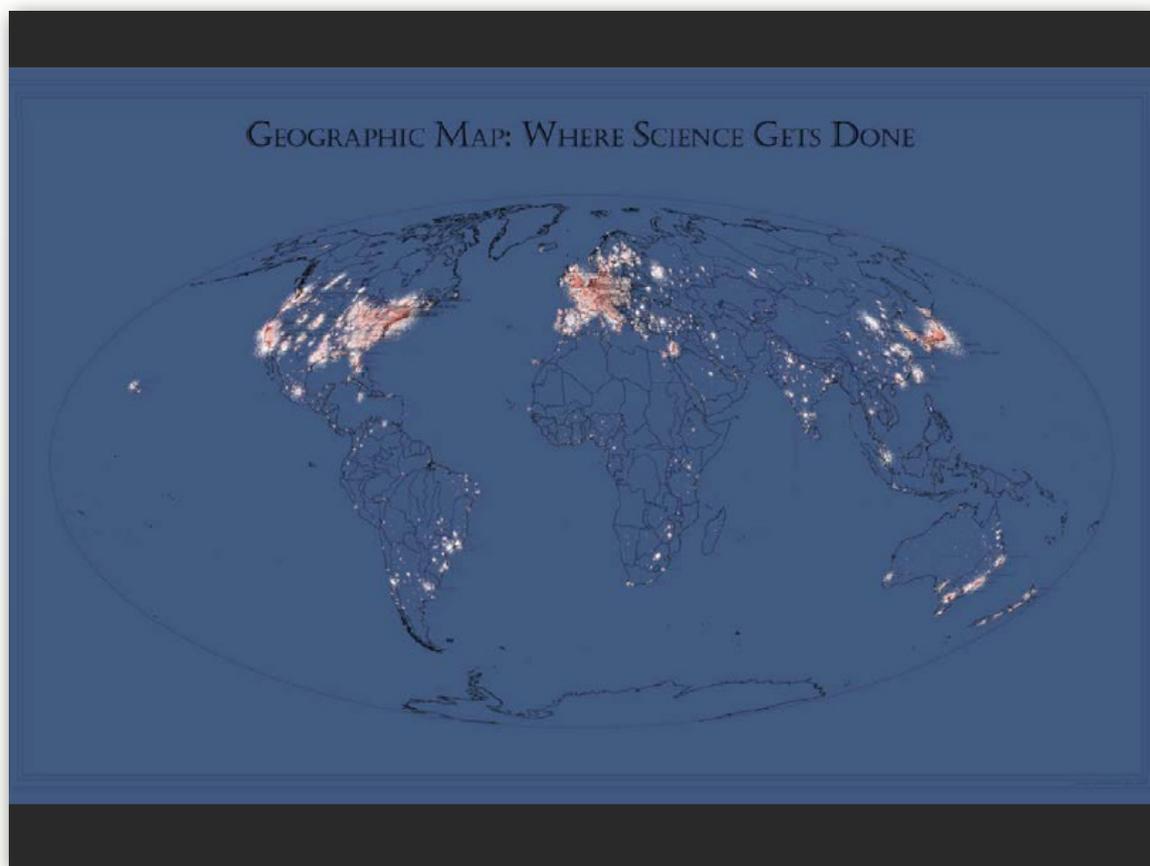


Figure 12

Slide 6 (see Figure 12):

Let's have a closer look at the Map of the World.

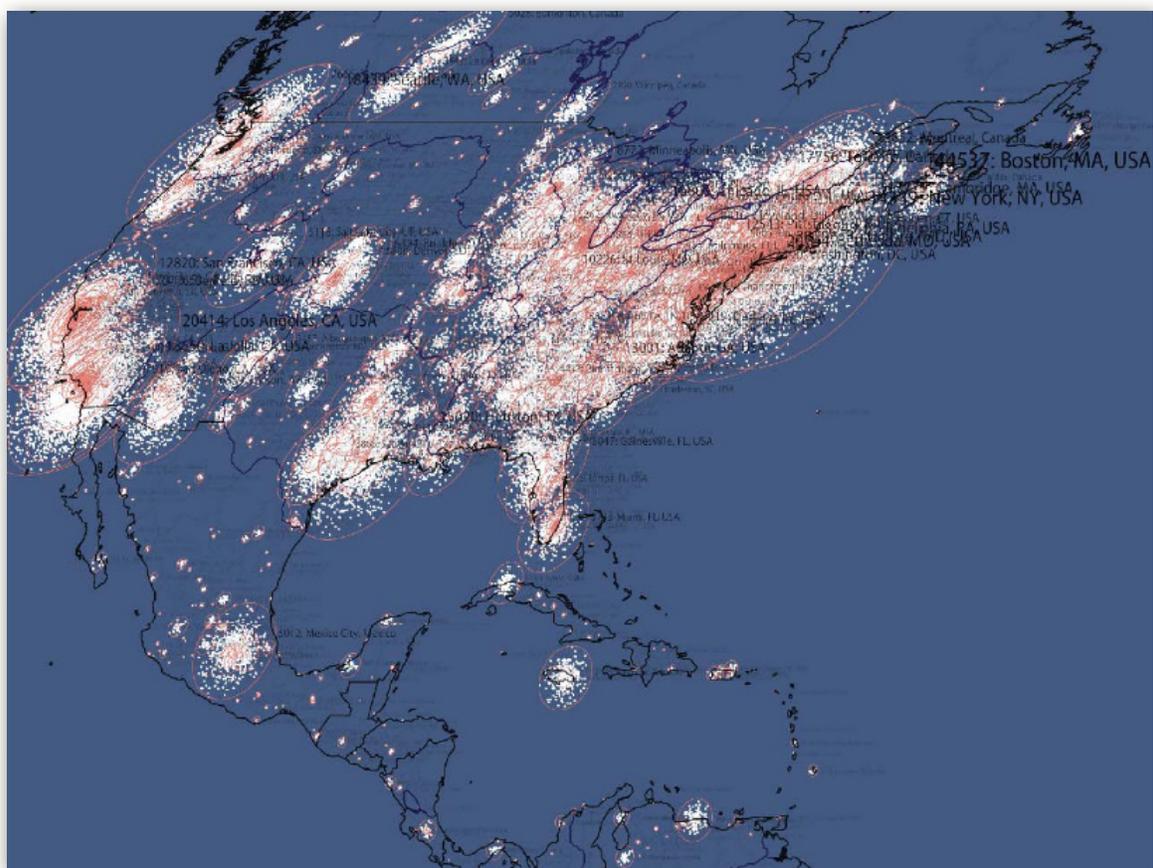


Figure 13

Slide 7 (see Figure 13):

Here you see North America. Every white dot shown is a paper published in the Thompson Reuters database. Some of the areas are circled by red ellipsoids to indicate just how much is actually published there.

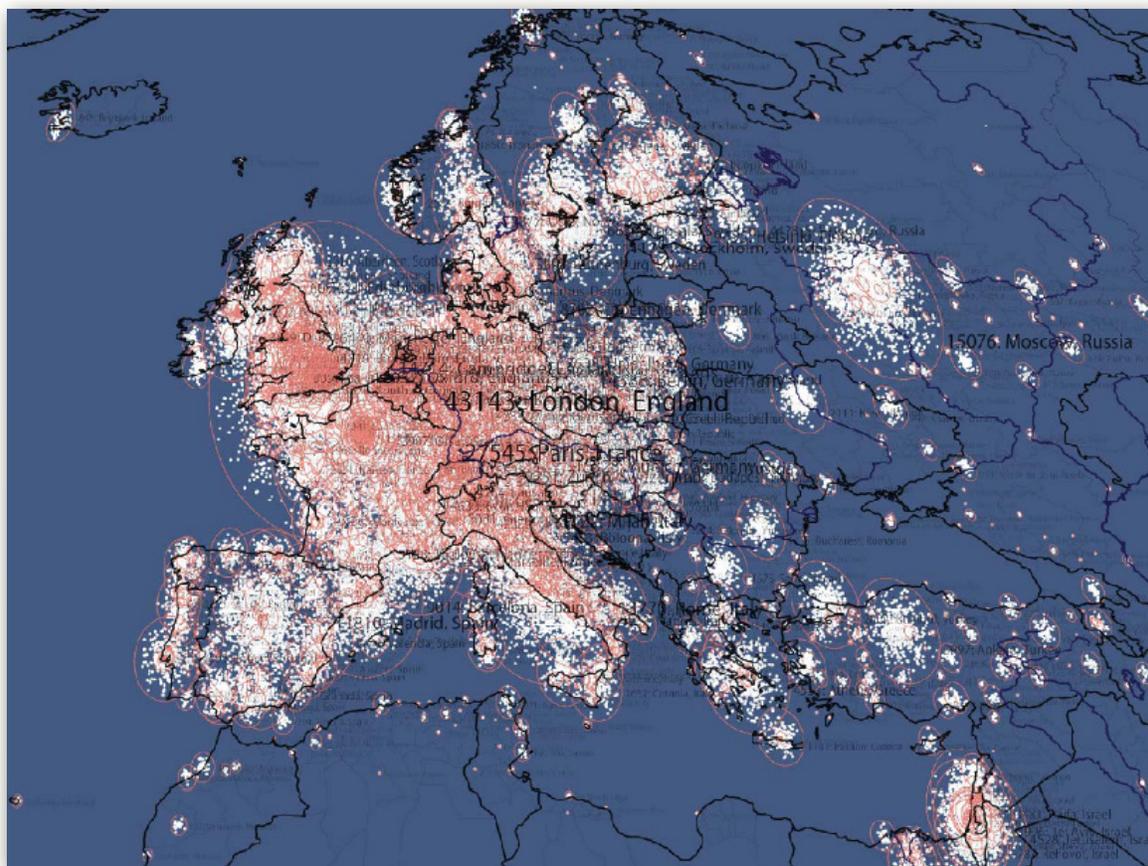


Figure 14

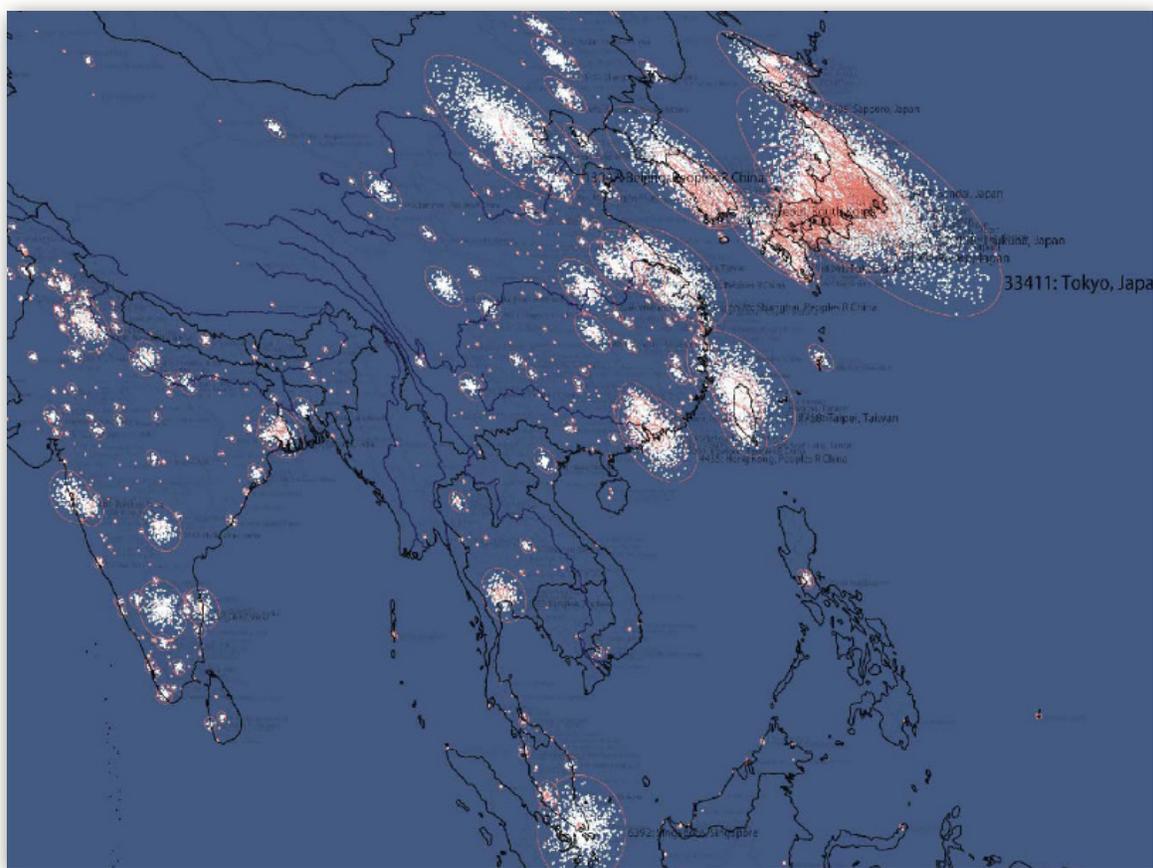


Figure 15

Slide 8 & 9:

This is Europe (Figure 14) and Asia (Figure 15).



Figure 16

Slide 10 (see Figure 16):

Similarly, you can also zoom into the Map of Science. Each major area (node) of science represents multiple journals and each has a flowing label of top keywords.

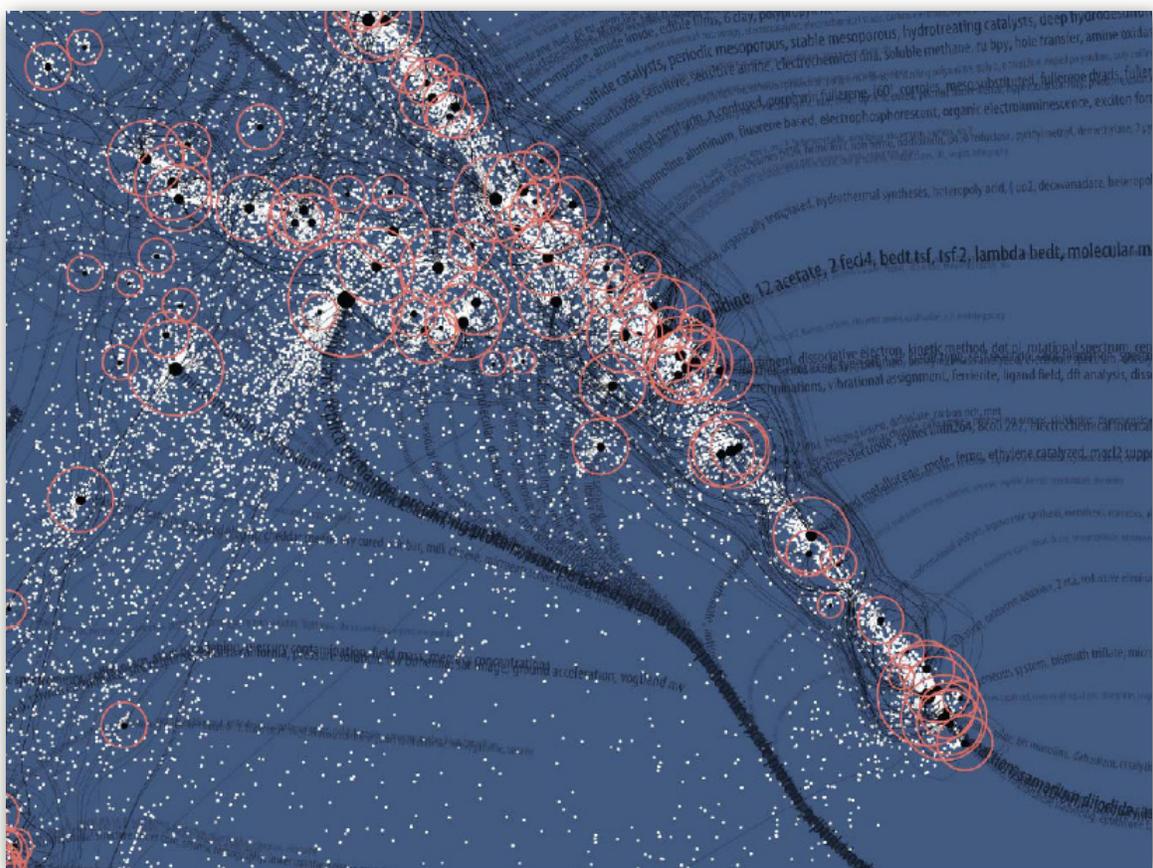


Figure 17

Slide 11 (see Figure 17):

Here is a zoom into the inorganic chemistry peninsula. This so called base map of science can be (and has been) used to overlay scientific career trajectories, the publication record of a university or country, or to compare funding profiles of different agencies.

Slide 12:

Currently, we are working on setups where you have not only two maps but multiple maps. So you could see a global map of science, together with a zoom into medicine, and further into cancer; a map of the world, and a zoom into Asia and further into Japan. A Wii like interface will be used to let people enter names of scientists or areas of research and matching records will highlight in the Illuminated Diagram Display making a large amount of data accessible for a general audience.



Figure 18

Slide 13 (see Figure 18):

We also design science maps for children. These maps show the raw data but we added water color paintings to major areas of science.

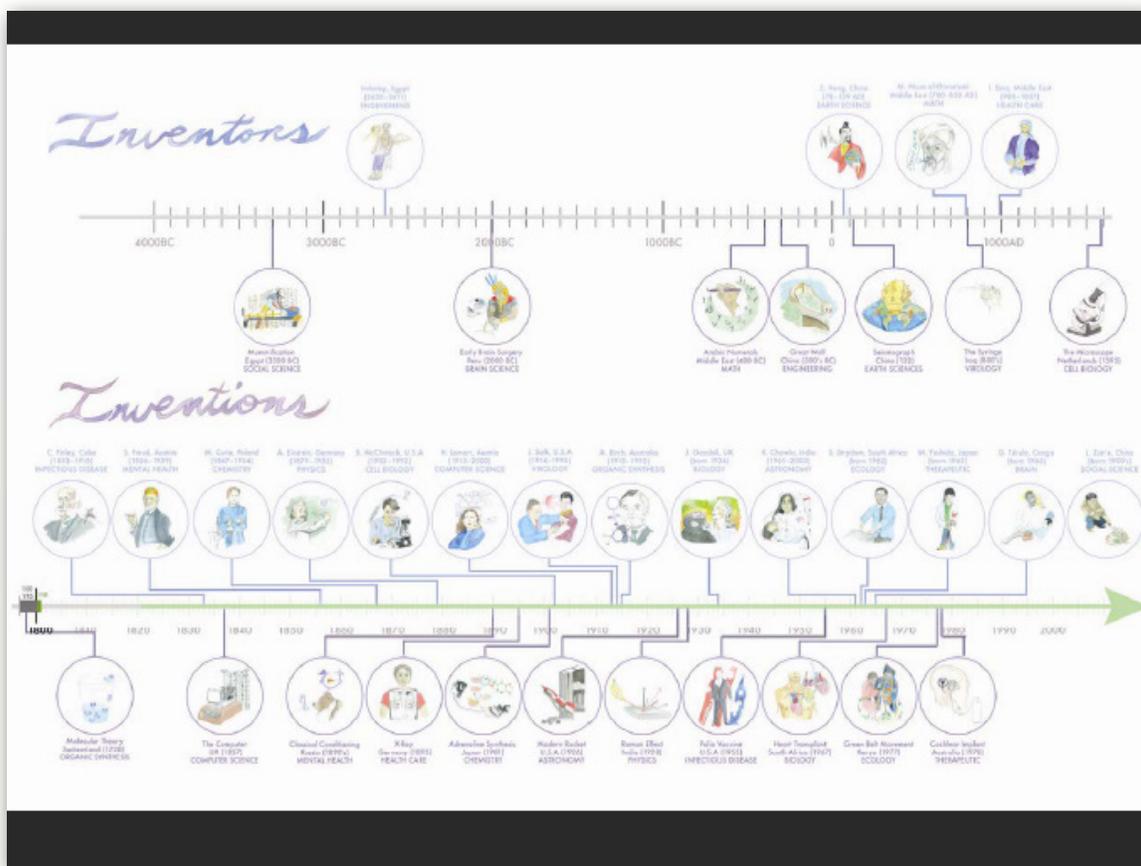


Figure 19

Slide 14 & 15 (see Figure 19):

Students, children or caretakers, are asked to overlay different inventors and inventions on the Map of Science and the map of the world.



Figure 21

Slide 18 (see Figure 21):

Here, you see the physical setup of the two puzzle maps in display at a public library in Bloomington, IN.



Figure 22

Slide 19 (see Figure 22):

We also took maps into classrooms. In the first session we introduced Google maps and asked children about famous explorers and how they travel over physical space and make discoveries. Christopher Columbus comes to mind.

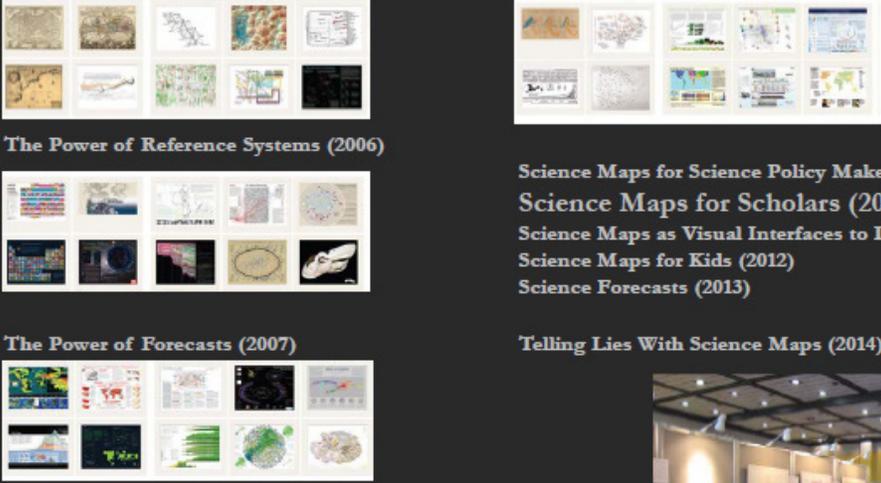
In the second session, we showed them Maps of Science and discussed how researchers also go from one area of science to another and make discoveries along the way. We asked the children where, e.g., Albert Einstein would go. It wasn't clear because he made contributions to many different areas of science. The idea was then to either put him in all three areas or put him in the middle of those areas, which might be "nowhere land" (in the Science Map) or to cut him apart and put the pieces in different areas. Perhaps the answer is not so important, but it is important for children to think about these issues.

Finally, I asked children to find their home in science. There was one seven-year-old girl, who said: "I want to be a nuclear physicist," and she put her star-shaped sticker in the corresponding place on the map of science.

I think it's important that children don't see science as an obstruction, alien, and abstract, but that they find their place in science and that they discover how the many different subjects they learn all day long are connected with each other.

Mapping Science Exhibit – 10 Iterations in 10 years

<http://scimaps.org>



- The Power of Maps (2005)**
- The Power of Reference Systems (2006)**
- The Power of Forecasts (2007)**
- Science Maps for Economic Decision Makers (2008)**
- Science Maps for Science Policy Makers (2009)**
- Science Maps for Scholars (2010)**
- Science Maps as Visual Interfaces to Digital Libraries (2011)**
- Science Maps for Kids (2012)**
- Science Forecasts (2013)**
- Telling Lies With Science Maps (2014)**

Exhibit has been shown in 72 venues on four continents. Currently at

- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA
- Wallenberg Hall, Stanford University, CA
- Center of Advanced European Studies and Research, Bonn, Germany
- Science Train, Germany.



Figure 23

Slide 20 (see Figure 23):

Eight out of 50 maps from the Mapping Science exhibit are on display at the back of this room. This is a 10 iterations in 10-year effort—10 new maps are added every year.

The first iteration was devoted to communicating the power of maps to a general audience. The second iteration discussed the importance of reference systems. Many scientists have created reference systems to locate and access data. Astronomers for instance can point to any segment of the sky and retrieve all data, all simulation results, all imagery, all measurements ever done there. Couldn't we have a similar system of reference for science? The fourth iteration introduced the power of forecasts, i.e., how we can learn from epidemic models, from economic models, oil depletion models, etc. for the forecasting of science itself.

Then there are six iterations which address the needs of specific user groups such as economic decision-makers, science policy makers, scholars (in 2010), maps as visual interfaces to digital libraries, science maps for children, and also science forecasts for the general public.

The 10th iteration will be on the topic of how to tell lies with maps. Maps have always been used for the interests of those who had the money to pay for them.

Slide 21:

If you would like to see the maps in their native size and archival quality—they are on display at Stanford University. It is our hope to bring the exhibit to Washington DC and your suggestions for possible venues are most welcome.

Slide 22:

My second point today is that: science and technology but also STEM are evolving dynamically. I don't think we need to do Meltdown modeling yet. However, we can learn from economic models and in particular this latest article by Mark Buchanan.

Slide 23:

It does not suffice to just count. We need a way to monitor, analyze and visualize STEM in real time so that anybody can see research results, policy decisions, teaching materials, job advertisements, together with bursts of activity and evolving communities of research and teaching practice, positive and negative feedback cycles. We need validated techniques, which are documented in a way that they can be understood and replicated across disciplinary boundaries.

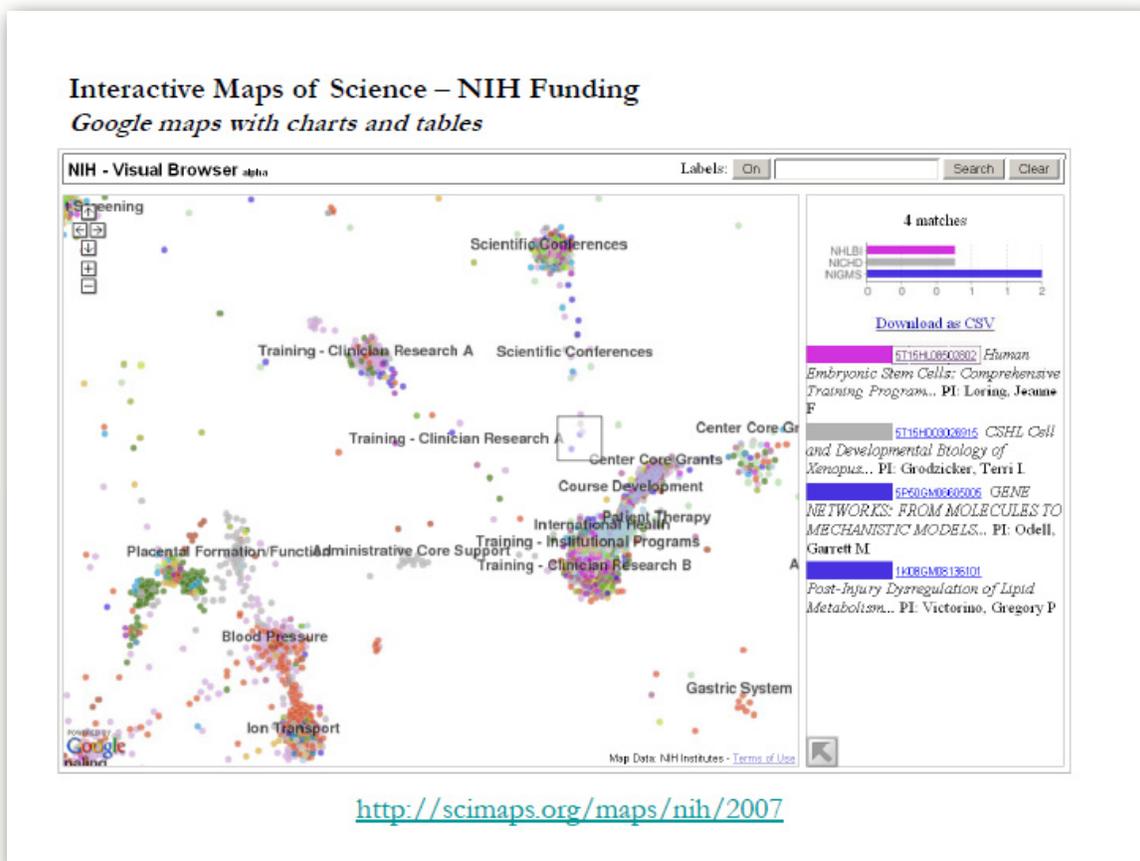


Figure 24

Slide 24:

I would like to inspire this by showing you maps developed for other datasets and different questions. However, these maps might inspire you to do similar analyses using STEM data.

This is a map of all funding awarded by the National Institutes of Health (NIH) in 2007 (see Figure 24). A simple Google map browser is used to interactively navigate the topic space of all awarded extramural NIH projects. Each project is represented by a dot that is color coded by the respective NIH institute. You might interactively explore it via the link given below the map. Specifically, the online version let's you zoom and pan, select projects to see what institutes fund them and to access information on their titles, PIs, and abstracts.

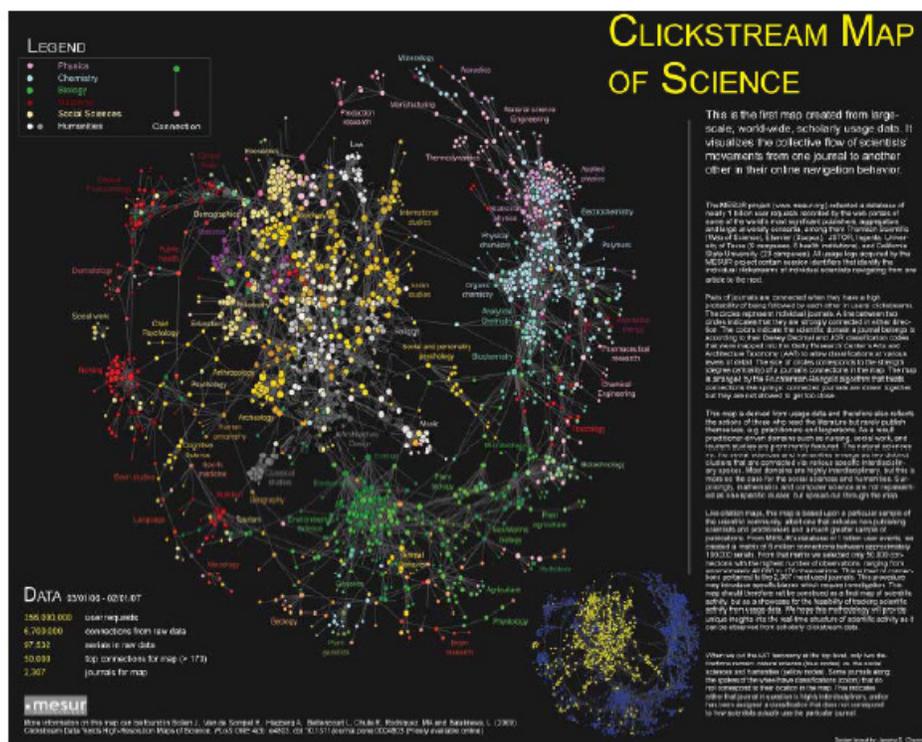


Figure 25

Slide 25:

This map (Figure 25) shows a map of science generated based on download logs by Johan Bollen and his colleagues. Whenever a user accesses paper A and then paper B, papers A and B are assumed to be related. Given more than 1 billion download counts a map can be created that reflect the access to (not citations) of scientific papers. As you might realize many doctors actively read Medline papers, but they might never write or papers or cite other papers. More details on the used approach are given in the text that accompanies the map and the associated paper. I would like to encourage you to actually read the text.

Interactive Maps of Science – Philanthropy



<http://www.philanthropyinsight.org>

Figure 26

Slide 26:

Another map I found interesting is an interactive map of financial funding (see Figure 26). It has a lot of very easy to read yet insightful ways to analyze and visualize philanthropy data.

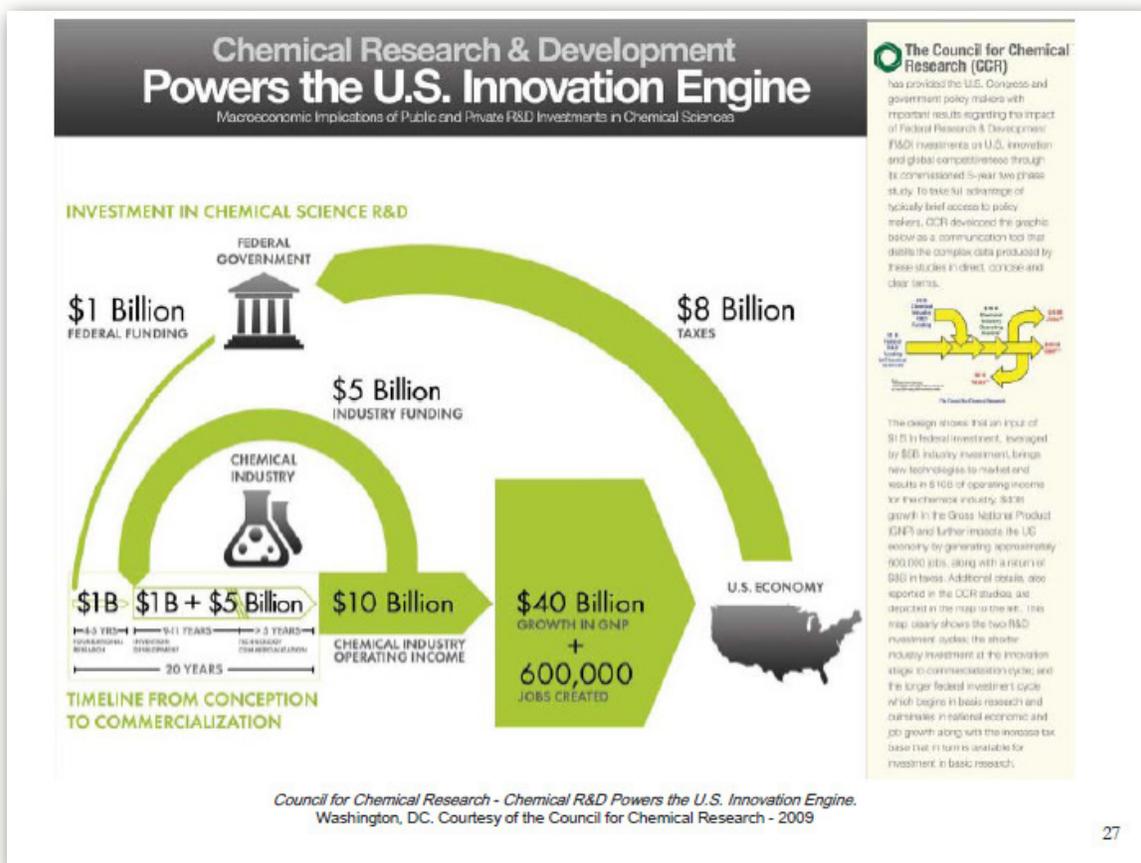


Figure 27

Slide 27:

This is a map entitled “Chemical R&D Powers the U.S. Innovation Engine” created by the Council for Chemical Research in 2009 (see Figure 27). It shows how \$1 billion of federal funding supports basic research, the chemical industry spends another 5 billion to fund invention development and technology commercialization, and how the revenue generated by the chemical industry results in \$40 billion in Taxes and 600,000 jobs ultimately providing the resources for the next round of federal funding of chemical research.

This map is in display here. Please do read the accompanying text for more information.



Mapping S&T Job Market Data in Real Time – GeoMap

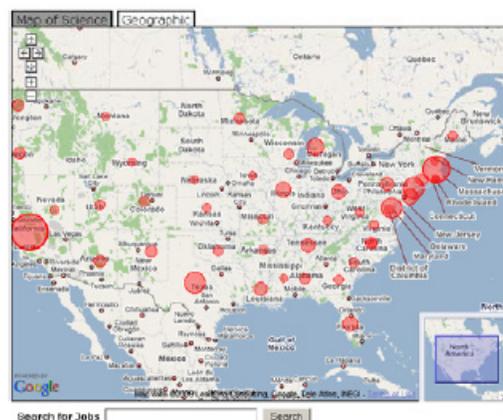
Angela Zoss, Michael Conover

Data

Thousands of full-text, location-specific, time stamped job postings from [Nature Jobs](#) and [Science Careers](#) RSS feeds. The posts have been parsed and stored in a relational MySQL database.

Jobs have been geolocated on a Google map.

Visualization of Job Postings



Geographic Visualization

Here we have a more traditional view of job postings – a geographic overlay. Featured here are the job postings that list both a city and state in the United States. Feel free to search, zoom, pan, and click on job descriptions.

Figure 28

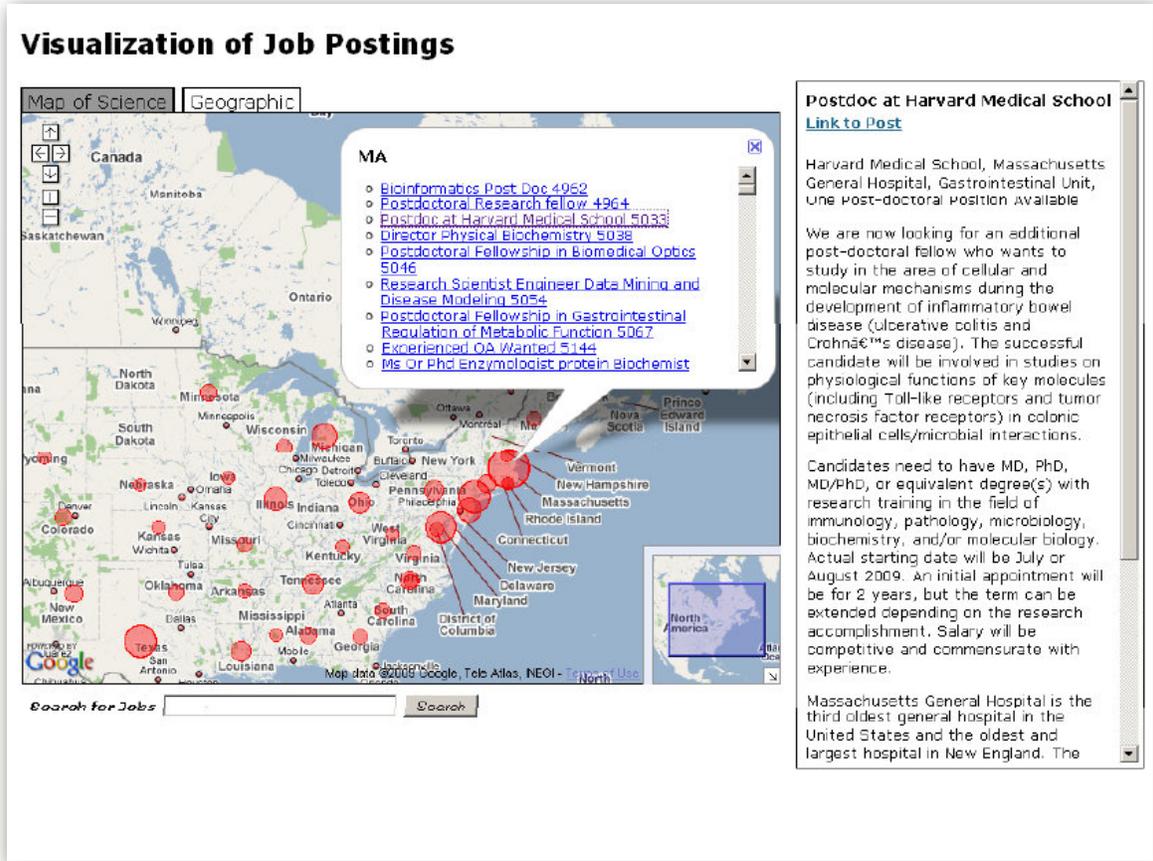


Figure 29



Mapping S&T Job Market Data in Real Time – SciMap

Angela Zoss, Michael Conover

The UCSD Map of Science used here is the product of a large study by researchers at the University of California - San Diego using 7.2 million papers and over 16,000 separate journals, proceedings, and series from Thomson Scientific and Scopus over the five year period from 2001 to 2005.

Jobs were associated with nodes in the Map of Science by way of keyword extraction.

Visualization of Job Postings

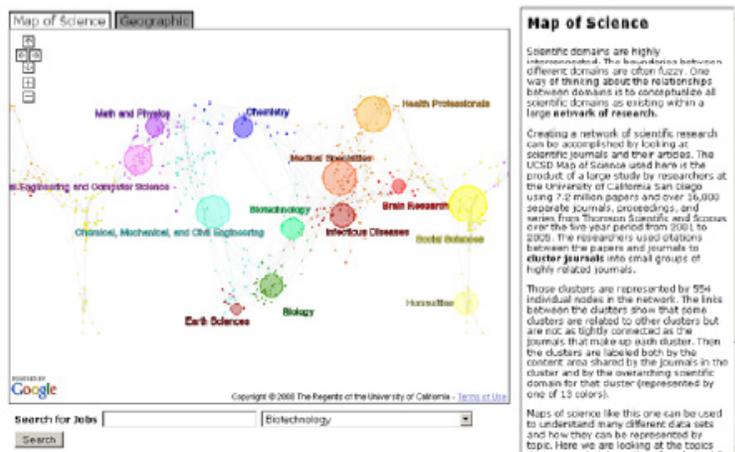


Figure 30

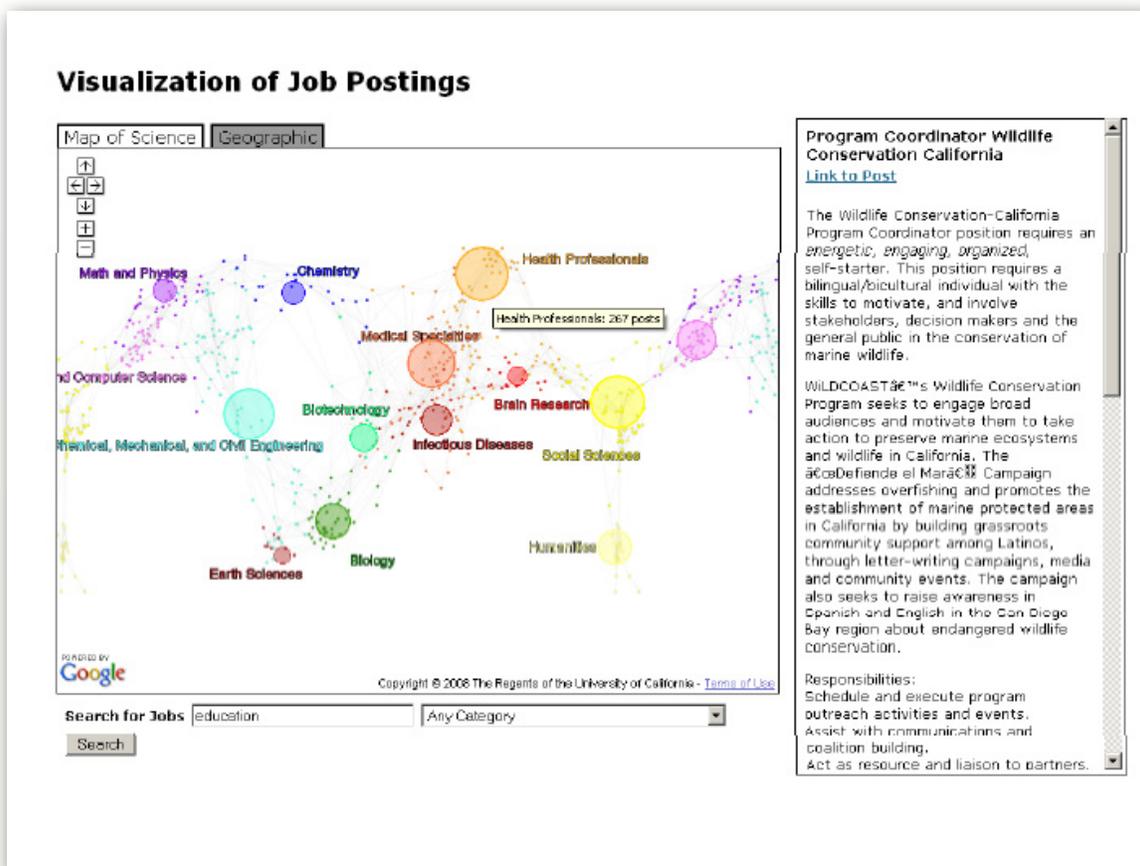


Figure 31

Slide 28-31:

Last but not least, I would like to demo a map of job market data that resulted from a 6 week class project as part of the Information Visualization class I teach at IU. Here, Angela Zoss and Michael Conover acquired information on available jobs from job market RSS feeds (Figure 28 and Figure 29). The data is then overlaid on a map of the world and a map of science (similar to the Illuminated Diagram Display) (Figure 30 and Figure 31). Circles represent sets of similar jobs; clicking on a circle results in a listing of all relevant jobs. Both map types support zoom and pan, search for keywords, e.g., nanotechnology, and access of detailed job descriptions.

As for the UCSD map of science shown here, 7.2 million papers published over a five-year timeframe went into the making of this map by my colleagues Kevin Boyack and Dick Klavans.

Science news, curriculum material, or other STEM relevant data could be rendered in a similar way. One could even add salary data to see what STEM teaching positions offer what kind of salaries.

If two students can create such a service in a six-week class project, then government could do much more insightful yet easy to use interfaces to STEM relevant data.

Slide 32:

The third argument I would like to make, relates to open data and open code for studying individual, local, and global STEM flows and activity patterns. Data needs to be made available in digital, fielded format (not as scanned pdf files) to be useful for data analysis and visualization. Ideally, data is shared as a database dump or MS Excel file with a data dictionary right next to it.

Plus, open code is key to replicable studies that can be trusted. If you work with contractors that use patented, “black box” software and you never get to understand what algorithms or exact parameter values are used then the results cannot be replicated, compared, or interpreted in a scientific manner. Ideally, there would be open data and open code for different levels and types of analysis as listed here.

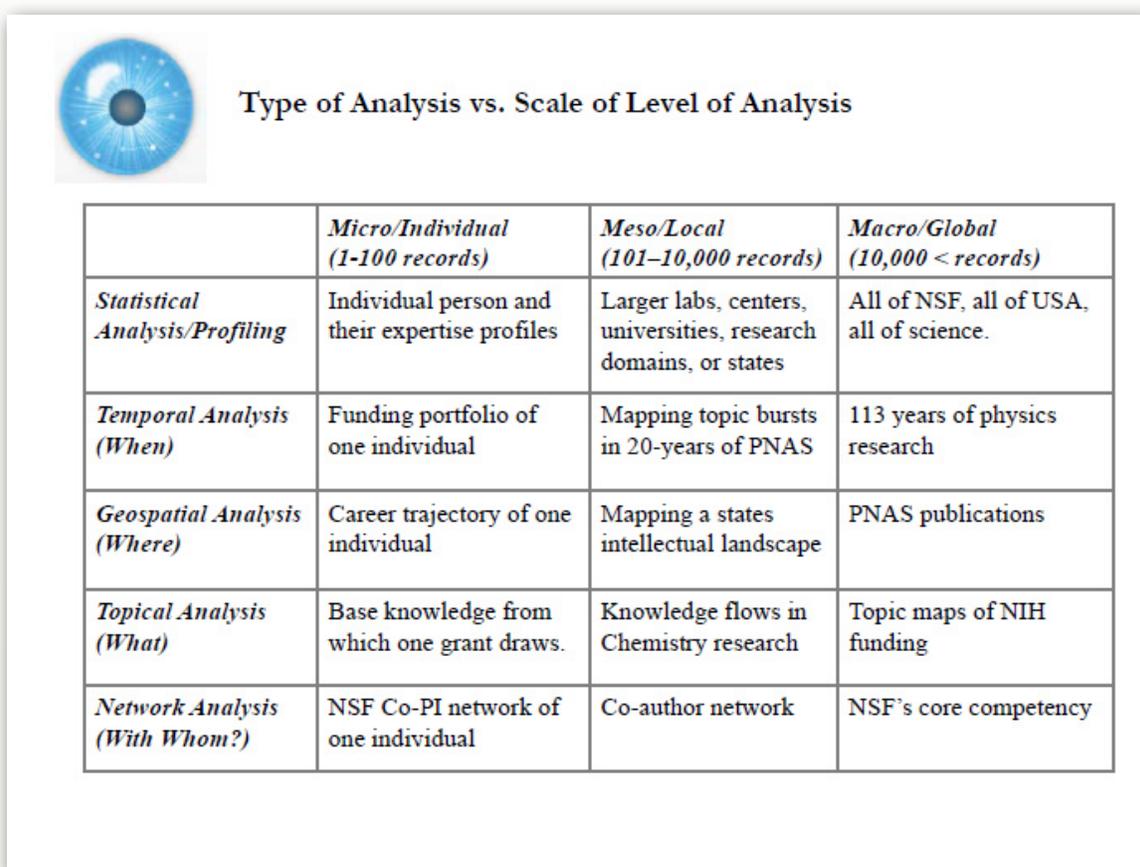


Figure 32

Slide 33 (see Figure 32):

The table lists examples of individual, local, and global level analyzes that use statistical analysis and profiling, temporal analysis, topical analysis, or network analysis. Temporal analyses answer “When” something happens.

Spatial analyses answer “Where” questions. Topical analysis answers “What” questions. Network analyses answers “Who” is involved, who is teaching whom, or who had an impact on what questions.

Micro and individual level studies deal with up to 100 records. Here interactive online interfaces can be designed where people can interact and manipulate each single record in real time. At the local scale, e.g., the job visualization, all data can be shown overlaid on a static reference system or base map. At the global scale, in the million or 10 million records range, displaying all records via online interfaces is not feasible. Instead, data might be rendered using desktop tools or simply printed into files. Plus, most analysis algorithms don’t scale beyond one million records.

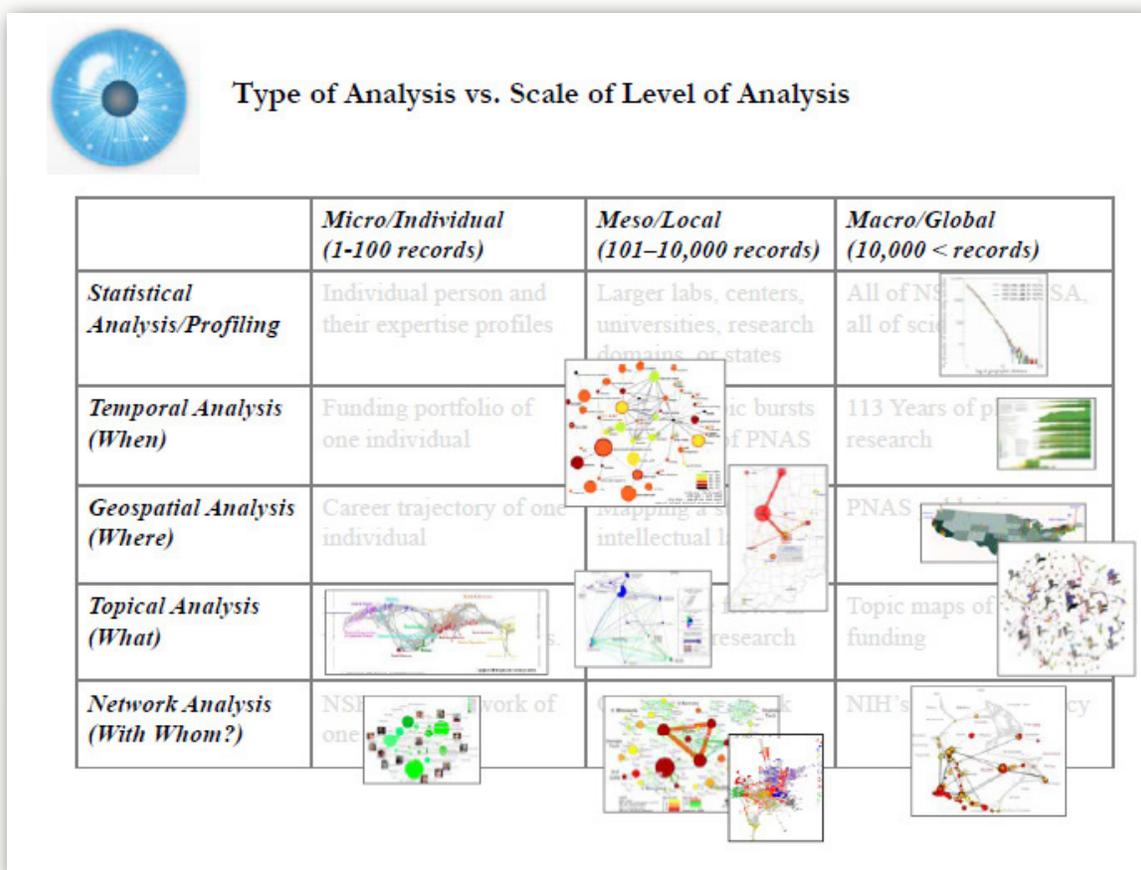
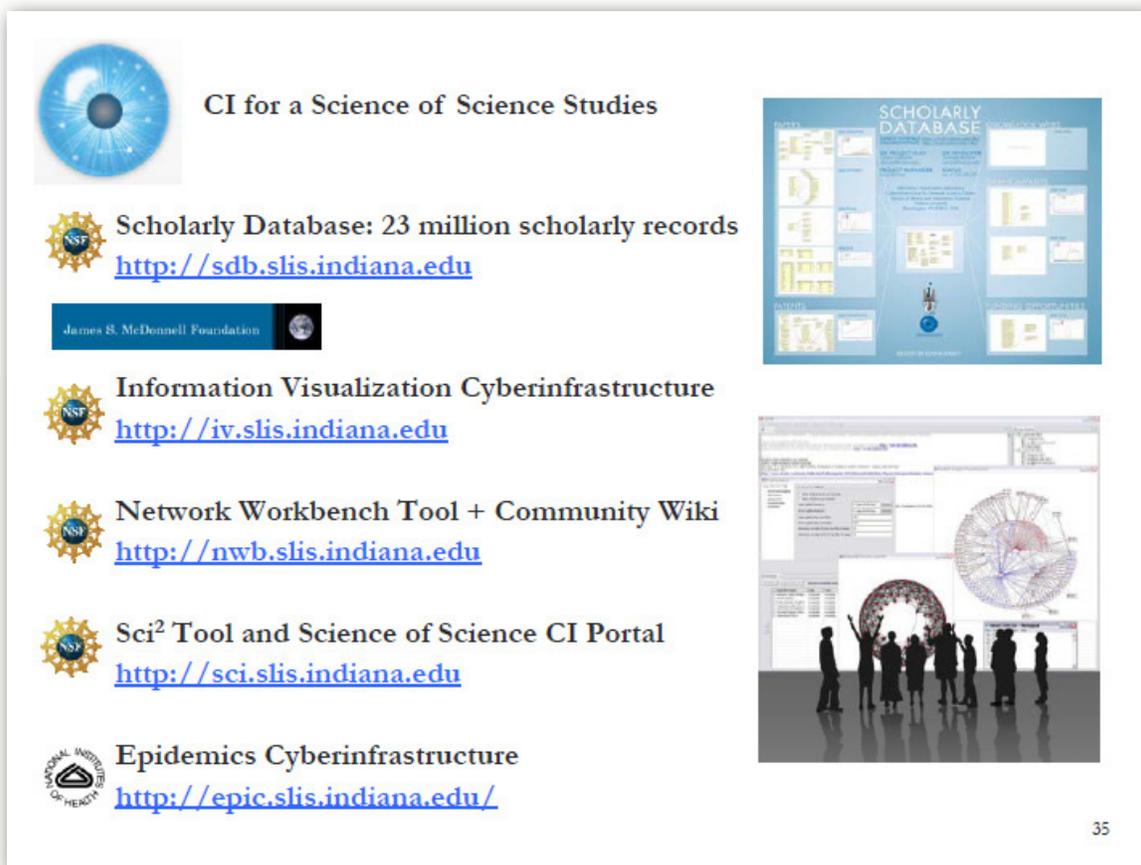


Figure 33

Slide 34 (see Figure 33):

These are some of the maps which you might be familiar with. If you are interested to learn more about these studies, please contact me. As one can see, temporal analysis looks at bursts of activity or plots data over time, e.g., in 113 years of physics research. Spatial analyses commonly use geospatial maps. Topical analyses, might use science maps or topic network layouts to display topic spaces. Social networks are commonly shown as

networks—sometimes as non-legible “spaghetti balls” but more and more commonly in a more legible manner using clustering and backbone identification techniques to give you more understanding about the main structure of the network, the groupings that exist.



CI for a Science of Science Studies

- 
Scholarly Database: 23 million scholarly records
<http://sdb.slis.indiana.edu>
- 
Information Visualization Cyberinfrastructure
<http://iv.slis.indiana.edu>
- 
Network Workbench Tool + Community Wiki
<http://nwb.slis.indiana.edu>
- 
Sci² Tool and Science of Science CI Portal
<http://sci.slis.indiana.edu>
- 
Epidemics Cyberinfrastructure
<http://epic.slis.indiana.edu/>

35

Figure 34

Slide 35 (see Figure 34):

We have managed, thanks to NSF, NIH, and James S. McDonnell Foundation funding, to create a suite of different tools and databases which are useful for the study of science. The Scholarly Database supports to cross-search 23 million scholarly records—Medline papers, U.S. patents, and NSF and NIH funding. You simply type in the name of the creator, title, years, and select a database to retrieve all relevant records, e.g., all papers, patent or grants that have “RNAi” in the title. Search results can be examined and downloaded in bulk in well-documented data formats.

The Network Workbench Tool has 160 different algorithms for the preprocessing, modeling, analysis, and visualization of networks.

The Science of Science Tool will be demoed in the remainder of the talk. The Epidemiology Cyberinfrastructure supports the study of diffusion processes, e.g., the spreading of H1N1 but also the diffusion of ideas or the workforce.

Flyers with more information on these infrastructures can be found on the table over there.

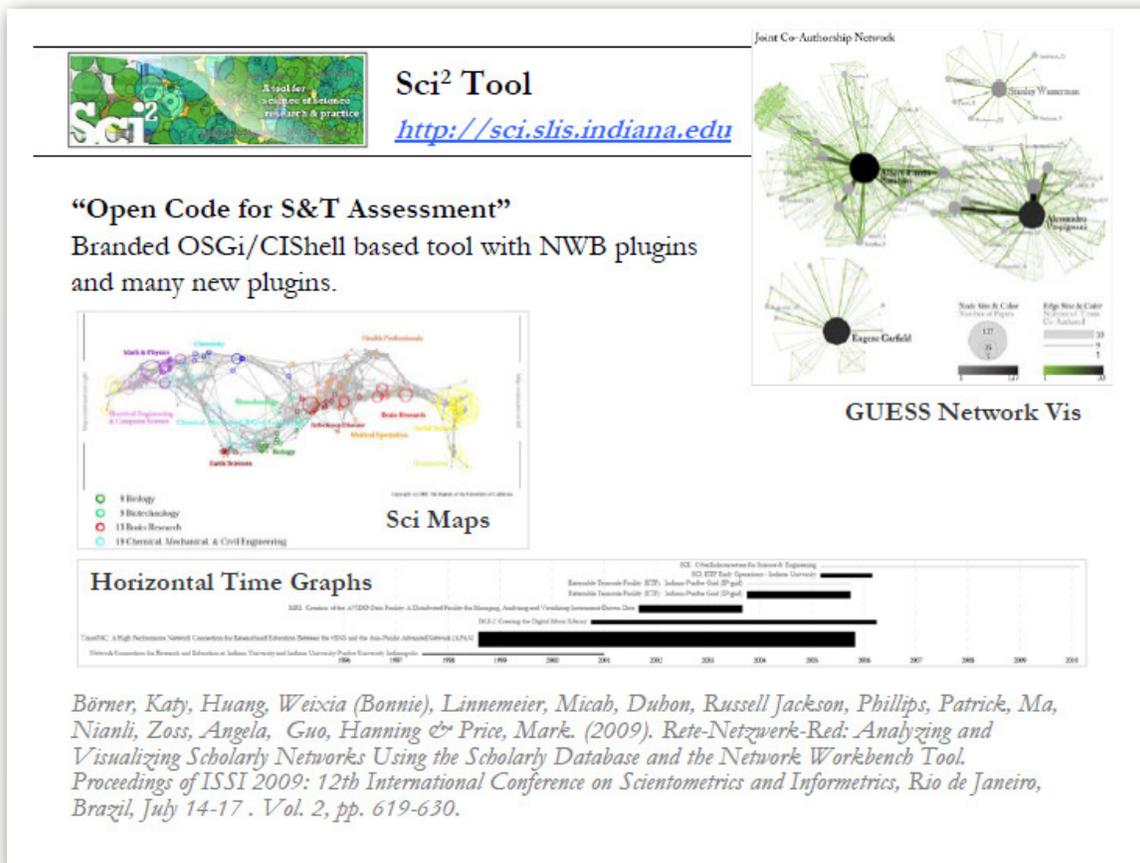


Figure 35

Slide 36 (see Figure 35):

The Science of Science Tool was funded by NSF’s SciSIP program. The tool can be used to extract scholarly networks and to render them in meaningful ways, but also to do science map overlays or so-called horizontal bar graphs. I have examples of the latter.

The bar graphs basically show you how much funding from the starting date of the funding to the ending date for a specific project which is titled here, and then the area is size coded by the amount awarded or the number of jobs created.

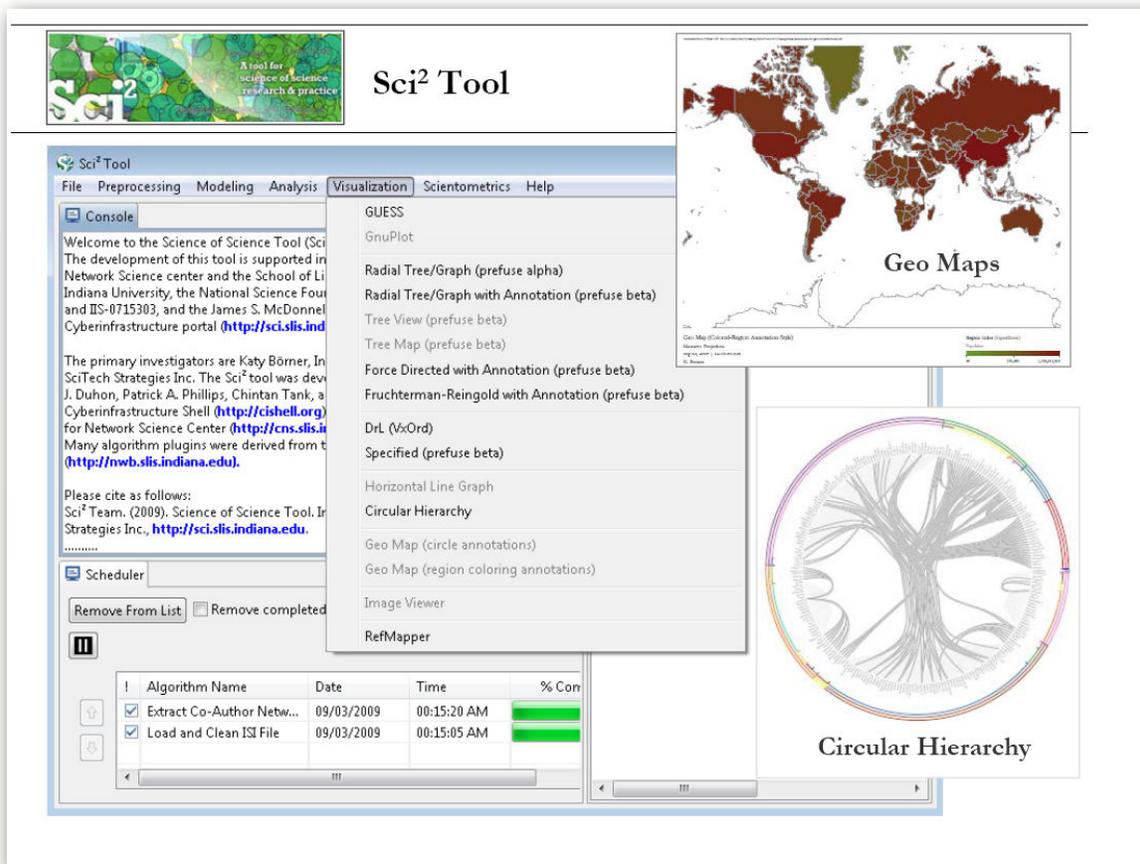


Figure 36

Slide 37 (see Figure 36):

The tool also supports very simple geomaps such as world map and U.S. map overlays. Plus, it can do circular hierarchy renderings. Again all this code is open and well documented. It is licensed using Apache 2.0 so that anybody can take it and create opportunities with it.



Sci² Tool: Supported Data Formats

<p>Personal Bibliographies</p> <ul style="list-style-type: none"> ➤ Bibtex (.bib) ➤ Endnote Export Format (.enw) <p>Data Providers</p> <ul style="list-style-type: none"> ➤ Web of Science by Thomson Scientific/Reuters (.isi) ➤ Scopus by Elsevier (.scopus) ➤ Google Scholar (access via <i>Publish or Perish</i> save as CSV, Bibtex, EndNote) ➤ Awards Search by National Science Foundation (.nsf) <p>Scholarly Database (all text files are saved as .csv)</p> <ul style="list-style-type: none"> ➤ Medline publications by National Library of Medicine ➤ NIH funding awards by the National Institutes of Health (NIH) ➤ NSF funding awards by the National Science Foundation (NSF) ➤ U.S. patents by the United States Patent and Trademark Office (USPTO) ➤ Medline papers – NIH Funding 	<p>Network Formats</p> <ul style="list-style-type: none"> ➤ NWB (.nwb) ➤ Pajek (.net) ➤ GraphML (.xml or .graphml) ➤ XGMML (.xml) <p>Burst Analysis Format</p> <ul style="list-style-type: none"> ➤ Burst (.burst) <p>Other Formats</p> <ul style="list-style-type: none"> ➤ CSV (.csv) ➤ Edgelist (.edge) ➤ Pajek (.mat) ➤ TreeML (.xml)
--	---

38

Figure 37

Slide 38:

These are some of the supported data formats (see Figure 37). You can read in your own bibliography data if you would like to map your personal academic profile. You can also read in Scopus or Web of Science publication data or funding data by the National Science Foundation. Thanks to Jim Onken (NIH), who is in the audience today, we now also support reading in RePORTER data about NIH funding and associated Medline papers and Edison patents.

Slide 39-41:

The Sci2 Tool offers easy access to more than 100 algorithms. Fortunately you have printouts of those slides, so I'm going to rush over those because I want to leave you with an understanding that you can use this tool to make sense of your very own data.

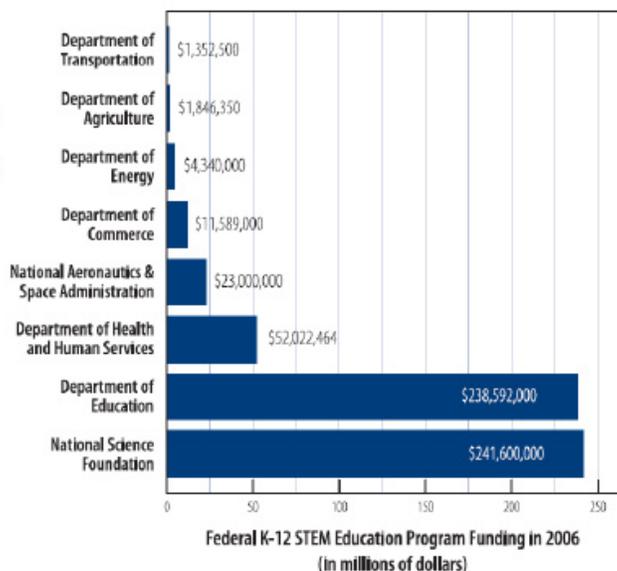


Sample Study – NSF Funding of STEM

Using NSF Awards Search:
<http://www.nsf.gov/awardsearch>
 download relevant NSF awards that have “stem” and “education” in title, abstract, and awards. Active awards only.

Number of awards: 1,340
 Total awarded amount to date: \$1,347,802,833

Retrieved on Oct 18, 2009



Federal K-12 STEM Education Program Funding in 2006

SOURCE: Department of Education, Report of the Academic Competitiveness Council, 2007

Figure 38

Slide 42-44:

According to the “Federal K-12 STEM Education Program Funding in 2006” figure in the 2007 Report of the Academic Competitiveness Council by the Department of Education, STEM is heavily funded by the National Science Foundation (see Figure 38).

To understand what projects are funded by NSF, I downloaded all currently active NSF awards that have “stem” and “education” in title and abstract from the NSF Awards Search site at <http://www.nsf.gov/awardsearch>. On Oct 18, 2009, the total number of awards was 1,340 with a total awarded amount to date of \$1,347,802,833.

Top-10 Projects with highest Award Amount to Date

Title	NSF Org	Program(s)	PI	State	Organization	\$ Awarded to Date
Next Generation Biometrics: Achieving Strength in Molecu	EPS	RESEARCH INFRASTRUCTURE	Paul Hill	WV	Higher Education Policy Commission	10,799,903
UMBC-BCPS STEM Project	DUE	Teaching & Mstr Tchng Fellows	Anne Spence	MD	University of Maryland Baltimore County	11,410,713
MRSEC: MRSEC on Nanostructured Interfaces	DMR	MATERIALS RSCH SCI & ENG	Juan De Pablo	WI	University of Wisconsin-Madison	11,894,150
Spatial Intelligence and Learning Center (SILC)	SBE	SILC ACTIVITIES	SCIENCE O Nora Newcombe	PA	Temple University	12,579,415
Project Pathways: Opening Routes to Math & Science Suc	DUE	Teaching & Mstr Tchng Fellows	Marlyn Carlson	AZ	Arizona State University	13,392,614
NCLT: A Center to Develop Nanoscale Science and Engine	DRL	NANO CTR FOR LEARN & TEAR	P. H. Chang	IL	Northwestern University	15,988,084
Enabling a Giant Segmented Mirror Telescope for the Unite	AST	MID-SCALE INSTRUMENTATION	William Smith	DC	AURA/National Optical Astronomy Obser	18,000,000
Support of Synchrotron Radiation Center Operations	DMR	MPS DMR INSTRUMENTATION	Martin Cadwalladr	WI	University of Wisconsin-Madison	19,526,600
TeraGrid Extension: Bridging to XD	OCI	ETF	Ian Foster	IL	University of Chicago	30,207,358
System-Wide Change for All Learners and Educators	DUE	Teaching & Mstr Tchng Fellows	Terrence Millar	WI	University of Wisconsin-Madison	35,900,000

Figure 39

Slide 44 (see Figure 39): The top 10 projects with the highest award amount are shown here.

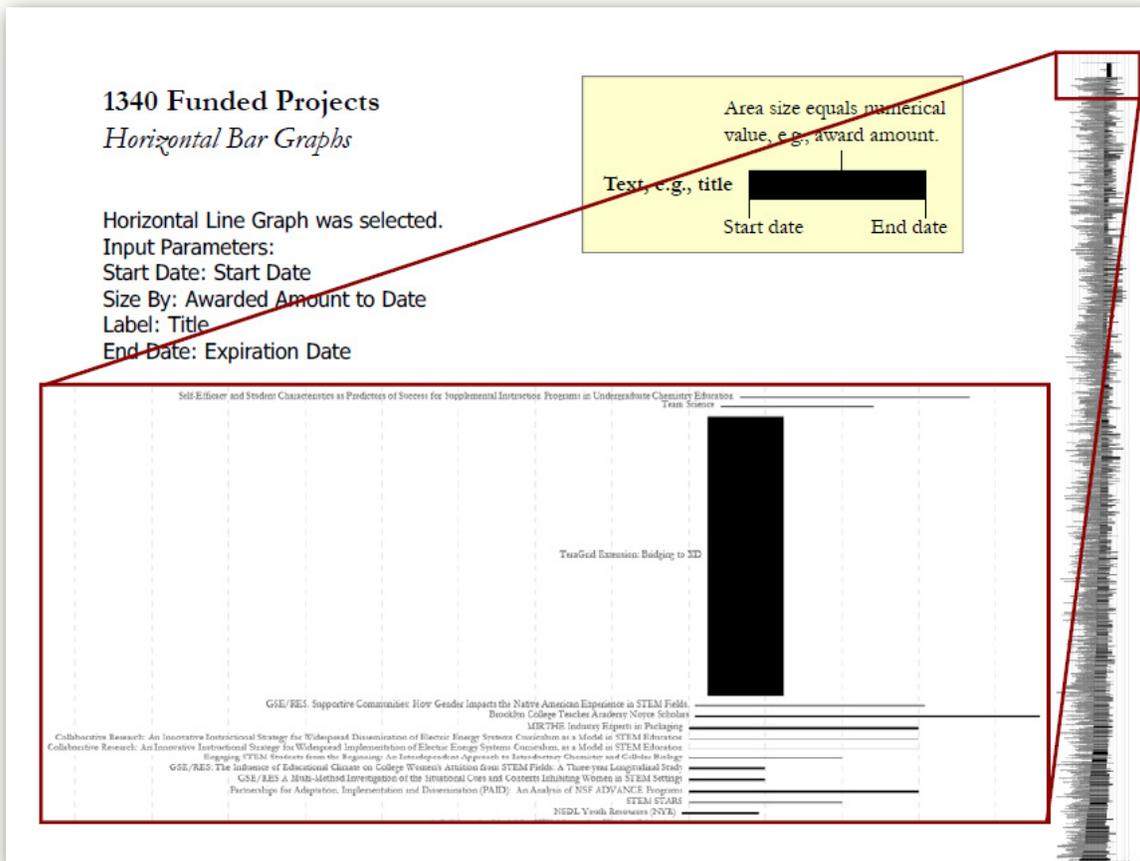


Figure 40

Slide 45: Interested to gain an overview of all funding durations and amounts, I used the Sci2 Tool to render the 1,340 awards as a so called “horizontal bar graph” (see Figure 40). Time runs from left to right and each project is represented by a horizontal bar labeled by its title on left. The beginning and ending of each bar corresponds to the project start and end dates respectively while its area size corresponds to the total award amount. Major projects are easily identifiable. Hardware funding (high award amount over a short duration) look like vertical bars. Color coding can be used to distinguish different award types.

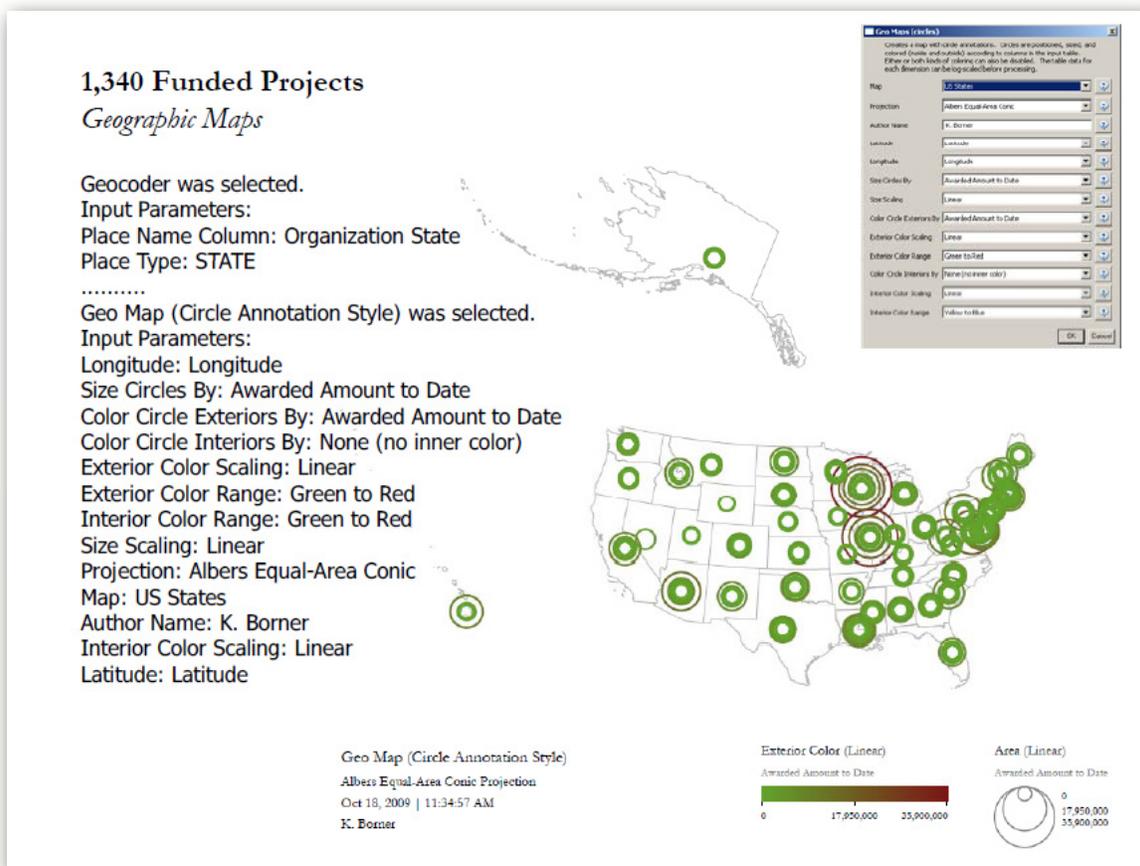


Figure 41

Slide 46-55:

The Sci2 Tool can also be used to geolocate all awards, to see who is collaborating (Co-investigating) with whom, to understand what projects fund which PIs or what NSF Programs are Co-Funding STEM, etc. (see Figure 41).

Slide 55:

It was interesting to see that the “Hist Black” and “Tribal” programs funds institutions that are only funded through these respective programs and by no other program.

According to this dataset, S-STEM:SCHLR SCI TECH actively funds 179 institutions.

Note that these analyses can be replicated by anybody.

Slide 56:

If you are interested to learn more, please consult the Science of Science Cyberinfrastructure Portal at <http://scislis.indiana.edu>.

This is the end of my talk. Thank you for your interest.

Your questions and comments are welcome.

Powerful Numbers or a Short Reflection on Influential Analyses in the History of Science of Science Policy

Presented by Dr. Diana Hicks

DR. DIANA HICKS: Although the name “Science of Science Policy” has emerged only in recent years, quantitative science policy analysis has a history dating back several decades. Over that time, there have been occasions in which scholarly analyses have escaped from the ivory tower and made an impact on policy discussions or on policy itself. Today I want to review with you some of these occasions, looking at what type of analyses were used, who used such analyses, and for what purposes.

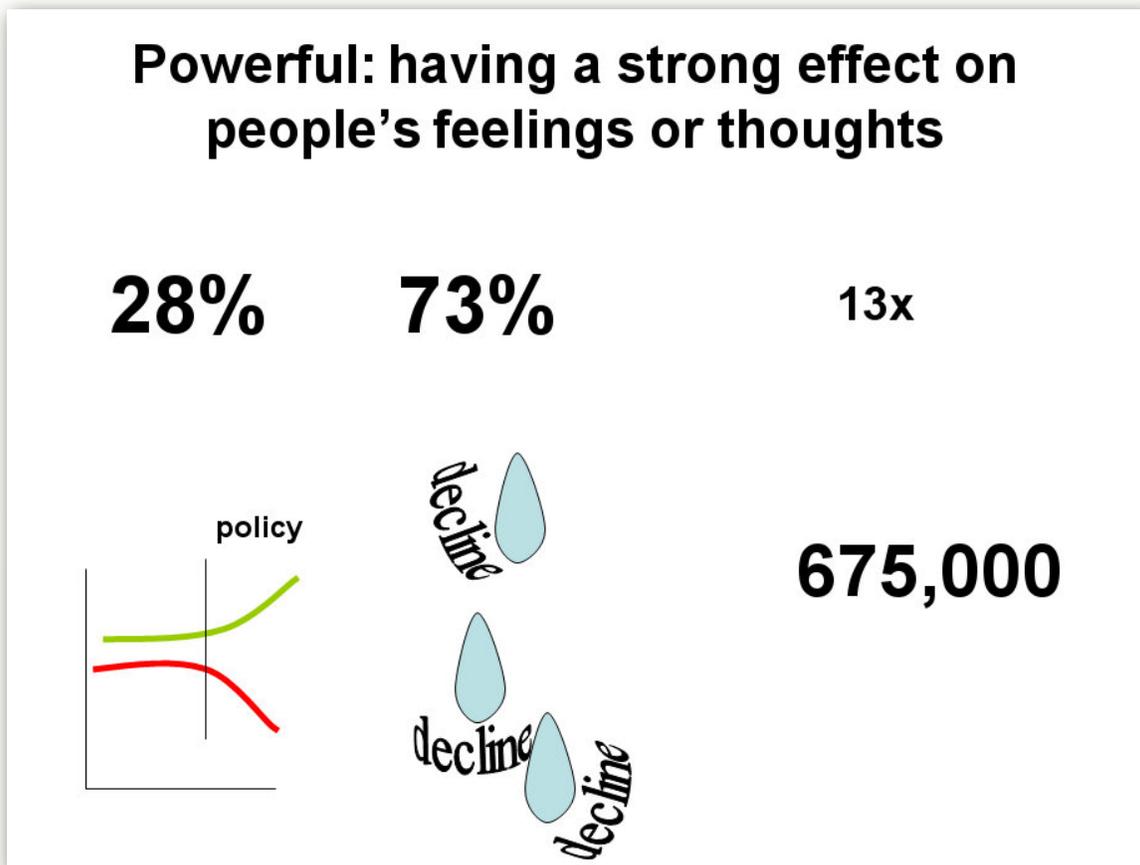


Figure 42

The first number is 28 percent (see Figure 42), produced by the eminent Edwin Mansfield, University of Pennsylvania, and reporting his empirically based estimate of the social rate of return to public research spending. Today there

is a very large literature doing this type of calculation, but Mansfield was the first. This is probably the most influential number in the history of Science of Science Policy. I had a little look back as to where this number originated. Mansfield started this work as early as 1977, but that first paper did not report any single number for the social rate of return.³ Nevertheless, the GAO picked up on it, presumably at the request of Congress, and reported that the work represented state-of-the-art methodology:

*GAO was asked how the results of federally financed research and development spending could be measured . . . Edwin Mansfield's recently completed study of innovations' rate of return exemplifies this methodology's current applied state of the art.*⁴

The specific number was published 15 years later in *Research Policy* (1991).⁵ “28” was scattered throughout this paper. Here is a part of the paper’s conclusion:

*A very tentative estimate of the social rate of return from academic research during 1975-78 is **28 percent**, a figure that is based on crude (but seemingly conservative) calculations and that is presented only for exploratory and discussion purposes. It is important that this figure be treated with proper caution and that the many assumptions and simplifications on which it is based (as well as the definition of a social rate of return used here) be borne in mind.*

Prof. Mansfield was encouraged to produce this study by the Policy Studies Unit in NSF, who funded the work.⁶ The resulting paper has been extremely influential in scholarly circles, i.e. highly cited, as well as in the policy world. Crucial to the influence of this analysis is that Mansfield did put forth a number. This is a bold move, and one avoided by many scholars. Nevertheless Mansfield’s number is surrounded by scholarly caveats. What happens to this number? What happens to the caveats?

Next year in an interview in *Science* President Bush, Republican candidate for President, is quoted as saying:

*Our support of basic research in these and other agencies is an investment in our future, but by its very nature it is impossible to predict where, when, or to whom the benefits will flow. Nevertheless, we can be sure that these benefits will be substantial. Professor Edwin Mansfield of the University of Pennsylvania has found that the social rate of return from such investments in academic research can very conservatively be estimated at 28%.*⁷

The President used the number in arguing for the value of research funding. A scholar could not ask for a more gratifying policy impact – not only is your number used, but you are mentioned by name. Not surprisingly however, the caveats have disappeared. Caveats do not work well in Presidential interviews.

Nowadays there is a very large economic literature estimating the private and social returns from R&D spending. Arguably Mansfield’s influence was greatest, possibly because he was first. In 1993 the Congressional Budget Office

3 Mansfield, E. et. al. (1977) “Social and Private Rates of Return From Industrial Innovations,” *Quarterly Journal of Economics*.

4 Report By The Comptroller General Of The United States (1979) *Assessing The “Output” Of Federal Commercially Directed R&D*.

5 Edwin Mansfield (1991) Academic research and industrial innovation, *Research Policy*, 20, 1-12.

6 Susan Cozzens, personal communication, 2009.

7 *Science* Vol. 258, 16 October 1992, Policy Forum, Interview with George Bush, President of the United States and Republican candidate for President.

reviewed Mansfield's work in response to a request from a House Committee. The CBO positioned Mansfield's work as a validation of the vision of Vannevar Bush, the patron saint of U.S. basic research funding and even mentioned caveats:

This staff memorandum was prepared in response to a request from the House Committee on Science, Space, and Technology. The Committee asked the Congressional Budget Office to comment on the policy relevance and statistical accuracy of Edwin Mansfield's estimates of the social rate of return from academic research. Since World War II, U.S. science policy has been guided by Vannevar Bush's vision that, if funded and left to set their own agenda, scientists would amply reward the nation for its investment. Mansfield has shown that, on average, academic scientists have indeed kept their part of the bargain. The return from academic research, despite measurement problems, is sufficiently high to justify overall federal investments in this area.

*Nevertheless, the very nature of the estimating methodology, as Mansfield has noted in his articles, does not lend itself to use in the annual process of setting the level of federal investment in R&D, nor to allocating that investment among its many claimants. Furthermore, given the nature of the assumptions, definitions, and other methodological questions, as Mansfield notes, his result is more properly regarded as indicating a broad range of likely orders of magnitude of the return from academic R&D than as a point estimate (**28 percent**) of the return from federal investment in this area.⁸*

In 1998, Mansfield produced an update in *Research Policy*⁹ and his influence grew. In 1998 the Congressional Budget Office did another report:

*Mansfield estimated that academic R&D gives society a **28 percent** return on its investment; given the uncertainties involved, a more appropriate summary of the study is a range from **20 percent to 40 percent**. Since most of the funding of those academic researchers came from the federal government, the returns should apply, at least roughly, to federal programs that fund academic research.¹⁰*

Accuracy cannot always be assured in the use of scholarly numbers. In 2006 ATP incorrectly reported:

*Mansfield's pioneering work in the 1970s and subsequently in two studies sponsored by the National Science Foundation (NSF) showed private rates of return averaging **25%-36%** and social rates of return averaging **50%-70%**.¹¹*

And in 2006, 28% grew to 40%

*It is no wonder that economist Edwin Mansfield calculated as much as a **40%** rate of return for the Federal investment in basic university based research.¹²*

However, even today the number endures, and thankfully accuracy has returned. As recently as 2007 the number

8 1993, CBO staff memorandum, *A review of Edwin Mansfield's estimate of the rate of return from academic research and its relevance to the federal budget process*

9 Edwin Mansfield (1998) Academic research and industrial innovation: An update of empirical findings, *Research Policy*, 26, 7-8: 773-776.

10 Congressional Budget Office (1998) The economic effects of federal spending on infrastructure and other investments.

11 Jeanne Powell (2006) Economic Assessment Office, ATP, *Toward a Standard Benefit-Cost Methodology for Publicly Funded Science and Technology Programs*, NIST IR 7319

12 The Task force on the future of American Innovation (2006) *Measuring the moment, Benchmarks of our Innovation Future II*.

was used in testimony before the House Committee on Financial Services:

*Mansfield concluded that the average annual rate of return to society from academic research was anywhere from 28 to 40 percent. The Congressional Budget Office, in a 1993 review of Mansfield's estimates, said that "the return from academic research, despite measurement problems, is sufficiently high to justify overall federal investments in this area."*¹³

Although this is no doubt an incomplete record, it does establish the enduring influence of Mansfield's number. Approaching two decades after the original paper was published, this number still influences our thinking.

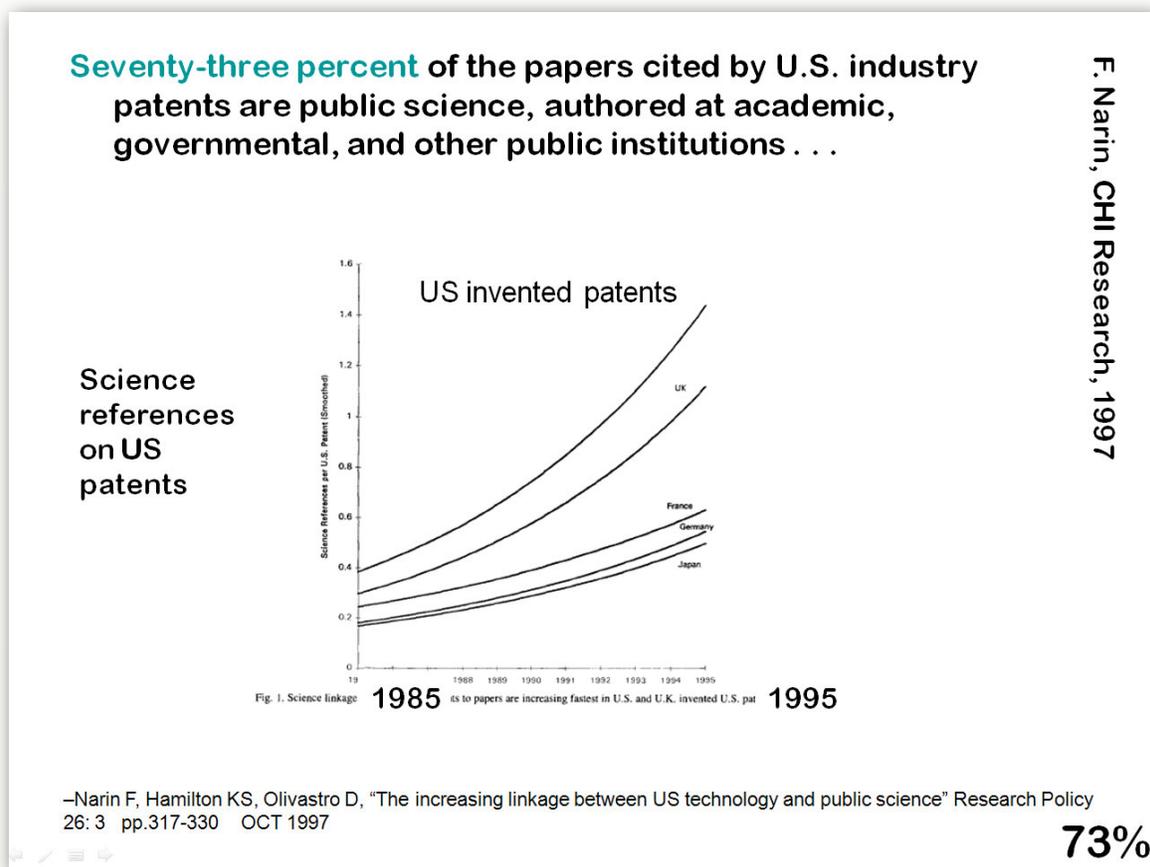


Figure 43

The second influential number highlighted here is 73% (see Figure 43). This was found in a 1997 paper published in *Research Policy* by Francis Narin at CHI Research. The paper revealed that patents were making prior art references increasingly to scientific papers. It was lovely because it is a very direct way of showing Congress that U.S. industry uses the research the government funds. Unlike Mansfield, Narin did not really focus his paper around producing a number. The author's summary of the paper would be that references from U.S. patents to U.S.-authored research papers tripled over a six-year period, from 1988 to 1994. Furthermore, the cited U.S. papers were quite basic,

in influential journals, authored at top-flight research universities and laboratories, relatively recent, and heavily supported by NIH, NSF, and other public agencies. However, the introduction to the paper did contain this:

Seventy-three percent of the papers cited by U.S. industry patents are public science, authored at academic, governmental, and other public institutions . . .

Again, this study was noticed and used by policy makers. A 1997 New York Times article by Bill Broad focusing solely on this paper was headlined: “Study finds public science is pillar of industry.”

There was again a Congressional Budget Office commentary in a report on the economic effects of federal spending:

CHI Research, a patent-citation consultancy, has collected indirect evidence on that point.¹⁴ Patent applications include two types of citations: to other patents and to scientific literature. Of the scientific papers cited in patents, 73 percent were articles written by academic scientists or scientists at governmental or other institutions developing what the authors call “public science.” The authors argue that industry has increased its reliance on public science over the last decade and that public science is, to a large extent, the product of federal funds.¹⁵

Following the pattern set by the Mansfield number, Narin’s number was also misquoted, this time in a report from the House of Representatives:

The above examples of basic research pursuits which led to economically important developments, while among the most well known, are hardly exceptions. Other instances of federally funded research that began as a search for understanding but gave rise to important applications abound. In fact, a recent study determined that 73 percent of the applicants for U.S. patents listed publicly-funded research as part or all of the foundation upon which their new, potentially patentable findings were based¹⁶

If indeed 73% of patent applicants cited public science, that would be a much more powerful number than the actual result, which was that 73% of the cited papers originated in universities. So an element of wishful thinking appears here, as it did with the Mansfield misquotes. The errors are clearly not random. The tendency to ignore reality and pretend numbers are more powerful than they are is one thing that makes scholars queasy and reluctant to interact with policy makers.

Nevertheless, most users did quote the result correctly, even five years later when the National Science Board quoted the results in two documents:

An NSF-supported study found that 70 percent of the scientific papers cited in U.S. industry patents came from science supported by public funds and performed at universities, government labs, and other public agencies.^{17, 18}

14 See <http://www.cbo.gov/doc.cfm?index=601&type=0>.

15 1998, Congressional Budget Office, *The economic effects of federal spending on infrastructure and other investments*.

16 1998 Unlocking our Future: Towards a New National Science Policy, Committee Print 105-B, Committee on Science, U.S House of Representatives, One Hundred and Fifth Congress, September 1998

17 2003, National Science Board, *Fulfilling the Promise: A Report to Congress on the Budgetary and Programmatic Expansion of the National Science Foundation*, NSB 03-151

18 2005, National Science Board, *2020 Vision for the National Science Foundation*, NSB 05-142

Narin also briefed interested Congress members in a breakfast meeting organized by the NSF as well as briefing the National Science Board. The NSB got interested and convened a subcommittee to write a report on Industry Reliance on Publicly-funded Research (IRPR). Caveats were a worry for the subcommittee who found the topic to be more complex than anticipated. The minutes of a subsequent NSB meeting reported that:

There are other indicators to account for, . . . It would be difficult to draw general conclusions, so the paper will contain a number of limited conclusions. Finally, there are issues of credibility to address. The Task Force was concerned that the paper not appear to be self-serving and that it be cautious about overstatement. Consequently, more study and discussion are needed as the Task Force's initial draft is revised.

The Chairman applauded the Task Force for its caution and urged them to continue their efforts which resulted in an addendum to Science & Engineering Indicators 1998 entitled: Industry Trends in Research Support and Links to Public Research (NSB 98-99).

The next example did come up with a number - in private. This is a British example. In the mid 1980s Ben Martin and John Irvine, Science Policy Research Unit, University of Sussex produced a series of commentaries in *Nature*.¹⁹ The titles tell the story: "Charting the Decline in British Science"; "Is Britain Spending Enough. . ."; and "The Continuing Decline . . ." The first one was an analysis of trends in publication output, the second compared levels of research funding in the UK with those of competitors. Martin and Irvine disliked existing funding data and went around the world talking to agencies to collect proper funding data; and their analysis was reported in the second commentary. The next year they updated the publication analysis in the third commentary.

As a result, John Irvine was called in to a meeting with the Minister and was asked, "How much is this funding gap?" The reply was, "£100 million." The Minister replied, "Well, we can do that." And £100 million was added to the science budget. So this series of analyses had a very significant influence on British science policy. At that time, they were doing an update of the funding part of the study and were asked what the new result would be because if it was \$100 million that would be good because the Minister could probably get that a second time, because the Government had that much. But if it was \$500 million they probably couldn't get that, because that was too much. And unfortunately to the academics it looked like \$500 million which put them in an ethical quandary.²⁰ In this example we see some themes repeated, namely the same focus on numbers useful in advocacy for national science budgets as well as the absence of a single, simple number in the original papers. Again a single, simple number was what had some utility and the policy user extracted one.

19 Martin, B & J. Irvine (1985) Charting the Decline in British Science, Commentary, *Nature*, v 316, 587-590; Martin, B & J. Irvine (1986) Is Britain Spending Enough on Science? Commentary, *Nature*, v 323, 591-594; Martin, B & J. Irvine (1987) The Continuing Decline of British Science, Commentary, *Nature*, v 330, 123 -126.

20 Private communication, Ben Martin, 2009.

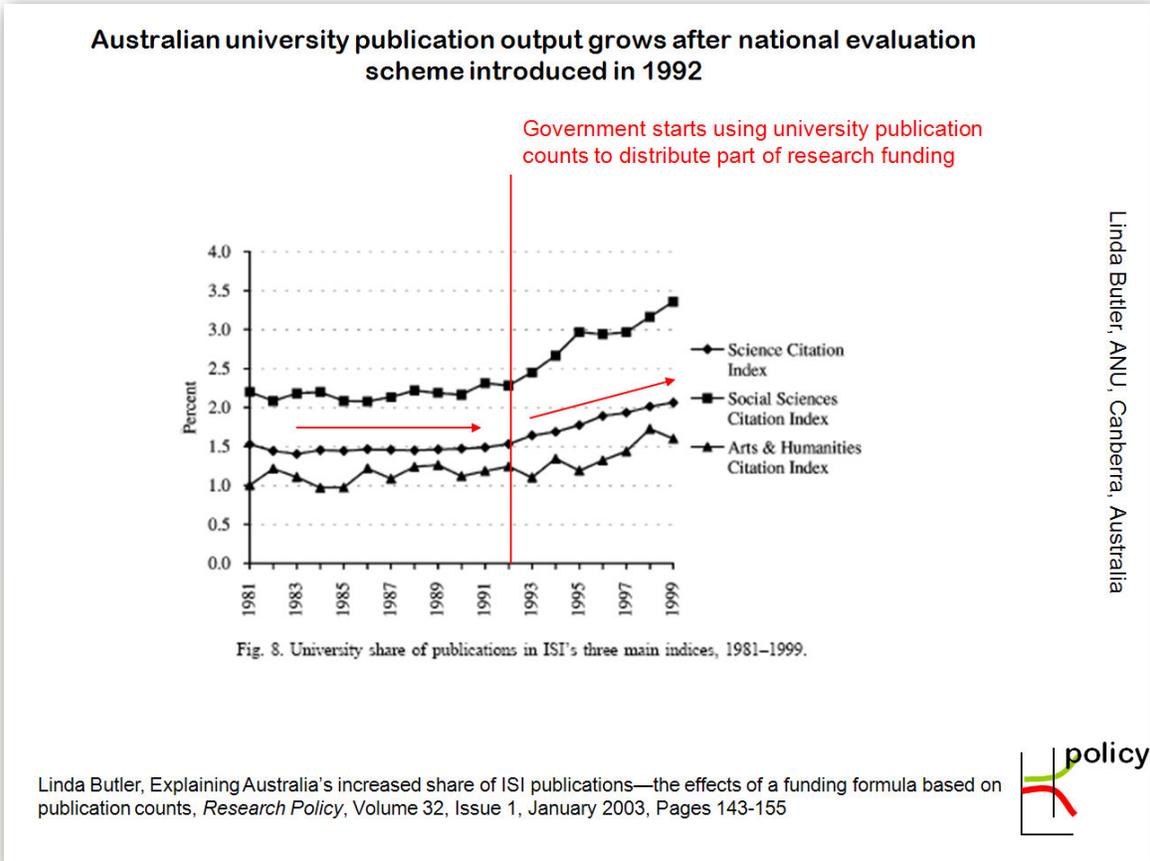


Figure 44

Our next example is also foreign and also changed policy. In Australia all universities have been required to submit to the government details of their publication output (see Figure 44).

Since 1992, all universities have been required to supply details of their publication output, initially through the Australian Vice-Chancellors' Committee, to the Department of Employment, Education and Training. The distribution of that part of the operational grants of universities earmarked for research (known as the Research Quantum) has to a limited degree depended on this information. As the categories covered by this collection have been refined and reduced in number, the importance of ISI-indexed journal publications has increased. It is possible for university researchers to put a dollar value (either to themselves or to their university) on their ability to place an article in an ISI journal. Other refereed journals provide similar rewards, but the difficulty of having their status accepted by independent auditors results in an increasing focus on the ISI journal literature.²¹ (p. 150)

21 Linda Butler, Explaining Australia's increased share of ISI publications—the effects of a funding formula based on publication counts, *Research Policy*, Volume 32, Issue 1, January 2003, Pages 143-155

In other words, the distribution of core research funding for universities was to some extent dependent on bibliometric data. As this exercise was refined over time the importance of having papers in a journal indexed in the *Web of Science* (WoS) increased tremendously and the universities could put a dollar value on their ability to place an article in a *WoS* indexed journal.

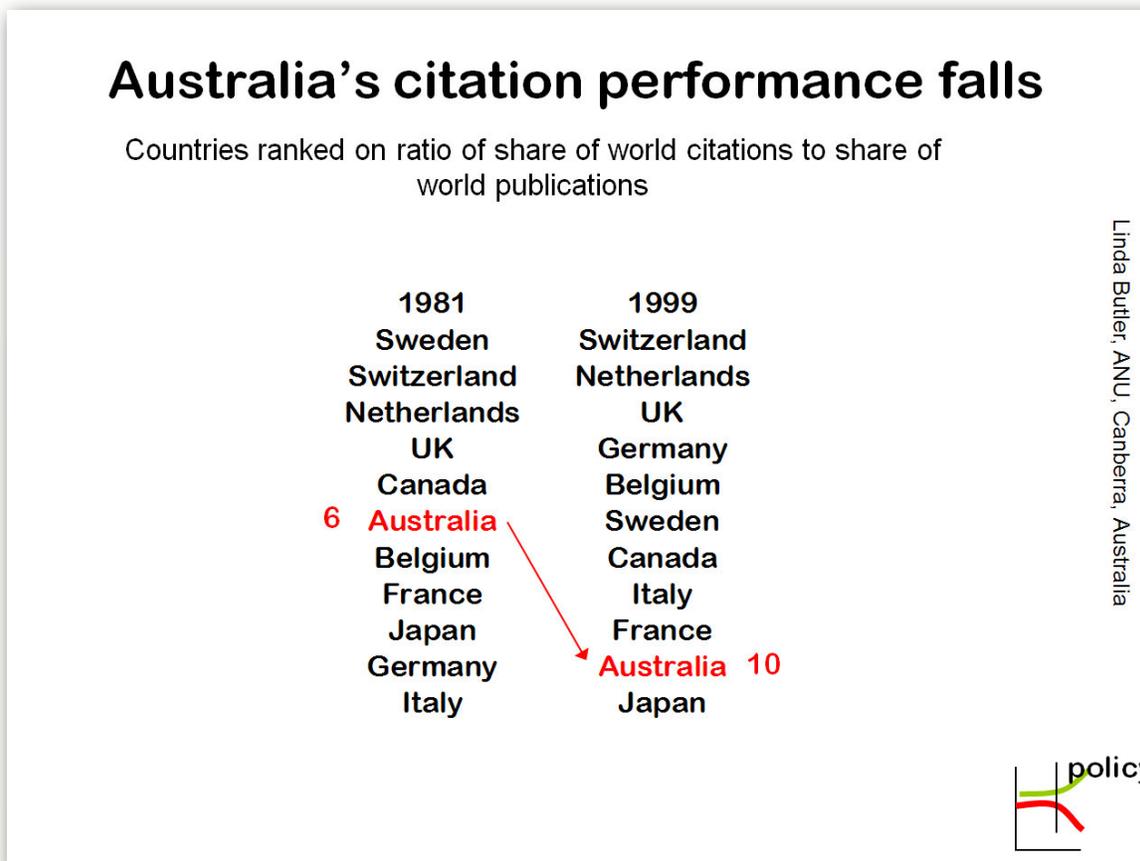


Figure 45

Linda Butler of the Australian National University discovered the striking consequences. She found that the Australian share of world publication output grew after the national evaluation scheme was introduced in 1992, contrasting with a steady state in the decade prior. This is a great result for a policy that was far cheaper than expanding the resources expended upon scientific research. It looks fabulous. But there was a problem. The citation performance of Australia fell (see Figure 45). Among countries ranked on ratio of share of world citations to share of world publications, Australia fell from number 6 in 1981 to number 10 in 1999. What had happened?

Average citation rate of journals carrying Australian publications

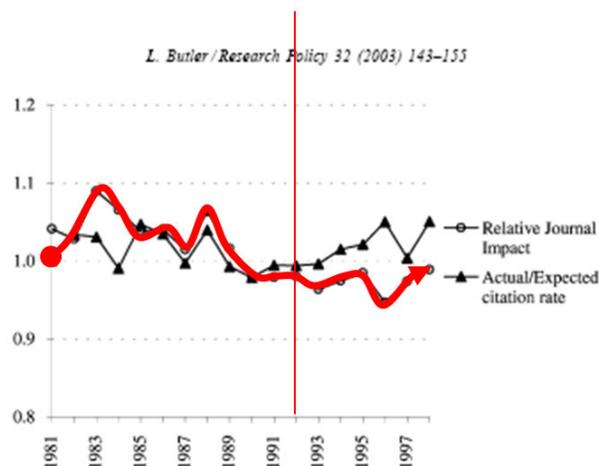


Fig. 5. Aspects of Australia's citation performance, Science Citation Index, 1981–1999.

Linda Butler, ANU, Canberra, Australia



Figure 46

Butler demonstrated that the impact factor of journals publishing Australian papers had declined in this period (see Figure 46). Australians were publishing in higher impact journals before the policy was introduced than after. Once the policy took effect and authors prioritized producing more papers, more Australian papers went to lower quality, yet still WoS indexed, journals. Butler concluded: “Australia’s research evaluation policy had become a disincentive to research excellence,” and the analysis illustrated this quite clearly.

This analysis provided policy makers with an evidential base for an alternative research evaluation policy premised on assessing the quality of research rather than just publication counts. For the assessment of the Butler group’s own research impact, they produced a diagram detailing the funded research projects on the topic, the resulting papers, the government White Papers that cited their papers and their participation in government working groups developing the new Research Quality Framework system. The full chain of influence was recorded.

This example differs from the others in that it did not concern advocacy for science budgets and did not revolve around a single number. Rather the authors changed the way people think, perhaps the highest goal of scholarly work in the social sciences. Another differentiator is that the authors also participated in the policy design process.

Furthermore, the influence of the work was international. The state-of-the-art in national bibliometric evaluation systems now is to have 2 to 4 weighted categories of publications, rather than simply relying on WoS indexing as a marker of quality. This feature directly responded to the conclusions of Butler's analysis.²²

The next example is a personal favorite because I'm claiming this number although there is no attribution. President Obama on September 21 2009 in a speech in Troy, New York, said:

*I've also proposed reducing to zero the capital gains tax for investments in small or startup businesses, because small businesses are innovative businesses; they produce 13 times more patents per employee than large companies do. (Applause.)*²³

The 13x number could only have come from a study for the Small Business Administration by Anthony Breitzman of 1790 Analytics and myself.²⁴ Although a mention in Presidential speech announcing new policy is somewhat better than an interview by the science press, it was unfortunate that our names were not mentioned, a la Mansfield. As in most of the other examples, impact was made by a single number. However, our report did not actually focus on a number, or even contain this number. The number was fished out of a table in the report and conservative rounding was done to slightly reduce the magnitude of the reported value. Alas, as in other examples, the statement is not entirely correct. Small firms do not in fact produce 13 times more patents per employee. Rather, *among America's most innovative firms*, small firms produce 13 times more patents per employee. The study was not concerned with the entire population of firms because most small firms actually run away from innovations as fast as they can. Only the firms with the most patents were studied. I have e-mailed the correction to whitehouse.gov.

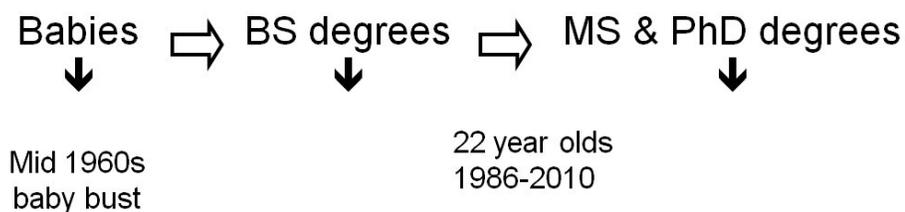
22 Gunner Sivertsen, personal communication, 2009.

23 Remarks By The President On Innovation And Sustainable Growth, Hudson Valley Community College, Troy, New York, September 21, 2009.

24 A. Breitzman & D. Hicks, An Analysis of Small Business Patents by Industry and Firm Size, Report for the Office of Advocacy, Small Business Administration on contract SBAHQ-07-Q-0010, November 2008, <http://www.sba.gov/advo/research/rs335tot.pdf>

675,000 shortfall in bachelor of science and engineering graduates between 1986 and 2010

The analysis was demographic:



675,000

Figure 47

My final example is the number 675,000 (see Figure 47). This number was produced by the Policy Research Analysis unit of the National Science Foundation. 675,000 was the predicted shortfall in the bachelors of science engineering graduates between 1986 and 2010. The number was the result of a very basic demographic analysis. The number of babies declined in the 1960s baby bust, so looking 22 years ahead when those people would be getting bachelors degrees, the analysts predicted bachelors degrees would decrease and therefore MS and PhD degrees would also decrease. Daniel Greenberg's discussion of this incident traces the origins to the appointment of Eric Bloch as director of NSF in 1984.²⁵ In 1987, the Policy Research Analysis division, which reported directly to Bloch, began issuing a series of "pipeline" reports such as its 1989 reports: *Future Scarcity of Scientists and Engineers: Problems and Solutions* (working draft, NSF PRA) and *The State of Academic Science and Engineering* (NSF PRA). Bloch used the number in quite a few public statements. But NSF never officially authorized release of any of the PRA pipeline reports and there were issues with peer review of them. In 1990 Eric Bloch left NSF.

The number was very influential; there were a series of stories in major newspapers including *Science*, the *Los Angeles Times*, *Wall Street Journal*, and *Christian Science Monitor*. Things seemed to be going well until the

President of the National Academy of Engineering went after the number in his Presidential address to the Academy.²⁶ He noted that there was no sign of a shortfall in real life, quite the contrary the job market for engineers was terrible. After this, articles began to appear about the terrible job market for engineers in the early 1990s. In addition, a postdoc in the Naval Research Laboratory, Kevin Aylesworth took an informal poll, published dire results concerning the job market in *Physics Today* and contacted lots of Congressional staffers with his information. It was a bad time for engineers, so these people were really pissed off at the NSF because the advocacy around the 675,000 had to do with generating more PhDs and getting more immigrants in. And the engineers who had PhDs in this country and couldn't find jobs were very annoyed.

Congress held a hearing. Rep. Howard Wolpe had this to say to Peter House director of NSF Policy Research and Analysis division (PRA):

Well, we're here today because of a terrible misunderstanding. I mean, that's really the bottom line. Hundreds if not thousands, of people believed that your study had something definitive to say about the scientific and engineering needs of this country. . .

Science education, immigration policy in this country have been affected by the study and by the number that was its product.²⁷

NSF was engaged in advocacy. Bloch used the number to advocate for greater NSF funding in Congress. NSF numbers were supposed to be above reproach because NSFers were scientists. Congress understood that the numbers produced by their colleagues demanded heavy scrutiny, but they didn't think NSF numbers were in the same category. Congressional disillusionment set in, and NSF's reputation was tarnished. This was a difficult time for NSF because they considered their reputation for being above reproach regarding numbers to be crucial for the continued support of science by Congress.

I noted that the original demographic analysis was very simple, simplistic even; proper workforce arguments are much more complex. That should have been caught in peer review in NSF. Internal problems in NSF were revealed in the hearings, including compromised or absent peer review of these reports. For example, text in *Science and Engineering Indicators* was reworked by the PRA unit anonymously in review to support the shortage analysis. It is ironic that around this time PRA funded the project that produced the most influential and respected number in the history of science policy – Mansfield's 28%.

Conclusion

This paper has reflected on a few examples of scholarly work in the science of science policy that have proved highly influential on policy. There are no doubt many more. In addition, we should not forget those highly influential sources of numbers that are more diffuse, and exert influence over a longer time span – NSF's *Science and Engineering Indicators* for example, or Shanghai Jiao Tong's ranking of universities around the world.

There are several lessons to be drawn from the examples considered here. Policy impact is made by numbers, single numbers. Only Mansfield actually gave the number in his paper. Other scholars did not and policy makers

26 Robert M. White (1990) "Science, Engineering and the Sorcerer's Apprentice," Address to the annual meeting of the National Academy of Engineering.

27 Hearing before The Subcommittee on Investigations and Oversight of the Committee on Science, Space, and Technology, U.S. House of Representatives, 102nd Congress, April 8, 1992, pg. 556-558.

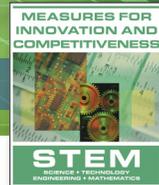
drew out the number that was subsequently used. Those who want to have an impact might be better taking the Mansfield approach and clearly focusing part of their paper on a number. This may help with the accurate reporting of the result in policy circles. Policy influence only comes through the pithy number.

For the most part, the numbers were used to advocate for more research funding (in this as in several other respects the Australian example is an exception). One can advocate for more money in two ways, either by saying the money being spent already is producing very high value, or by pointing out national crisis and decline due to a funding gap. In the United States the numbers that were influential were numbers celebrating the strength of the scientific system – 28%, 73% and 13x. Crisis and decline worked better elsewhere – Britain and Australia, but proved toxic here – 675,000.

Scholars whose work is influential cannot afford to worry too much about caveats or even accurate representation of their results. Some advocates are going to get it wrong. However, scholars must attend to caveats and quality in their original papers. Independent peer review of influential analyses is absolutely critical. If peer review becomes compromised or is absent scholars need to extract themselves from the situation very quickly. This is what went wrong in the 675,000 example.

Finally, it is not clear any of these studies were funded through peer reviewed grant funding mechanisms. Most underwent review, but were commissioned. Mansfield's study for example was solicited by PRA; Narin's work was funded by a larger contract to produce tables for *Science & Engineering Indicators*; my study was for the Small Business Administration which solicits studies on topics of interest and internally reviews the proposals; Martin & Irvine were funded by a consortium of agencies, not the social science funding council in the UK. The PRA work was internal to the NSF. The results discussed here were descriptive and comprehensive. Social science peer review privileges empirical work that is theoretically interesting and analytically complex (complexity is not ideal for producing a clear number). Comprehensive, systemic analysis and description is not well respected in social science scholarly circles. Having said that, the published papers discussed here are all highly cited.

We may conclude that science policy makers over the past few decades have drawn upon analytical scholarly work, and so scholars have produced useful analyses. However, the relationship between policy and scholarship contains tensions. Policy users need a clear number. Scholars hide their light under a bushel, and do not encapsulate their discoveries in simple numbers. Scholars prize accuracy and caveats. Policy makers find caveats muddy the message and their staffs' comprehension of the results they are summarizing is not always accurate. Scholars aiming for impact should attend to cultural differences and avoid stories of decline in the US and of supremacy abroad. Finally, standard peer review granting mechanisms may never fund analyses with the impact of the studies reported here because of differences between the ethos of peer reviewers and the needs of policy makers. Nevertheless, peer review of the results of studies is crucial and must never be compromised.



Measuring and Evaluating the STEM Enterprise Outcomes and Productivity

Presented by Dr. James Hosek, Director, Forces and Resources Policy Center RAND National Security Research Division

DR. JAMES HOSEK: Thank you very much for the invitation to speak. My talk was developed with my research colleague Titus Galama, and it follows on work we did about a year ago when we took an overall look at the U.S. competitiveness in science and technology. The main theme of the talk has to do with recent attempts to improve the ability to estimate the contribution of science and technology to economic growth and in particular to output and productivity. That's the theme we were asked to talk on.

And related to that, recognizing that the education system is itself important to output and productivity, the second theme of the talk concerns will also discuss trends and topics in the U.S. science and engineering workforce and the production of scientists and engineers by the U.S. education system. At the close of the talk, I'll offer some conclusions and policy recommendations.

As we reviewed the literature on recent work on the measurement of output and productivity, we found many different strands of research, which isn't surprising because as other speakers this morning have emphasized this is a very complex area and there is no single metric that is going to tell the whole story.

We Focus Here on Economic Outcomes and Productivity (and How to Measure It)

- Growth accounting
- Studies of economic effects of R&D or new technologies
- R&D in national income accounts
- STEM labor supply
- Bibliometric and patent studies
- Funding for R&D, private and public
- Infrastructure, regulations, incentives, market structure
- National security assessments of S&T

RAND

4 10/09

Figure 48

The talk focuses on just the top four bullets on this chart (see Figure 48). These are growth accounting, studies of the effects of R&D, R&D in national income accounts, and the STEM labor supply. The bottom four bullets, that is, bibliometric and patent studies, funding for R&D, infrastructure, regulation, incentives and market structure, and national security assessments, also represent large bodies of work that deserve attention, but I should apologize right now because we they will not be covered.

The foundation of growth accounting was laid in the 1930s when economists devised a national income and product accounts. As they put these together, they had data on labor, capital investment, and the value of output, and they devised ways to try to deflate the output series to obtain an estimate of the real increase in output and to adjust the capital series for price changes and depreciation to estimate of the real increase in capital. As they did this growth accounting, they discovered that there was a significant increase in output that was not accounted for by the increase in capital and labor inputs.

Accounting for the Contribution of Technology in Economic Growth

- Economists in the 1930s and 1940s modeled long-run economic growth as a function of capital investment and labor availability, leaving an unexplained “residual”
- Solow (1957) attributed almost all the observed growth in output per hour worked to exogenous technological change

$$Y = F(K, L ; A)$$

$$Y / L = F(K / L ; A)$$

- Romer (1990) introduced the premise that technological change arises due to “intentional actions taken by people who respond to market incentives”

$$Y = F(K, L, H, A)$$

RAND

5 10/09

Figure 49

In the '50s Robert Solow wrote an important paper that developed a model that combined output, labor, and capital with consumption and savings to analyze the dynamics of economic growth (see Figure 49). His particular interest at that time had to do with the conditions under which at a macro level there would be steady state growth characterized the rate of saving equaling the rate of investment. He also wanted to relate his model to growth in the U.S. economy, and his work led him to introduce a term in the production function that represented technological change.

He was dealing with the macro economy and used a single production function with output as a function of capital and labor and a term, A, representing technology. In his particular production relationship, which was assumed to be homogeneous, he could divide through by labor and to portray the production function in terms of output per hour of work.

In 1990, a paper by Paul Romer expanded on the Solow model to treat technological change as the purposeful response of economic agents to incentives. In Solow's model, technological change had been exogenous. Romer's work represented a valuable new step by treating technological change as an economic process driven by decision makers in response to the incentives they faced.

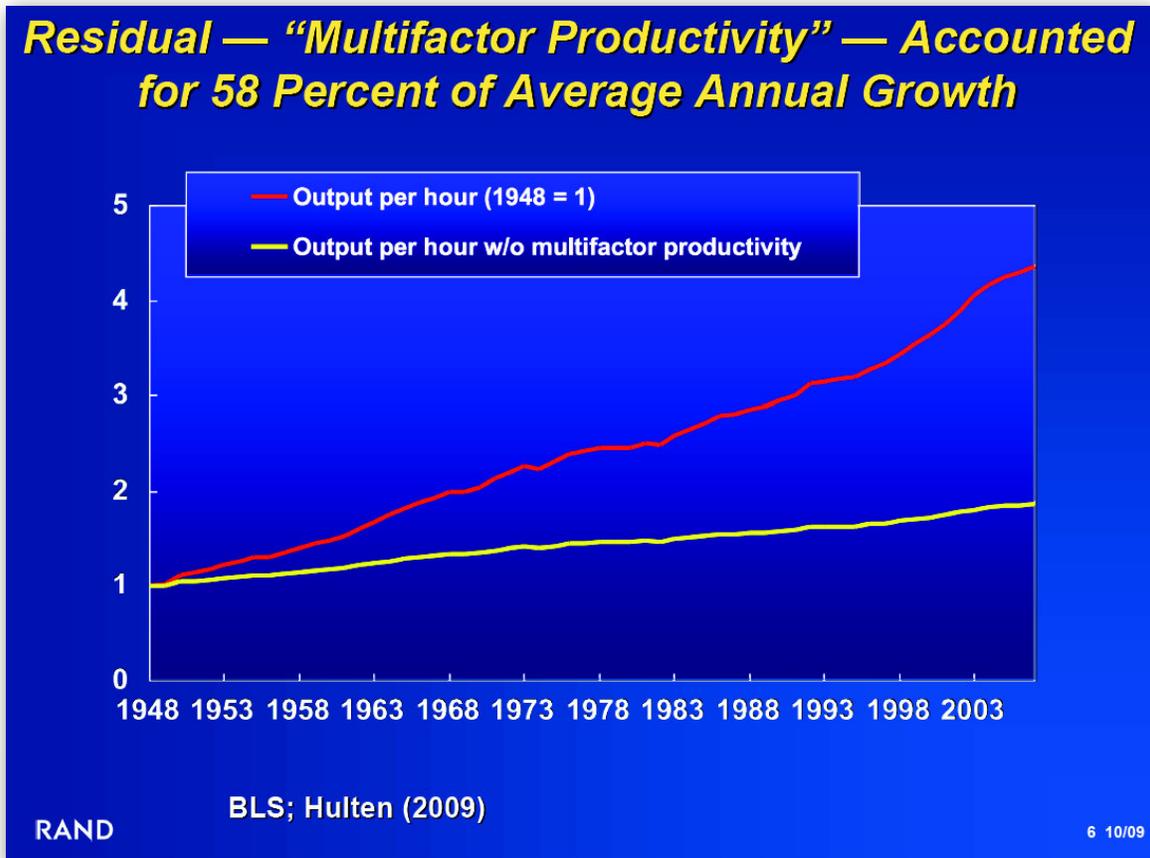


Figure 50

How important has technological change been for U.S. economic growth? We get a sense of this by considering multifactor productivity. Multifactor productivity accounts for the year-to-year increase in labor and capital inputs and then asks, how much of the growth in output cannot be attributed to the growth in inputs? The increase in output not attributable to the increase in inputs is labeled multifactor productivity, i.e., an increase in the productivity of all the factors on net. The chart shows two lines (see Figure 50). The red line shows the growth in the U.S. economy starting from a base in 1948 set to a value of 1. By 2007 we were up above 4, a four-fold increase in real GDP. The yellow line represents the portion of that increase accounted for strictly by inputs, i.e., the growth in capital and labor.

The difference between these lines in 2007 was a factor of 2.33. In other words, the “Solow residual” as it’s called accounts for very much of the growth. And in fact as the title of the chart shows, 58 percent of the average annual growth rate is attributable to the residual rather than the explicitly accounted for inputs.

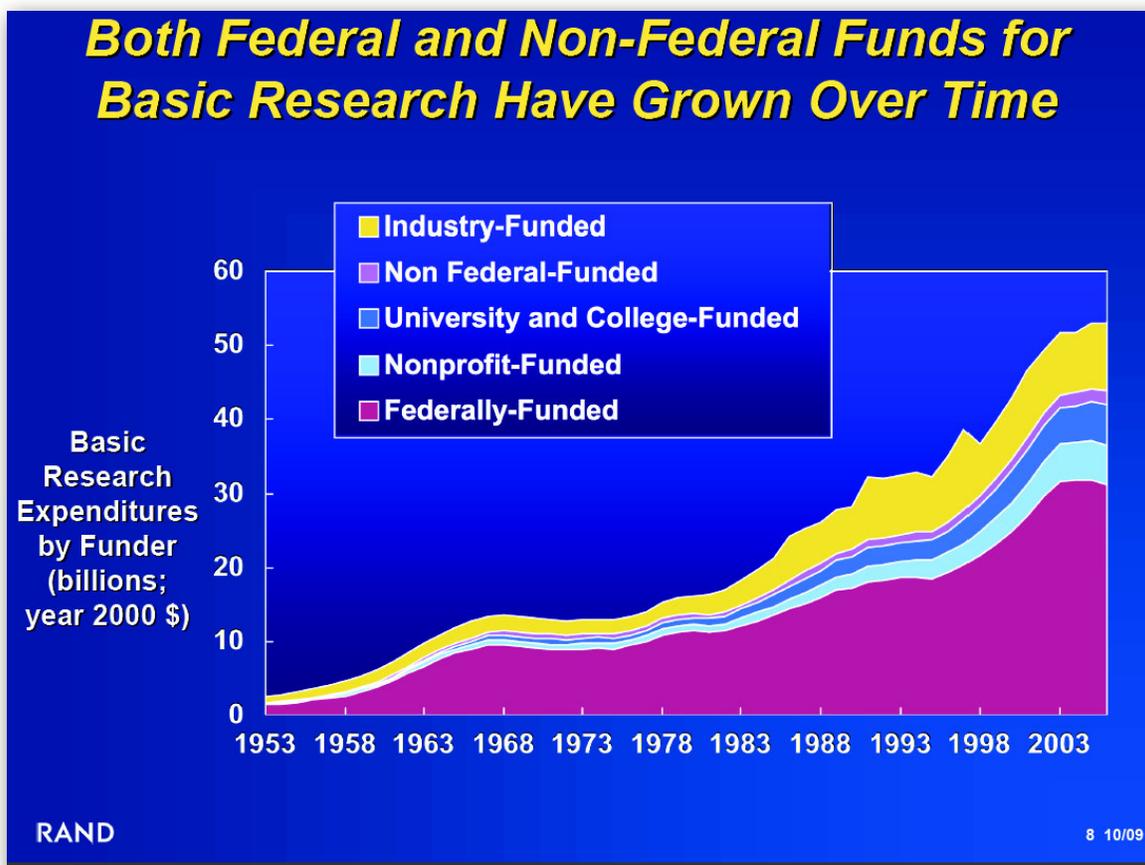


Figure 51

The residual raises questions. What is behind it and what goes into it? Accompanying the macro look have been a large number of studies at the micro level. Here, this chart (Figure 51) draws on a recent study by Robert Sveikauskas at the Bureau of Labor Statistics summarizing a variety of studies. In the papers he summarizes on privately financed R&D the private return is about 25 percent and the social return is about 65 percent. There are always difficulties in making such estimates, but these values give you some idea of the range of estimates in the literature today.

Unlike the macro series, these studies are narrow in nature. It's important that they be narrow in nature because the idea is to establish a causal relationship between R&D and the return to R&D and it's important to control for a lot of factors. But because they are linear in nature and attempt to identify causal effects, they may miss a number of things. You'll notice a big difference between the private return of 25 percent and the social return of 65 percent, and both estimates required some modeling assumptions. More generally, it is empirically hard to isolate the return to R&D, whether private or social.

Funds for basic research are an important measure of investment in R&D. Although there has been some slowing in growth for basic research in the recent years at the federal level, measured in constant \$2,000, overall these funds for basic research continued to grow fairly steadily through 2007. In the '50s and since 1983 privately funded basic research has accounted for about 40 percent of the funds for basic research. This percentage fell to 30 percent in the intervening years from the mid-1960s to the early 1980s. Those years registered a fairly large amount of federal funding for basic research.

When we think about the impact of the STEM Enterprise on outputs and productivity it is important not to think of STEM Enterprise narrowly, as just scientific R&D and PhDs. There are many things in the Solow residual besides scientific R&D such as software, strategic planning, business processes, and organizational design. These can largely be grouped under headings like human capital, organizational capital and brand equity. There is a quote at the bottom of the chart from a Harvard researcher, Bhidé that criticizes an overly narrow view. Again, many aspects beyond scientific output narrowly defined go into improving overall productivity and contributing to growth.

Recent work by Corrado et al. has attempted to take stock of these intangible investments. Corrado et al.'s assessment attributes a significant portion of the residual to these intangibles. Basically what is going on is that, although technological discoveries themselves have very important role to play in increasing output, they need to be accompanied by know-how and efficient organizational design and good management. Social scientists use the scientific method to learn about the micro, intangible aspects of the growth residual.

Just as there is research on intangibles, there is research aimed at refining the income accounts. There is a joint effort involving the Bureau of Economic Analysis and the National Science Foundation to develop a so-called satellite account that changes the way research and development is treated in the national income accounts. The satellite account has been under development this decade. The current national income accounts, treat R&D as an expense rather than an investment, and the satellite account aims to treat it as an investment. In work to date, the current estimate is that treating R&D as an investment can account for 5 to 7 percent of the real growth in GDP.

But we saw earlier the Solow residual is much greater than half, and here we're getting 5 to 7 percent. And as noted on the chart, if we look at investment in business structures for comparison, it's 2 percent. So what is going on? What are we likely to get out of efforts to chip away at the residual in this way?

I think it's worthwhile to treat R&D as an investment, and it's important to understand why it is so difficult to do so. And this gets back to the point of the complexity of trying to assess the output of the STEM Enterprise and attribute a role to R&D. There are basically three challenges here. The first is to establish a price, not a cost, for the value of R&D output. What chiefly lies behind this is that R&D discoveries, particular industrial R&D or for that matter general science, don't have any immediate market value. A lot of research is done at industries, and the initial impulse of the industry may be to put that discovery to work in new products and processes rather than to trade it and share it.

Second is the challenge of estimating the rate of depreciation of R&D. There is work underway on this by various people including Bronwyn Hall at Berkeley. Third, and perhaps most important in explaining the difference between the small contribution of R&D in the satellite account versus the large Solow residual, are spillovers. These are the synergistic effects from the diffusion of a new technology through the economy. As BEA researchers recognize, they haven't yet and probably will not be able to account for spillovers.

With spillovers in mind, it was interesting to hear Katy Borner's presentation about information networks as revealed through downloads of papers. That's one way of transmitting information. Another, of course, is the movement of people.

As final point in this area, there has been a reinterpretation of the Solow residual by Jim Bessen at Boston University. When Solow developed his model and applied it to U.S. data, he emphasized neutral technological change. This type of technological change increases the marginal productivity of capital and labor by an equal percentage. But Solow recognized that there could be labor-biased or capital-biased technological change.

Bessen has worked out the math for the Solow model allowing for biased technological change, giving a generalized residual. He was motivated to do this because empirical research has rejected the assumption of neutral technological change, and in fact if you look at the national income accounts there has been capital deepening. That is, the capital/labor ratio has increased, suggesting a higher rate of technological improvement in capital than in labor, and capital deepening has led to a huge increase in output per worker.

In applying his model, he found that when he uses his generalized residual the story for the U.S. in the 20th century is very much the same story that we've heard before. For the most part, it appears as though the neutral technological change assumption is a pretty good assumption. His estimates are only slightly different. But for emerging countries like those in East Asia, it looks as though the generalized residual leads to a much greater role for technological change. What's going on is this. The generalized residual decomposes technological change into the effect of a neutral technological change and then the effect of input biased change. And in East Asia there has been an increase in capital relative to labor. Basically, what's going on in East Asia is that they are importing technologies new to their economies and applying them, and there is a capital-labor substitution that is technologically driven.

Bessen has a great example in his article about what happened in the cotton mills in Lowell Massachusetts around 1850. Initially there were two looms per worker, and then they shifted to three looms per worker. This was initially interpreted as capital deepening, which is not technological change. Bessen said this should not be interpreted as capital deepening. The mills could add the third loom because they learned how to use the first two looms more efficiently and the workers could figure out how to handle a third loom. So it was really the know-how that came from using the technology. This is a great example of an intangible.

Next, I want to present a few charts on U.S. science and engineering workforce. I'll touch on three topics. Is the U.S. increasing the number of PhDs in S&E awarded? How does S&E pay compared with other professions? And has U.S. employment in S&E grown slowly?

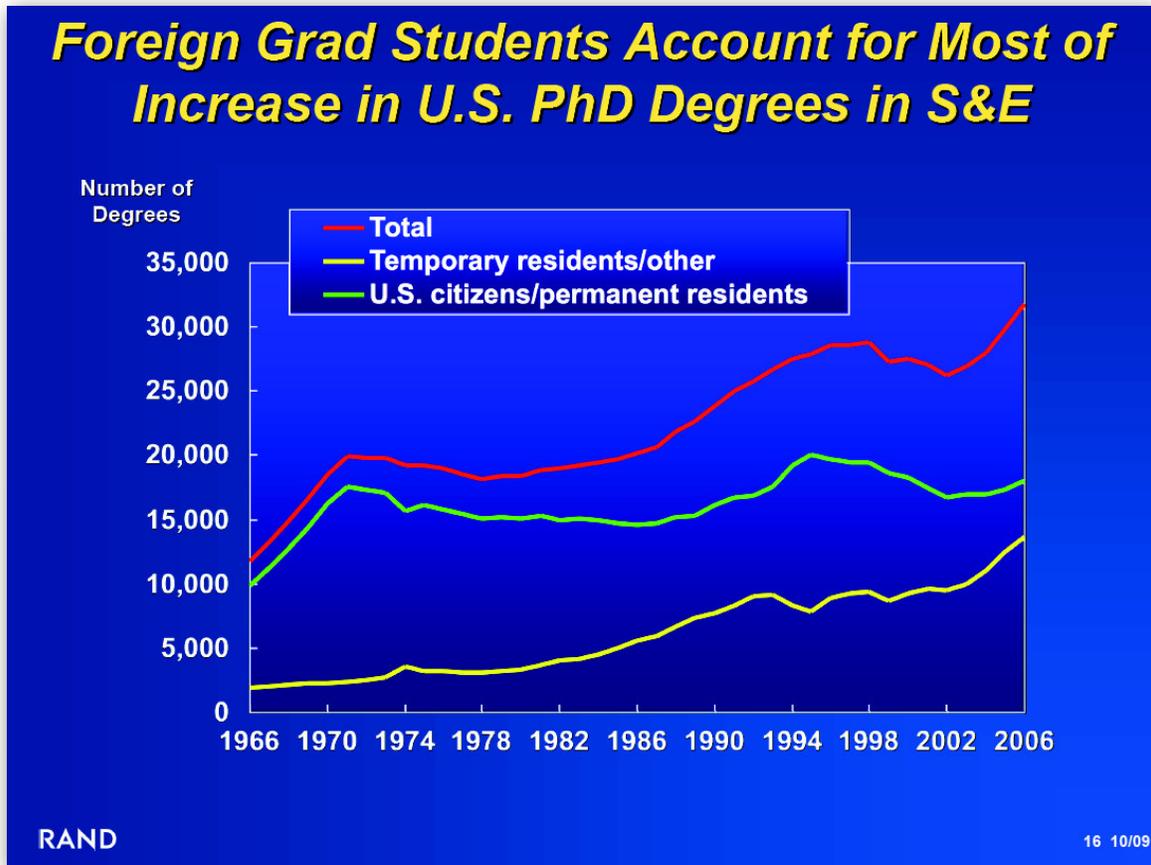


Figure 52

To me, one of the most interesting findings is that much of the increase in the number of PhD degrees awarded in the U.S. since 1980 comes from degrees awarded to foreign grad students (see Figure 52). The red line on the chart shows the number of PhDs in science and engineering awarded by U.S. universities from 1966 to 2006. The green line is PhDs awarded to U.S. citizens and permanent residents, and the yellow line is PhDs awarded to foreign graduate students studying in the U.S. As seen, much of the increase in the U.S. production of PhDs has come from foreign graduate students.

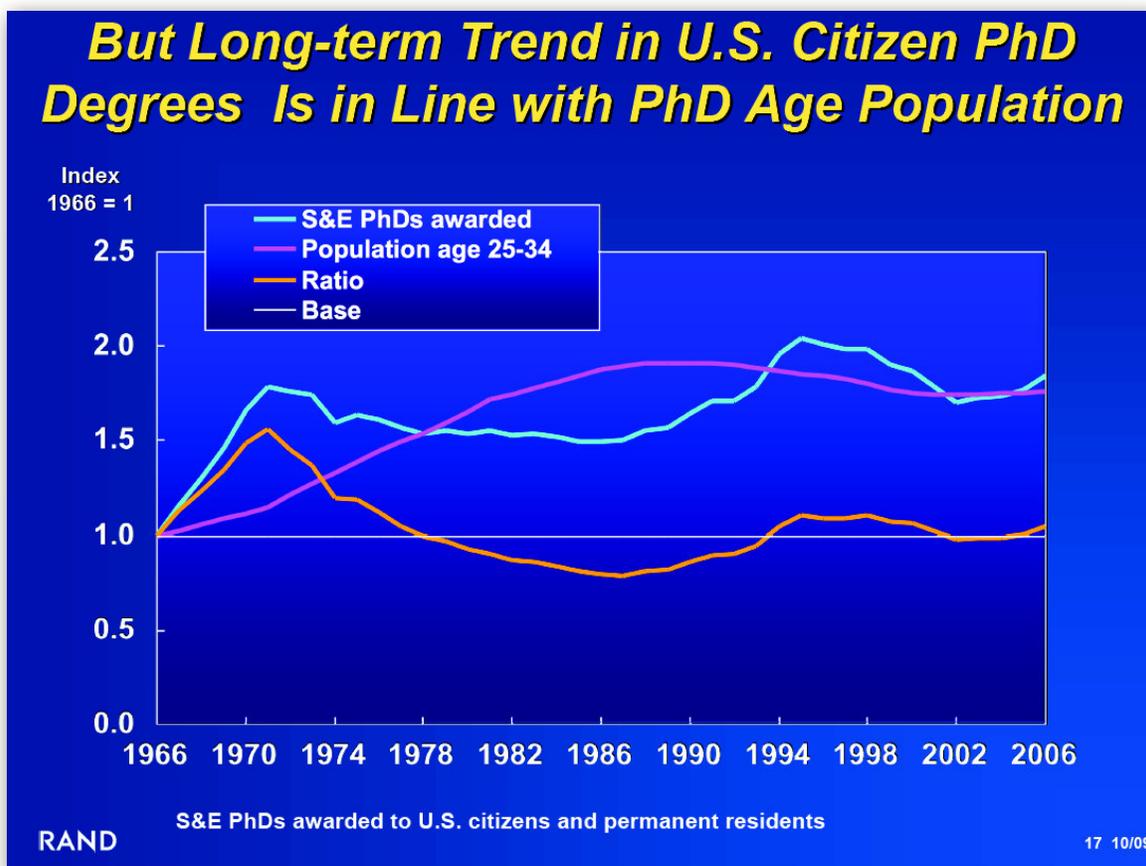


Figure 53

One of the unheralded factors behind the comparatively flat trend in PhDs awarded to U.S. citizens is demographics. The green line on the next chart (Figure 53) again shows PhDs awarded to U.S. citizens and permanent residents. The pinkish line reflects the U.S. population aged 25 to 34. Why that? Because most PhDs are awarded over that age range, so it is a reasonable demographic base population. The faint, straight line is the ratio of PhDs to 24-34 year olds set to a value of 1 in 1966.

The orange line shows the ratio of PhD degrees to population. The pink line peaks 1987, about 30 years after the peak in 1957 of the baby boom. I say 30 years because we are looking at an age range here in the population number of 25 to 34, which has an unweighted average age of 29.5 years. So the pink line replicates the baby boom. The ratio of PhDs to population is above 1 in the late '60s and early '70s, and then it falls to 75 to 80 percent of its initial value. However, since the mid '90s it has been around 1. There is clearly some movement in the ratio, and a 5 percentage point deviation from 1 is a noticeable deviation, yet I think the overall message is that U.S. demographics themselves have a fairly large role to play in understanding why U.S. universities have not produced more PhDs.

This is not in any way an argument against the idea of greater incentives to bring more individuals into science and engineering majors or PhDs. It's just an observation about what's going on in the U.S.

These outcomes have been influenced by internal and external factors. Countries like Korea, India, and China are expanding their undergraduate education, and they were able to do that more rapidly than they expanded their graduate education. This has probably help create a significant increase in students from those countries into U.S. universities. By the way, data from a paper by Bound, Walsh and Turner show that after WWII there was an increase German graduate students studying in the U.S., and it went on for about a dozen years and then it tapered off. Why? The conjecture is, because Germany reestablished its graduate programs. Today, India and China are building their graduate programs. So it is likely that we our universities will have more competition from them at the PhD level and we may have fewer foreign grad students coming to the U.S.

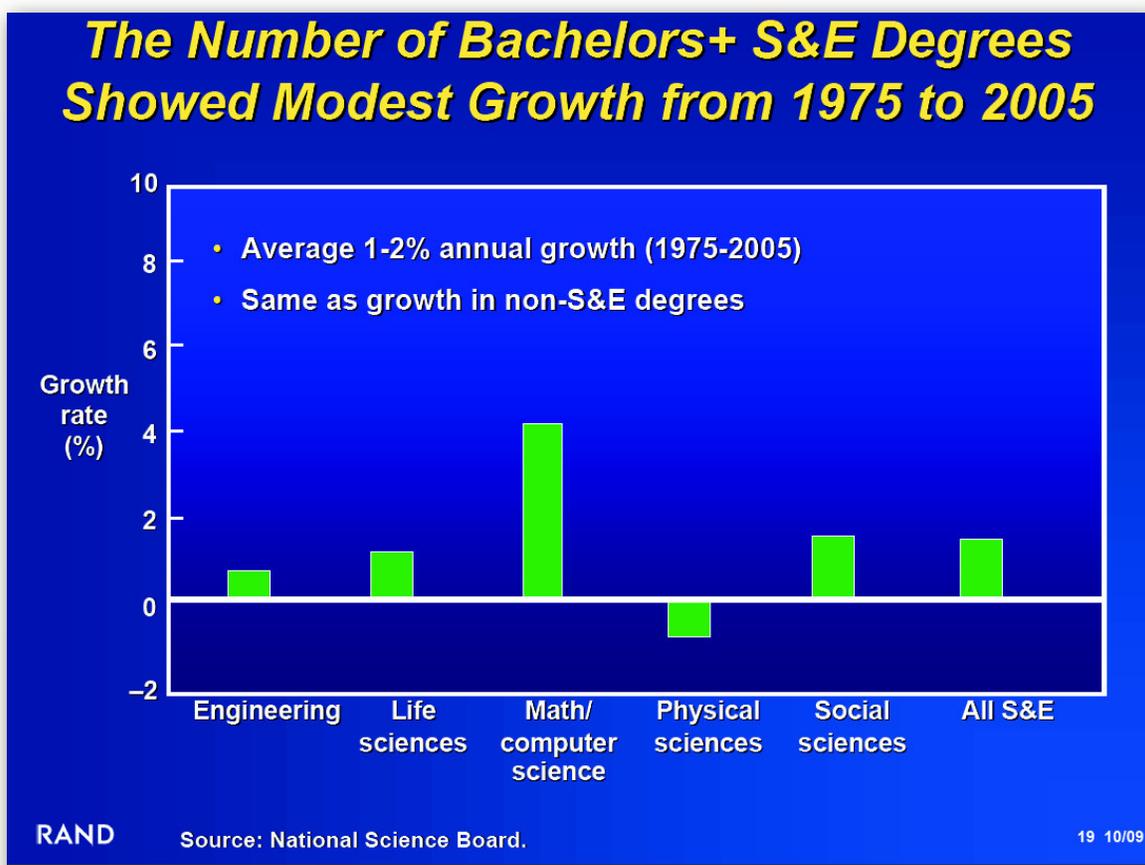


Figure 54

With respect to the total number of bachelors and higher science and engineering degrees, the average annual percentage change from 1980 to 2000 varies by field (see Figure 54). It's highest in math and computer science; it's lowest, actually negative, in physical sciences. But overall it averages about 1.5 percent over this period. You will notice that the numbers on the chart, 1975 to 2005 are a little broader than the 1980 to 2000, and that's because Titus and I have other datasets for the longer range. So the slide is representative.

So one last point on this chart: the 1.5 percent growth rate in bachelors or higher science and engineering degrees over this period was the same as in non S&E.

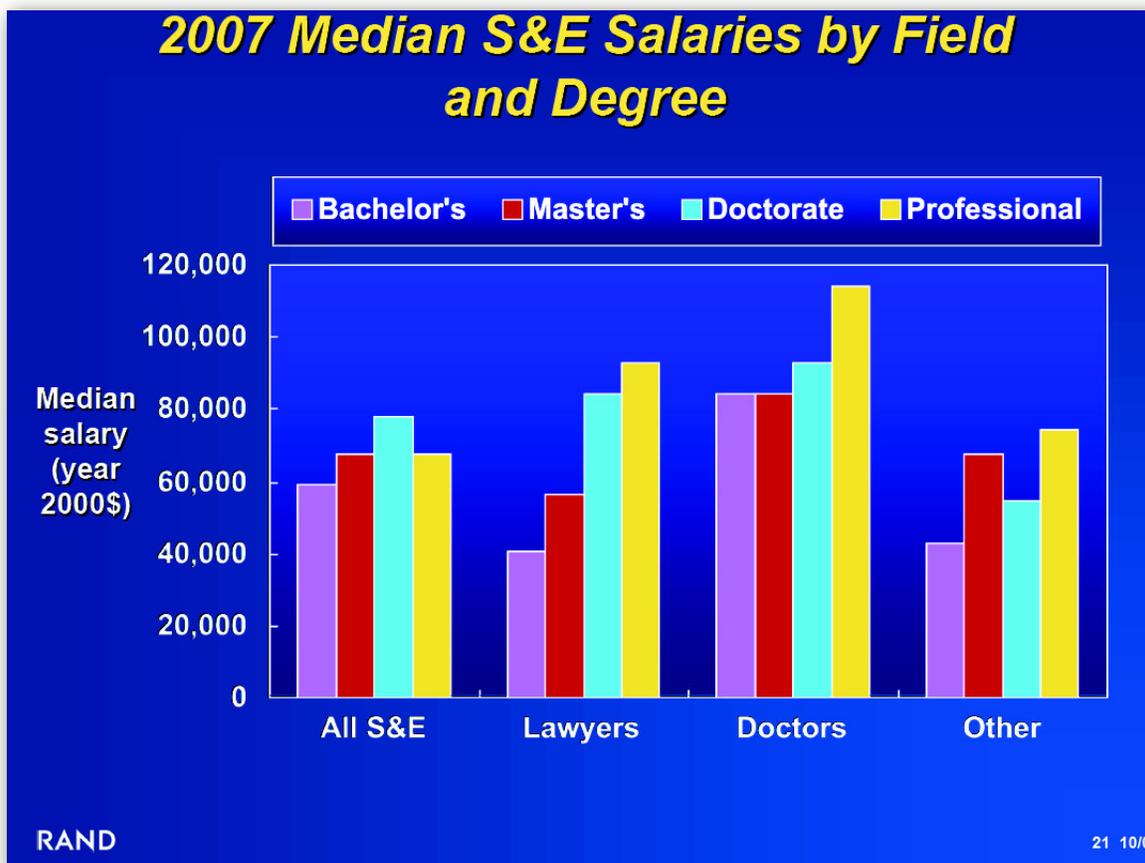


Figure 55

Our rough look at whether or not this degree production was associated with indicators of a shortage of scientists and engineers suggested that it wasn't, because there has been relatively no difference in the unemployment rate in S&E versus non S&E over time, and no unusual wage growth for S&E versus other fields. Again, these are first approximations. Some of the estimates differ by field, et cetera. In the interest of time, I'm going to largely skip over these charts on pay (Figure 55), but the key point is that at the doctoral level the median salary according to the American Community Surveys is around \$80,000 in 2007 versus around \$60,000 or less in non S&E fields. Lawyers and doctors are included here, but constitute only about 7 percent in total of the non S&E fields. Still, one could argue that even though they are 7 percent, many scientists and engineers would have gone into those fields.

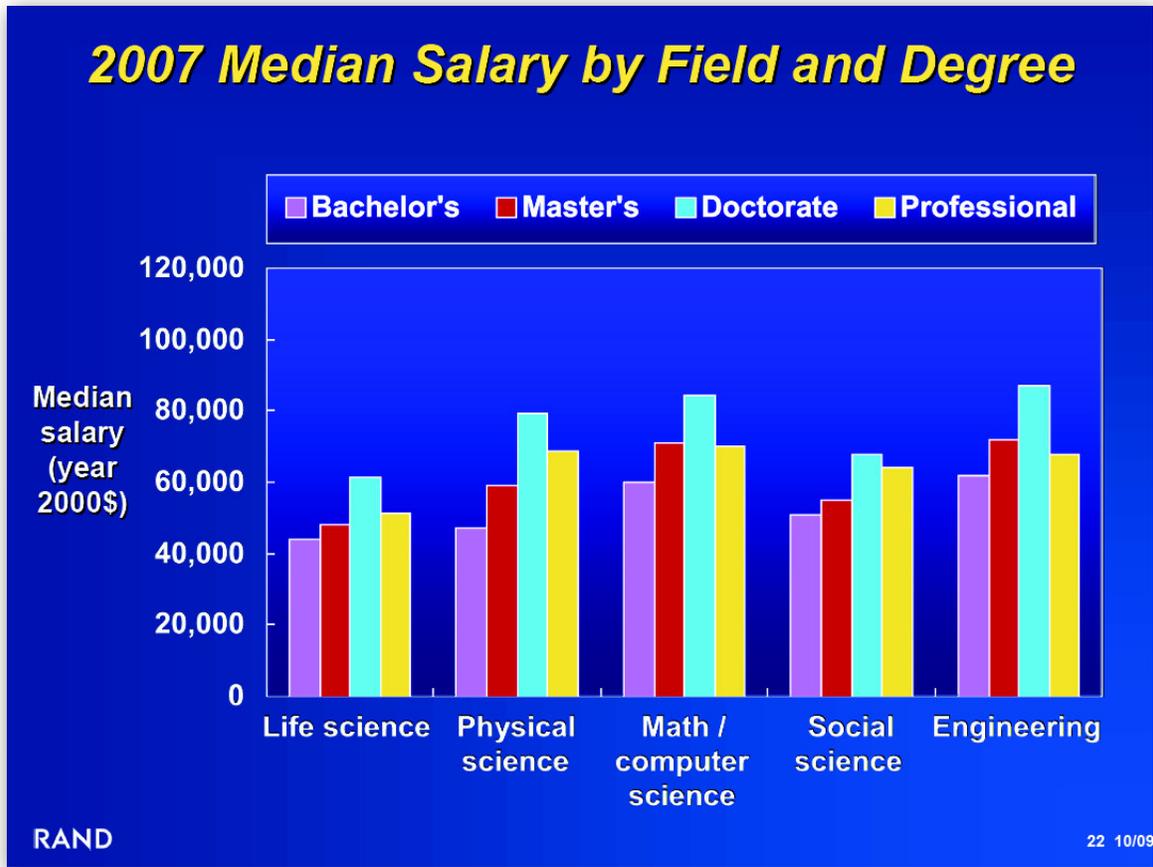


Figure 56

Here is a chart that gives some detail by field (Figure 56). As you'll see, the lowest PhD salary is \$60,000 in life sciences, the field that's had the largest infusion of federal research dollars and has had a relatively large increase in the number of PhDs awarded.

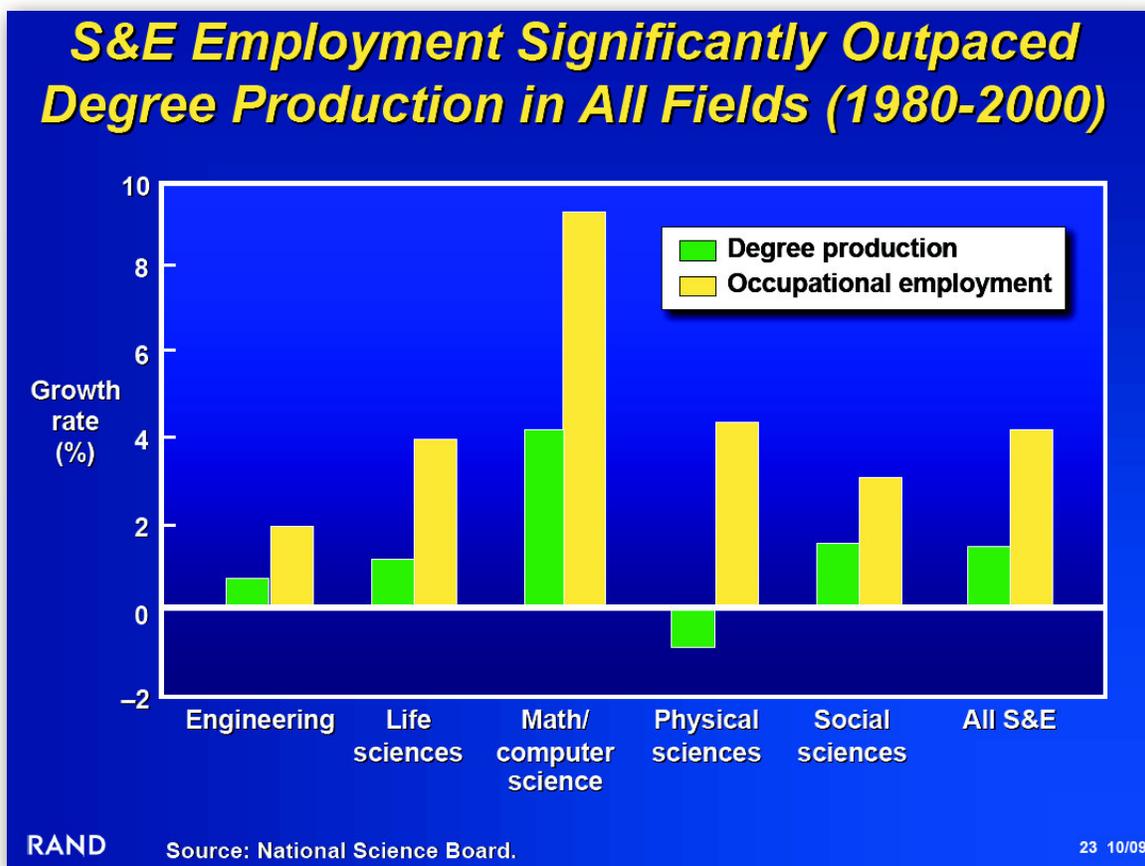


Figure 57

Given those statistics on degree production, what about S&E employment? S&E employment grew on average over 4 percent from 1980 onward (see Figure 57). That’s in comparison to a degree growth rate of 1.5 percent. And the biggest increase was in math and computer science. So there has been a significant expansion in S&E employment despite the lower rate of degree growth. Where are the workers coming from? Many Americans are entering science and engineering careers from other occupations. The National Science Board estimates that employment in science and engineering occupations ranges from 4 to 7 million, depending on how you count the field. However, the number of individuals who have a science and engineering degree as the highest degree awarded totals over 14 million. So there are people out there with degrees who aren’t working in science and engineering.

Another element is immigrants. Many of the PhDs being awarded now go to immigrants and other S&E immigrants enter the U.S. with a degree. These trends in employment and immigration have led to a fairly fast growth rate in science and engineering sector of the economy. In fact, one of the fastest overall: 4.2 percent and 2.7 million additional jobs.

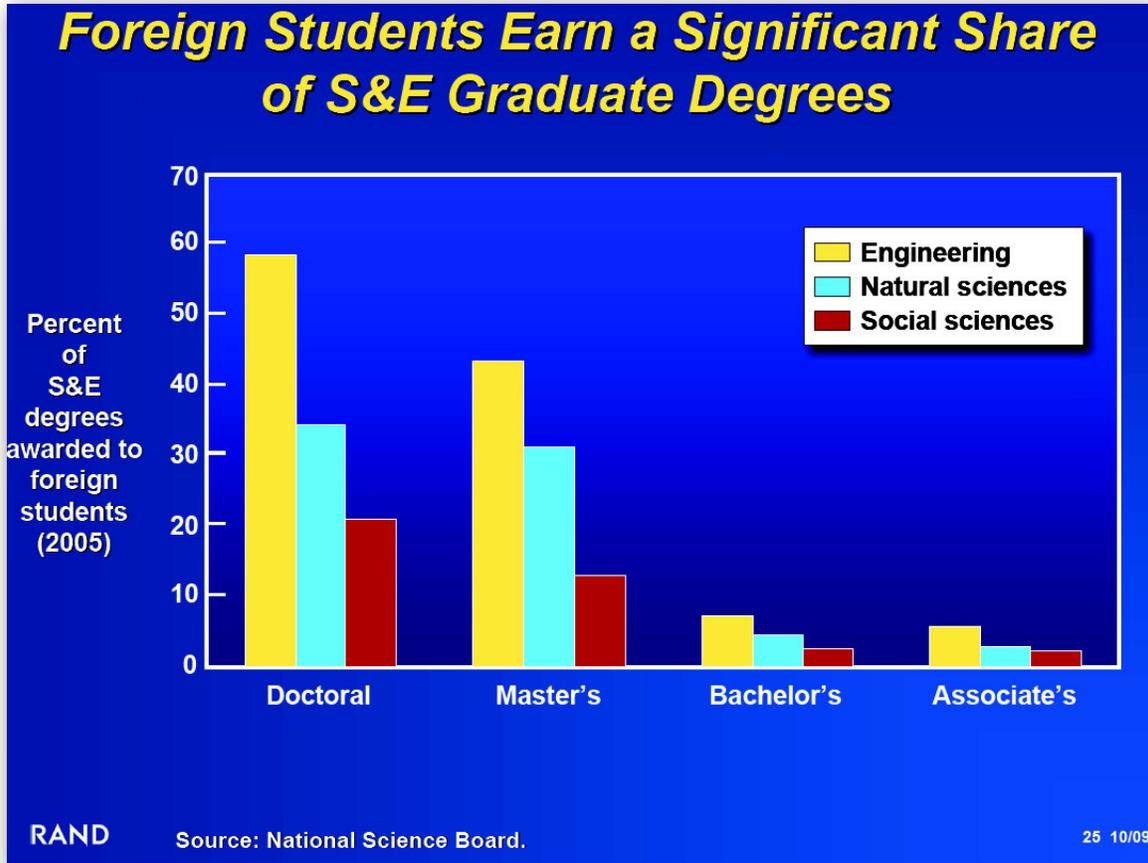


Figure 58

Foreign students earn a significant share of S&E graduate degrees (see Figure 58). Right now in engineering it is about 60 percent of the PhDs awarded in this country. In natural sciences, it is about 35 percent. But do these foreign PhD graduates remain in the U.S.? Many have stayed in the U.S. From 1987 to the early part of this decade, the two-year stay rate rose from about 50 to nearly 70 percent, though it has decreased in recent years.

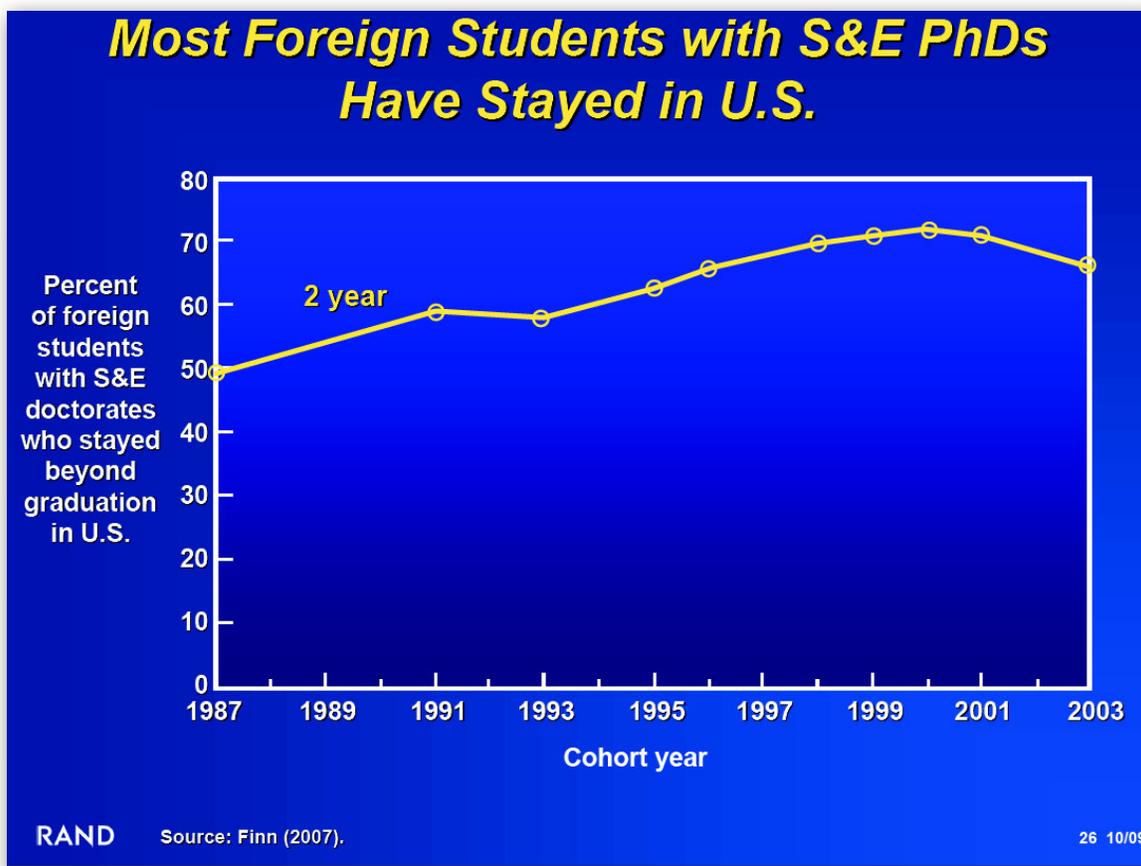


Figure 59

The two-year stay rate is a short-term stay rate (see Figure 59). But if you look at a five-year and ten-year stay rates, they are also high (see Figure 60). But as they say in the mutual fund business, past returns are no guarantee of future returns. As study and employment opportunities improve abroad and if U.S. visa policies remain tight, the stay-rates could decline.

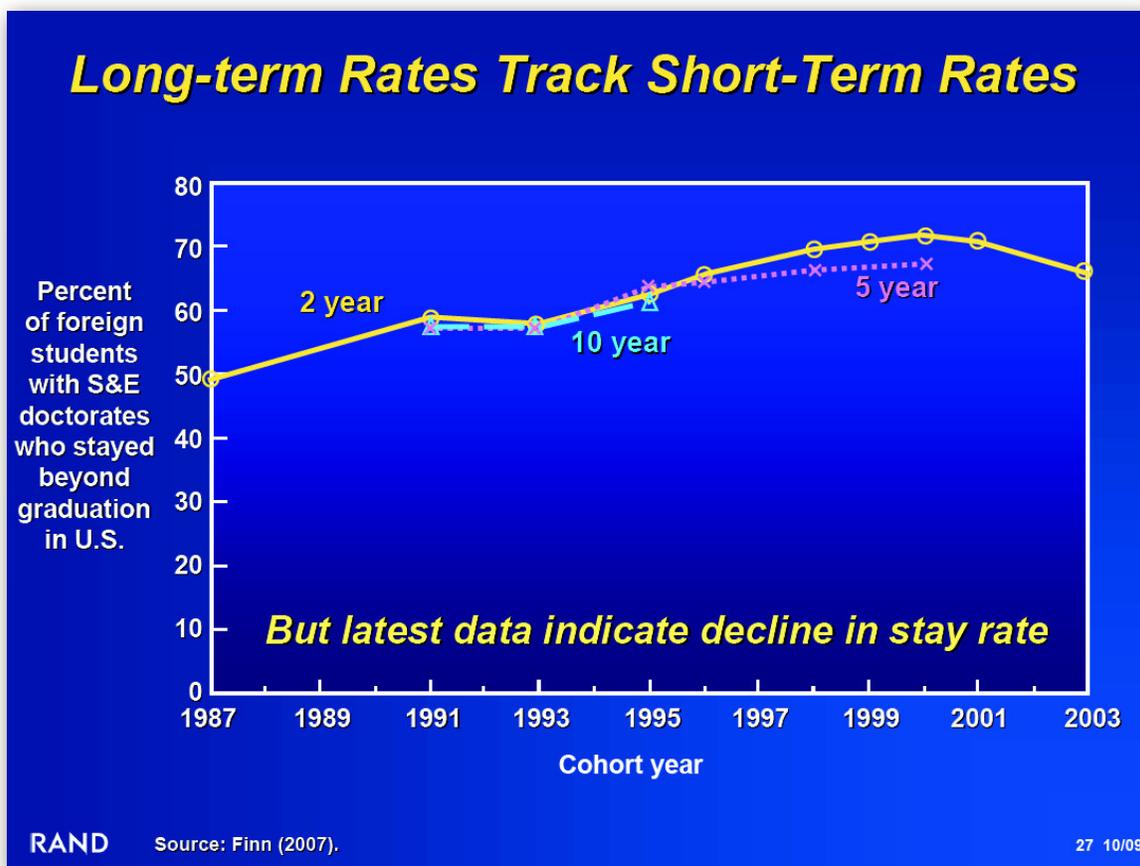
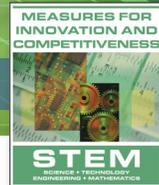


Figure 60

Some overall conclusions: growth accounting at the macro level and causal inference studies which almost of necessity must be done at the micro level are a very good dual for trying to learn about the impact of STEM Enterprise on output and productivity. Either taken alone is insufficient. Second, there is a growing recognition of the importance of intangibles. We see this in work at the micro level and through things like the development of the satellite account at the macro level to try to learn more about what's really driving the change in this country.

Third, the complexity of the S&E echo system suggests that there is no single indicator, no small set of indicators that will be sufficient. The outcomes that we look at really have to be viewed from many different perspectives, and of course rigor in the studies is always welcome.

I hope the talk has helped to highlight a number of the efforts that are underway in federal and related organizations such as BEA, BLS, NSF (through its Science of Science Policy program and ongoing collection of S&E data), OSTP, and of course the national academies. With that said, the point I want to leave you with, the one that Titus and I put in the report that we did last year, is that we feel there ought to be a permanent, chartered, funded,



independent entity responsible for assessing overall performance of the S&E workforce and STEM Enterprise. That is to say, it is great to have all the data and it certainly is essential to do studies that attempt to provide linkages between research and causal effects of R&D. But at some point, somebody needs to bring these together and do an assessment.

It's not necessarily federal entity, or necessarily nonfederal; we are agnostic about that. But we do think a rigorous research agenda focused on such assessments is a good idea. Thank you very much

R&D Activities in the U.S. Department of Defense & Technology Priorities

Presented by Mr. Robert W. Baker, Deputy Director, Plans & Programs Office of the Director, Defense Research and Engineering

MR. ROBERT BAKER: Thank you very much, Marty for the warm introduction. It's great to be here. It's always fun to get out of the Pentagon and talk about what's going on in the DoD science and technology program. I do this quite a bit as industry groups around town ask me to come to lunch and give talks. I always like to do it, so thanks for the opportunity, and thanks to IEEE for arranging this conference.

As Marty mentioned, the DoD requests about \$11.5 billion for its science and technology program. This includes Basic Research, Applied Research, and Advanced Technology Development. Congress also adds money to that budget in terms of earmarks and the total grows to the low \$13 billion.

Connecting Researchers to Warfighters



President Obama, National Academy of Sciences, April 27, 2009



"I believe it is not in our American character to follow - but to lead. And it is time for us to lead once again. I am here today to set this goal: **we will devote more than three percent of our GDP to research and development.** We will not just meet, but **we will exceed the level achieved at the height of the Space Race, through policies that invest in basic and applied research,** create new incentives for private innovation, promote breakthroughs in energy and medicine, and improve education in math and science. **This represents the largest commitment to scientific research and innovation in American history.**"

Investment in Basic and Applied Research is a commitment to the future warfighter

Figure 61

This slide shows some words from our leadership (Figure 61). What the leadership passes down to us as guidance has a great impact on what we actually do in the area of science and technology. Regardless of what you think about the Stimulus Package, bank bailouts, and health care; you have to like what the President has said about science and technology. He talks about trying to grow the National investment to 3 percent of GDP, reaching funding levels in excess of what we had during the space race, particularly in Applied and Basic Research. Investment in Basic Research is really an investment for the future war fighter because that investment doesn't usually come to fruition for about 8 to 10 years.

This year we sent the budget to Congress a little late because the President wanted Congress to work on the issues that were "front and center" on his agenda. Realizing that the DoD budget would be submitted late, Secretary Gates talked to the President and pointed out that we were going to make some big changes to the defense budget and he wanted to give people a "heads up." With Presidential approval, Secretary Gates gave a news conference in the Pentagon and talked about the big changes he was making, which cancelled a lot of platforms like the F22, naval ships, the vehicles for Future Combat Systems in the Army. He wanted to give people a chance to think about this before the budget was actually submitted to Congress. The DoD did not submit the budget until first part of May.



Three Principal Objectives -DoD Strategic Imperatives-

Secretary of Defense, Budget Recommendation Statement, Arlington, VA, April 6, 2009

1. **Take care of our people**
2. **Develop the right capabilities for today and tomorrow**
 - Persistent surveillance
 - Cyberspace operations/protection
 - Combating weapons of mass destruction
 - Irregular warfare
3. **Reform the Procurement, Acquisition, and Contracting processes**

Secretary of Defense Posture Statement on the FY2009 Budget, February 2008

*"As changes in this century's threat environment create strategic challenges – irregular warfare, weapons of mass destruction, disruptive technologies – this request places greater emphasis on **basic research**, which in recent years has not kept pace with other parts of the budget."*



3

Figure 62

Secretary Gates pointed out in that speech that there are three real priorities (Figure 62); one is taking care of our people, and I can tell you he takes it very personally every day that he sees the list of casualties that come in from Iraq and Afghanistan. That's his number one priority. Protecting our troops and the equipment they operate. We are also making a large investment in advanced medical care technology. The Secretary is also concerned about the future and what types of capabilities the Department is going to need. You don't see a new fighter or aircraft carrier on that chart. He's talking about capabilities like persistent surveillance, cyber operations, and information and communications networks. The Secretary is also talking about capabilities for irregular warfare, an area which is causing us a great deal of difficulty.

Secretary Gates also talked about the importance of basic research in the FY 2009 budget he submitted. He actually increased Basic Research by \$270 million. This represented a 16 percent increase after inflation. Never before have we ever increased Basic Research by that amount of funding. What we hope to get out of this investment it is more scientists and engineers since the bulk of the money is spent primarily at universities.

But when you have a huge increase to a budget line like this, Congress tends to wonder how are they going to execute this efficiently? And maybe Congress will be unwilling to support that large an increase.

So what the Department did was to identify the grand challenges you see on this chart as areas we would spend this research money. We also have identified executive agents in the Army, Navy, Air Force or Defense agencies that execute the programs associated with the grand challenges. Congress did support our increased request, and we actually have started about 500 new research efforts with this new money.

In our FY 2010 request we increased Basic Research by another \$100 million, and that represents about 3.5 percent increase after inflation. Basic Research is the fastest growing piece of the Defense S&T budget.

New DDR&E Zachary J. Lemnios



- **Education**

- BSEE, University of Michigan
- MSEE, Washington University in St. Louis
- Harvard Kennedy School of Government - Program for Senior Executives in National and International Security

- **MIT Lincoln Laboratory**

- Chief Technology Officer
- Assistant Division Head, Solid State Division
- Senior Staff, Solid State Division

- **DARPA**

- Director, Microsystems Technology Office
- Deputy Director of the Information Processing Technology Office
- Program Manager and Assistant Director of the Electronics Technology Office

- **Industry**

- Hughes Aircraft Company
- Westinghouse Electric Corporation
- Ford Microelectronics, Inc.



5

Figure 63

We have a new Chief Technology Officer. His name is Zachary Lemnios. He came to us from MIT Lincoln Lab where he was also the Chief Technology Officer. You can see from this chart (Figure 63) that he also was a DARPA program manager and he also has extensive industry experience. When Zack arrived on the 6th of July, he called his Directors and Deputies to his office and said, “Gentlemen, this is what we’re going to do. This is not my vision, not my goals, not my objectives.” He said, “These are imperatives. Imperatives mean we are going to do this.” So we got off to a flying start with Zack on his first day in the office. And you can see these imperatives mirror a lot of the things Secretary Gates said we were going to accomplish. Mr. Lemnios wants to accelerate the delivery of capabilities to our forces in the field today. He also wants to prepare our forces of the future in terms of creating capability surprise and also defending against capability surprise.

DDR&E Imperatives



- **Accelerate delivery of technical capabilities to win the current fight.**
 - **Solve the most difficult near term problems and transition compelling concepts to the warfighter.**
- **Prepare for an uncertain future.**
 - **Shape the Department's science and technology investments to open options that counter (and create) strategic surprise.**
- **Reduce the cost, acquisition time and risk of our major defense acquisition programs.**
 - **Provide systems engineering leadership, deep system analysis, and technical assessments across the Department.**
- **Develop world class science, technology, engineering, and mathematics capabilities for the DoD and the Nation.**

6

Figure 64

You can see on the chart (Figure 64) that he wants to fix the acquisition process. It still costs too much and it takes too long to acquire Defense systems.

The last Imperative deals with STEM. He recognizes the importance of having a technologically superior military, and that only comes from scientists and engineers working on the development of DoD war fighting capability, so STEM a big priority for Zack.

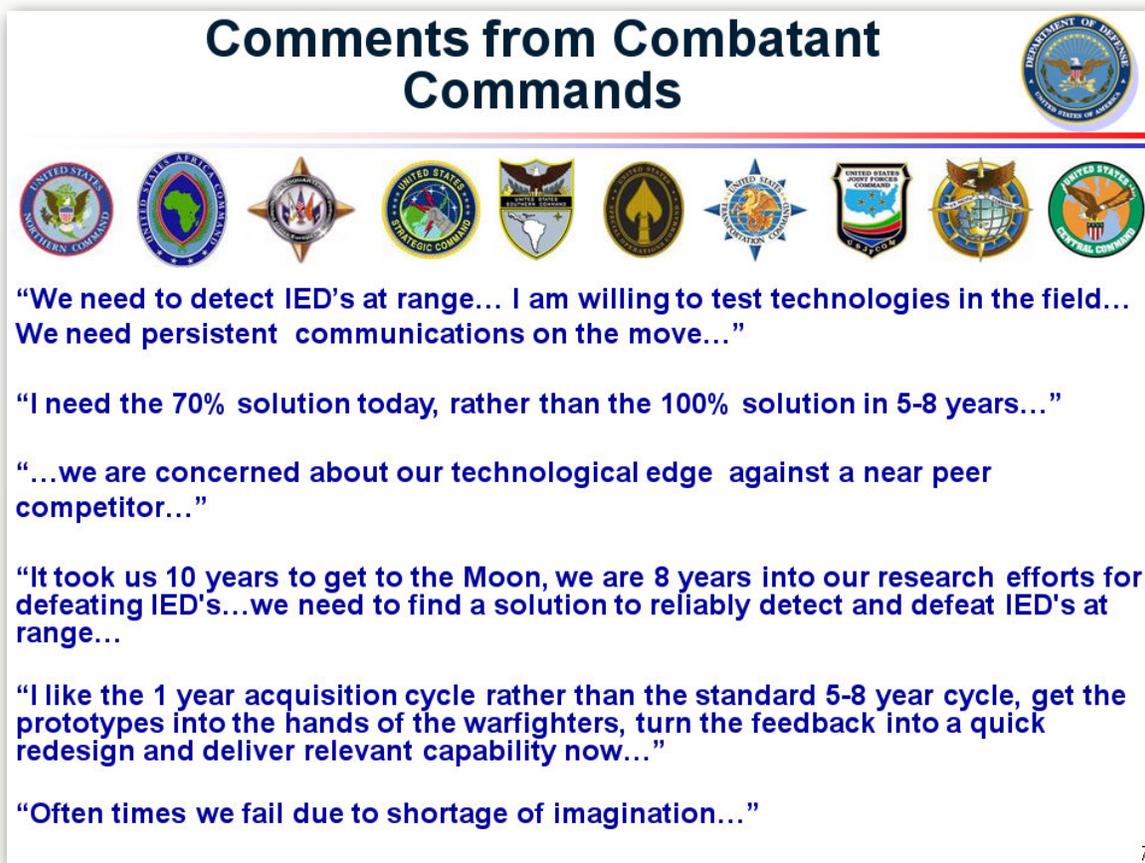


Figure 65

Mr. Lemnios also realized he needed to go out and listen to his customer, the war fighter. I’ve been working in the Pentagon since ’91 and this is the first DDR&E I’ve ever seen go out and talk to the Combatant Commanders. Those symbols across the top of the chart (Figure 65) represent the 10 four-star generals who we have that actually lead the conduct of military operations. They are responsible for putting together the force package that consists of Army, Navy, Air Force and the Marine Corps. You can see some of the comments that they made to Mr. Lemnios when he went out to visit. They said, “We need to detect IEDs at range.” IED are improvised explosive devices. Another Combatant Commander said, “I’m willing to test the technologies in the field.” He said, “Let’s not go through the big acquisition process; give me prototypes, and we’ll take a look at these and see if they have military utility. We’ll give you feedback and tell you what needs to be fixed. I need technology today. I can’t afford to wait for the acquisition process.”

This is an interesting comment, “I need the 70 percent solution today rather than 100 percent solution 5 to 8 years from now.” So, Mr. Lemnios is trying to get the latest that technology can deliver to the battlefield. This is necessary because the adversary is going downtown to Best Buy, buying things off the shelf, and figuring out innovative ways to use this technology on today’s battlefield. They don’t have an acquisition cycle to deal with. Purchase it today, figure out how to use it next week, and it shows up the week after that on the battlefield.

An Effective Process for Major Defense Systems – but not for Disruptive Technologies

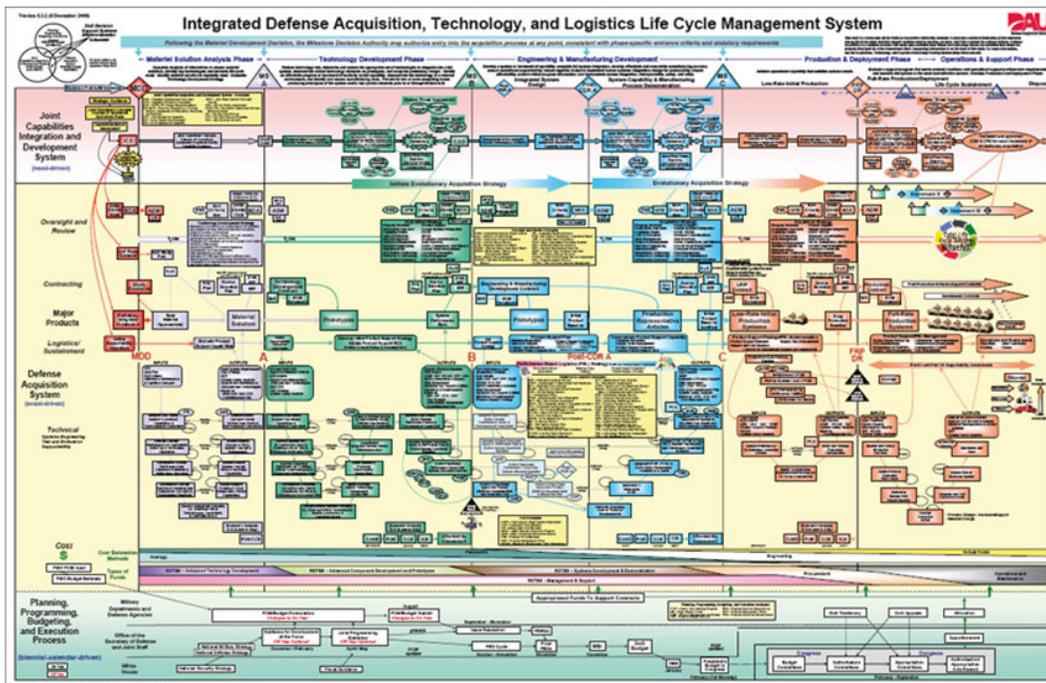


Figure 66

If you want to build an aircraft carrier, a tank or a fighter airplane, this chart (Figure 66) shows is the acquisition process you must follow. See up in the right-hand corner: it says DAU that stands for Defense Acquisition and University. Mr. Lemnios and the Secretary say we can't afford to go through this lengthy process any longer. That's what we are trying to eliminate when we go out and work directly with the folks in the field.

Desert Storm



- **US dominance over Soviet-era systems “shocked” potential adversaries and combined to give US conventional superiority**
 - **Precision Weapons**
 - **Night Vision**
 - **Low Observability**
 - **Networked Systems**
- **The advent of information-based warfare feed the emergence of irregular warfare**



Figure 67

Today we are engaged in irregular warfare. How did we get into this situation? Well, we sort of did it to ourselves in Desert Storm when the capability you see in those pictures (Figure 67) was employed in Iraq, and the world saw that technologies like precision weapons, night vision, stealth, and networked systems, provided a tremendous overmatch against the Soviet systems. No adversary wants to engage the U.S. in a conventional military engagement. Instead, what they are now engaging in irregular warfare.

This has created a very complex operating environment because technology is becoming so globalized, it is available to a lot of people and they are figuring out innovative ways to use it on the battlefield. The global security environment is quite different now. It's affected by economics, resources, shortages of water and fuel, and demographics. These are all things that come into play in determining the security environment and the security of regions. These are things our armed forces have to deal with that they didn't have to deal with in the past.

Let's take a look at where our planning guidance comes from in terms of documentation. The last thing the Department put out was the *Quadrennial Defense Review* in 2006. However, the Secretary's speech on the 6th of

April was enough for a lot of people in the Pentagon to say, “We’re not waiting for the QDR. We know what the Secretary said, and the QDR coming out in February 2010, is only going to mirror those comments.” In the 2006 QDR there was a discussion about challenges. There were four of them: 1) Traditional, which is military on military type operations; but the challenges that are causing us difficulty and concern are 2) Irregular, 3) Catastrophic, and 4) Disruptive Technologies. These later three challenges are where we’re trying to move some of our investment.

Also, a gentleman named John Young, who used to work over on the Hill, as a program analyst, came to the Pentagon and became the Director of Defense Research & Engineering. He wrote a memo to Secretary Gates on the 24th of August 2007. The very first thing he told Secretary was, increase the investment in Basic Research. The Secretary listened.

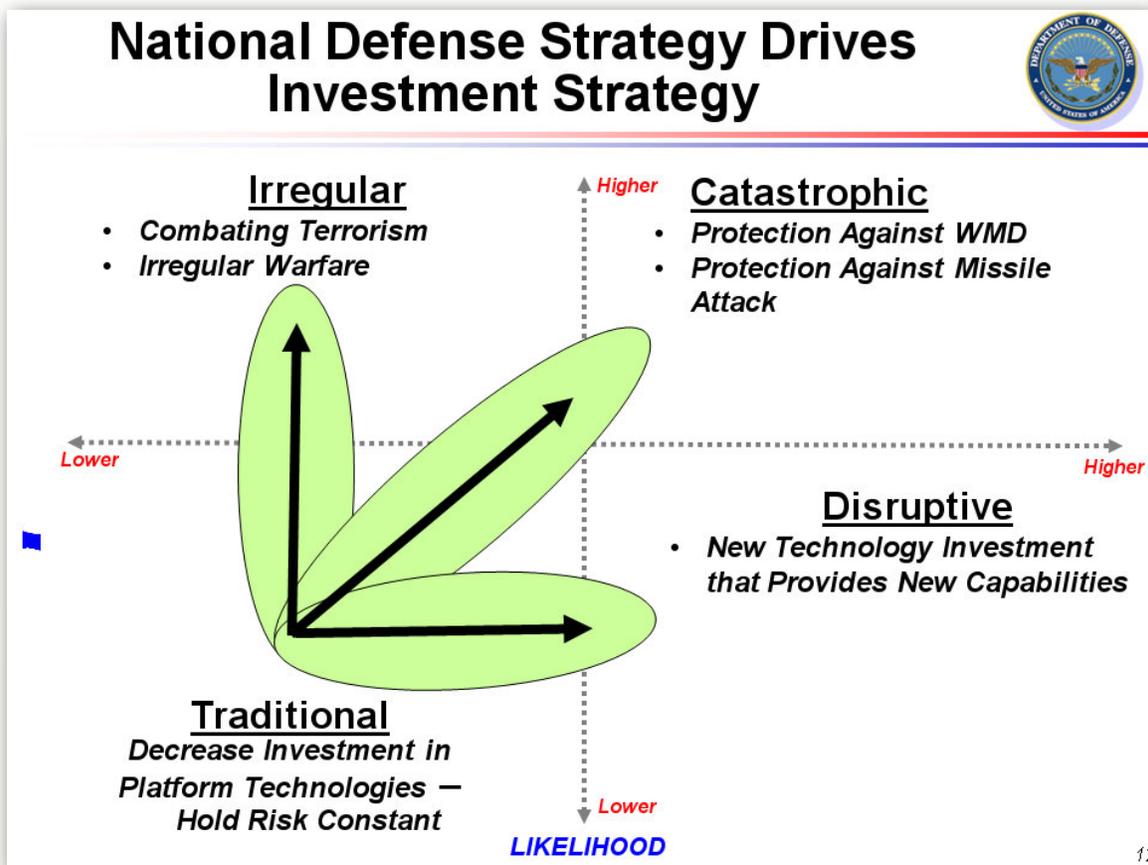


Figure 68

When we look at our total S&T investment and what new areas we want to invest in, we want to hold risk constant in the Traditional challenge area (Figure 68). While holding risk constant, we want to push some investment out into the areas of Irregular Warfare, Catastrophic, which deals with weapons of mass destruction (WMD), and Disruptive Technologies. Fortunately we haven’t encountered a WMD attack yet, but it’s what keeps everybody awake at night. Disruptive Technologies are new technologies that will allow us to create capability surprise, or be a hedge against technological surprise.

S&T Enabling Technology Priorities

--Supporting the QDR Strategic Outcomes--



- **Technology focus areas:**

- Biometrics and Biological exploitation
- Information Technology and applications
- Persistent Surveillance Technologies
- Networks and Communication
- Human, Social, Cultural, and Behavioral Modeling
- Language Translation Technologies
- Manufacturing Technologies
- Cognitive Enhancement
- Directed Energy Technologies
- Autonomous Systems Technologies
- Hyperspectral Sensors
- Nanotechnology
- Advanced Materials
- Energy and Power Technologies
- Organization, Fusion, & Mining Data
- Combating Weapons of Mass Destruction Technologies
- Energetic Materials

In Blue—Areas with Substantial Increases in FY08/09/10 President's Budget Request



Figure 69

The QDR says if you're successful in balancing your investment across these challenge areas (Figure 69), you will be able to achieve the strategic outcomes listed on this chart: Defend the Homeland, Defeat Terrorist Networks, Shape Countries at Crossroads, and Prevent the Use of Weapons of Mass Destruction. Given that these are the strategic outcomes we want to achieve, what type of capabilities do you need? These capabilities are all listed in the QDR. What the DoD S&T Community did was back out the enabling the technologies for these capabilities. The list of enabling technologies are shown on this chart. The technologies that you see in blue are the ones we have made a significant increase in the investment in Fiscal Years 2008, 2009, and 2010.

DDR&E Investment Initiatives S&T Thrust Areas (from 24 Aug 07 memo)



- Foundational Sciences
- Active & Conventional Armor
- Defeat of Speed of Light Weapons
- Adaptive, Interactive, Full Immersion Training for Soldiers/Marines
- Metamaterials
- Information Warfare
- Information Assurance
- Networking Technologies
- Manufacturing Science Technologies
- Neuro-Ergonomics

*In Red—Areas not on QDR
enabling technology list*

15

Figure 70

Previously I mentioned a memorandum Mr. Young sent to the Secretary, listing those technologies the Department should invest in to enable future capability. Those technologies are listed on this chart (Figure 70) and the technologies you see in red were not on the list I showed you before. So these are also technologies to emphasize, in addition to those on the previous QDR list. Meta materials are on the list. Those are materials with a negative index of reflection and refraction, and have tremendous implications in terms of stealth capabilities for vehicles; something the Chinese are investing in heavily.

DDR&E Investment Initiatives (Cont'd) S&T Thrust Areas (from 24 Aug 07 memo)



- Directed Energy Technologies
- Autonomous Operation of Networks of Unmanned Vehicles in Complex Environment
- **Advanced Medical Research** *In Red—Areas not on QDR enabling technology list*
- **Software Development Technology**
- Energy and Power Technologies
- Organization, Fusion, & Mining of Large Data Sets for Enhanced Decision Making
- Combating Weapons of Mass Destruction Technologies
- Energetic Materials

16

Figure 71

I mentioned advanced medical research. The Secretary is very concerned about providing improved medical care to the troops and advanced medical technologies are on the list of technologies that Mr. Young sent to the Secretary (see Figure 71). So those two documents, the 2006 QDR and that 24 August 2007 memo, are driving our S&T investment right now.

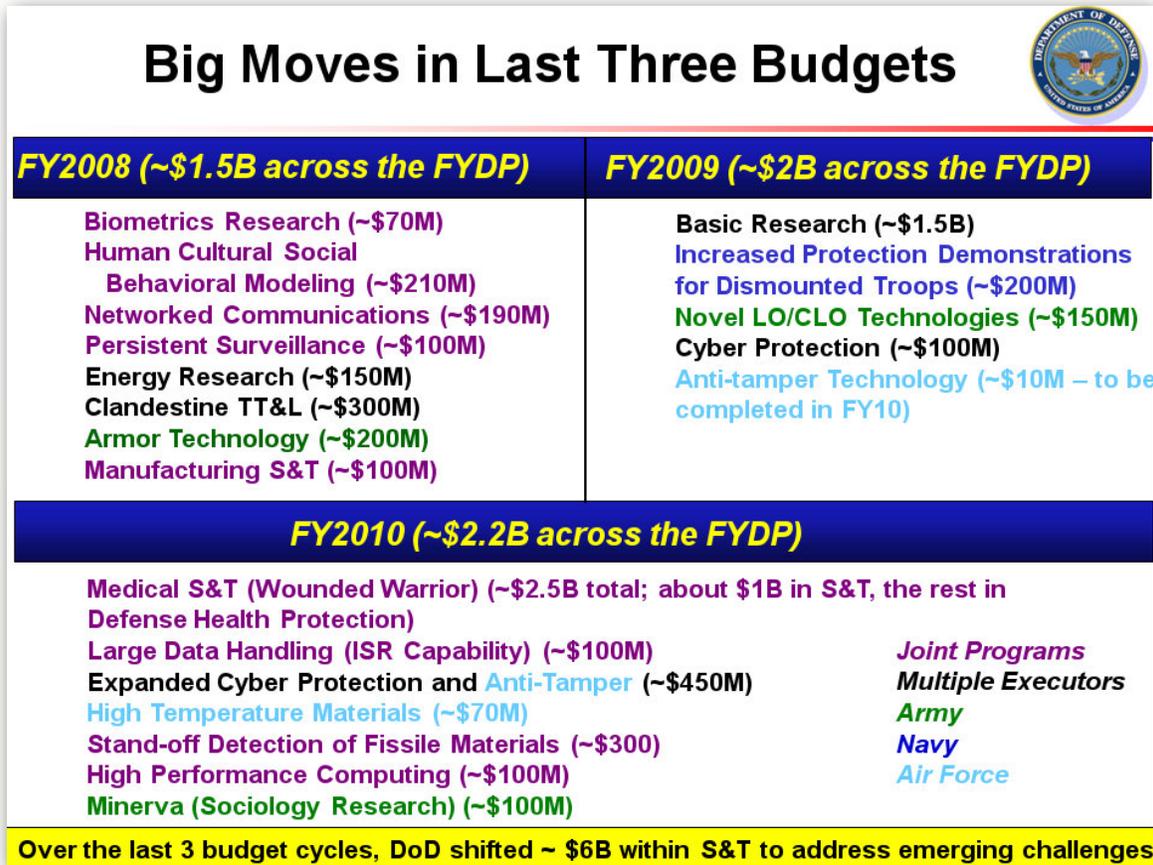


Figure 72

If we examine what difference these documents have made in our budgets in FY 2008, FY 2009, and FY 2010; a close examination reveals that we have shifted about \$5.7 billion out of the Traditional area and moved it into the Irregular Warfare, Catastrophic, and Disruptive Technology areas. On this chart (Figure 72) you see a \$1.5 billion increase in Basic Research. There are also things like protection technology and cyber protection. The color codes identify Army, Navy, Air Force programs, and joint programs in black, which means two organizations or multiple contributors. So what we have done is moved \$5.7 billion across the FYDP, which is the Pentagon’s term for Future Years’ Defense Plan. So, what you see on this chart is a five year snapshot of the DoD S&T budget in terms of funding shifts.

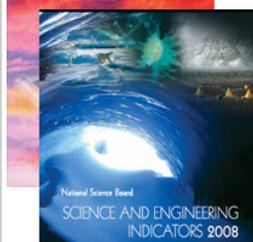
The bottom line is the Secretary said on the 6th of April to take a holistic approach on the capabilities we need for the future. We don’t see a need for new platforms. The investment is going into protection for the troops and those platforms we already have. Also, there is additional funding to obtain more information about the battle space. In other words, finding out where the adversary is located. We have no problem neutralizing adversaries if we can determine where they are. The problem in today’s environment is locating where the adversary is hiding.



Some Common Concerns

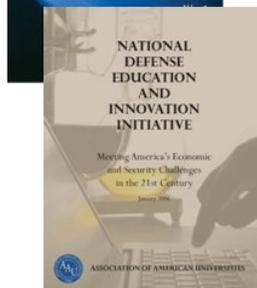


Need for STEM Qualified and Engaged Teachers – “10,000 teachers, 10,000,000 minds” [Rising, 2007]



Scientific Output from Asia and Western Europe is Increasing [S&E Indicators, 2008]

Advanced training in natural sciences and engineering is becoming widespread, eroding the U.S. advantage [S&E Indicators, 2008]



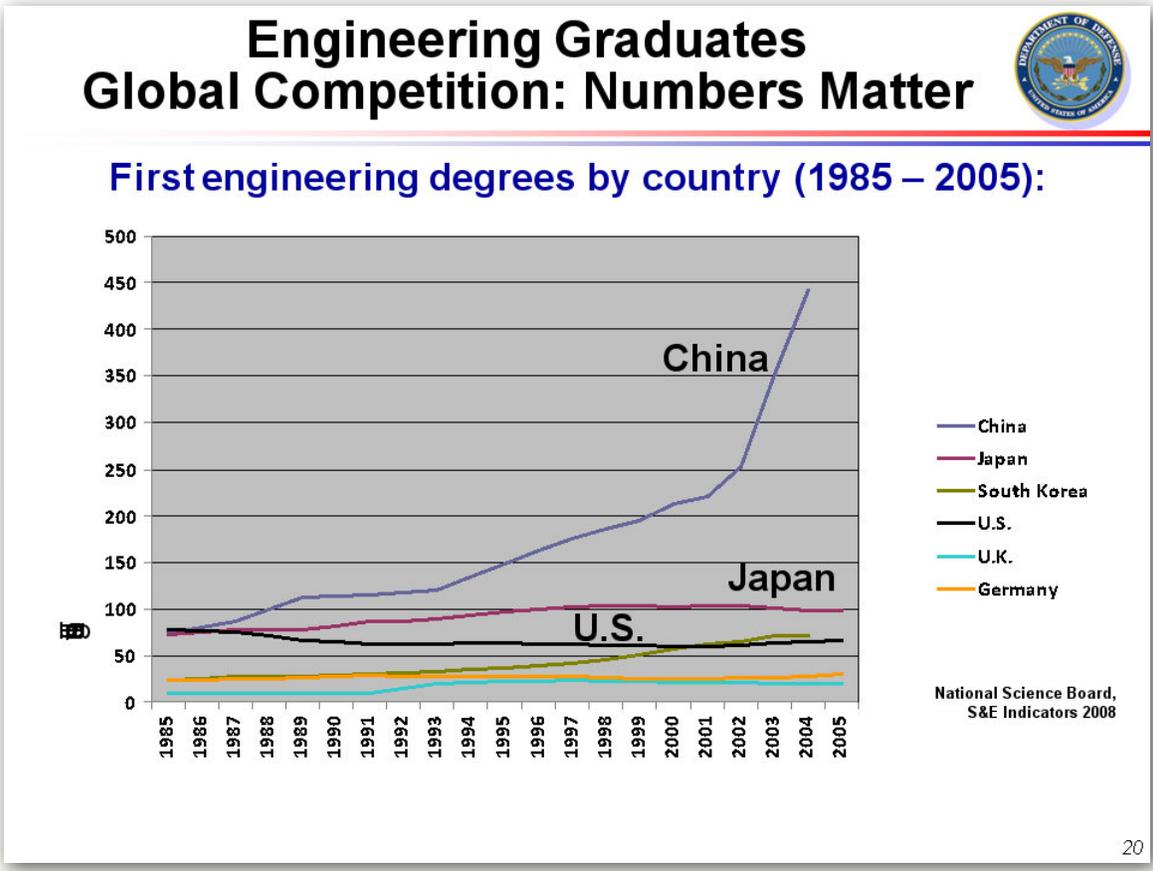
Decreasing incentives for students to pursue and remain in STEM careers [NDEII, 2006]

“Asia and Europe are expanding their capacity to educate and train engineers” [NDEII, 2006; S&E Indicators, 2008]

18

Figure 73

The key ingredient to the execution of an S&T program is scientists and engineers. We, in the DoD, read the same documents that you do, the *Rising Storm*, *Science and Engineering Indicators*, and *Natural Defense Innovation Initiative*. On this chart (Figure 73) you see some of the comments made in these documents. These comments are consistent with what we have been seeing since the mid '90s.



20

Figure 74

I assure you DoD has been paying attention to the S&E problem, particularly when we see graphs like this (Figure 74) showing up in the National Science Board, *S&E Indicators* for 2008, where the U.S. in 1985 was keeping up; we were right there with China and the rest of the world, and have now fallen behind. We are producing S&Es at a fairly constant rate, while the rest of the world has increased its production significantly.

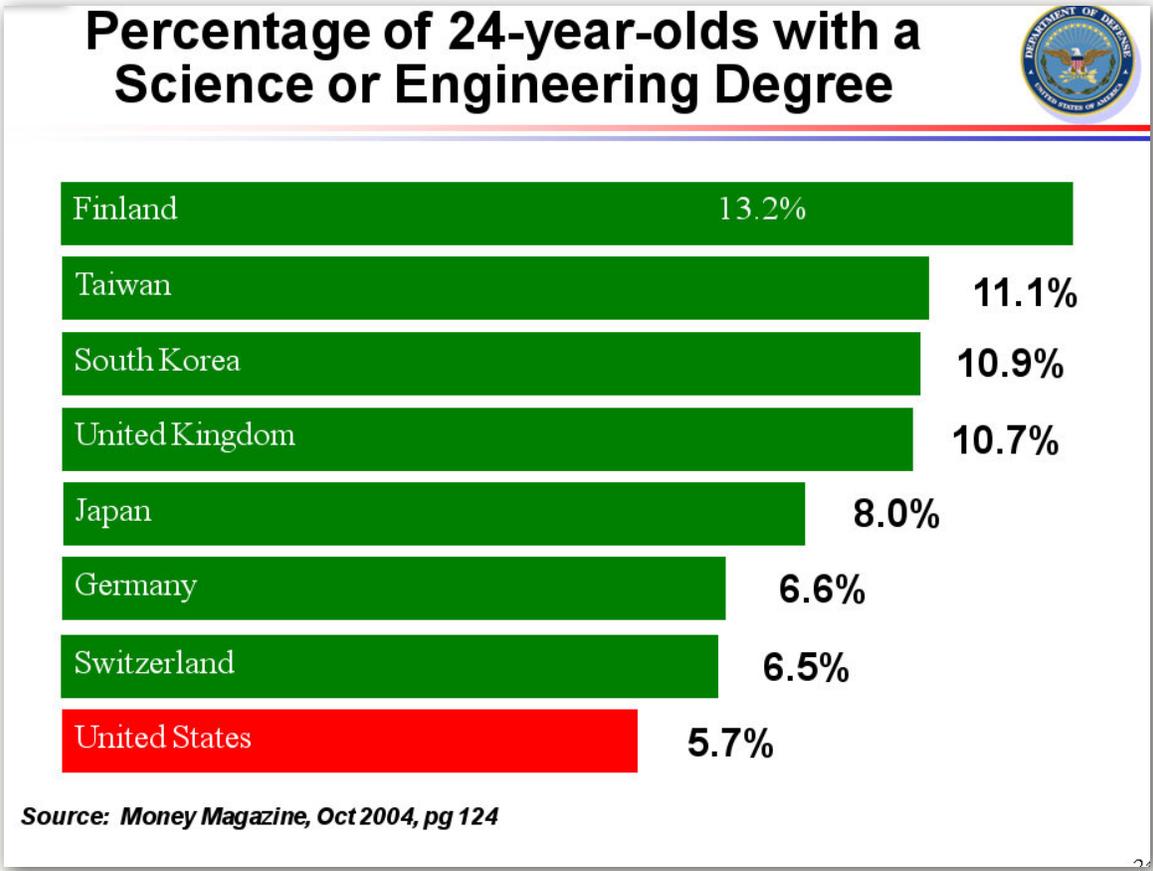
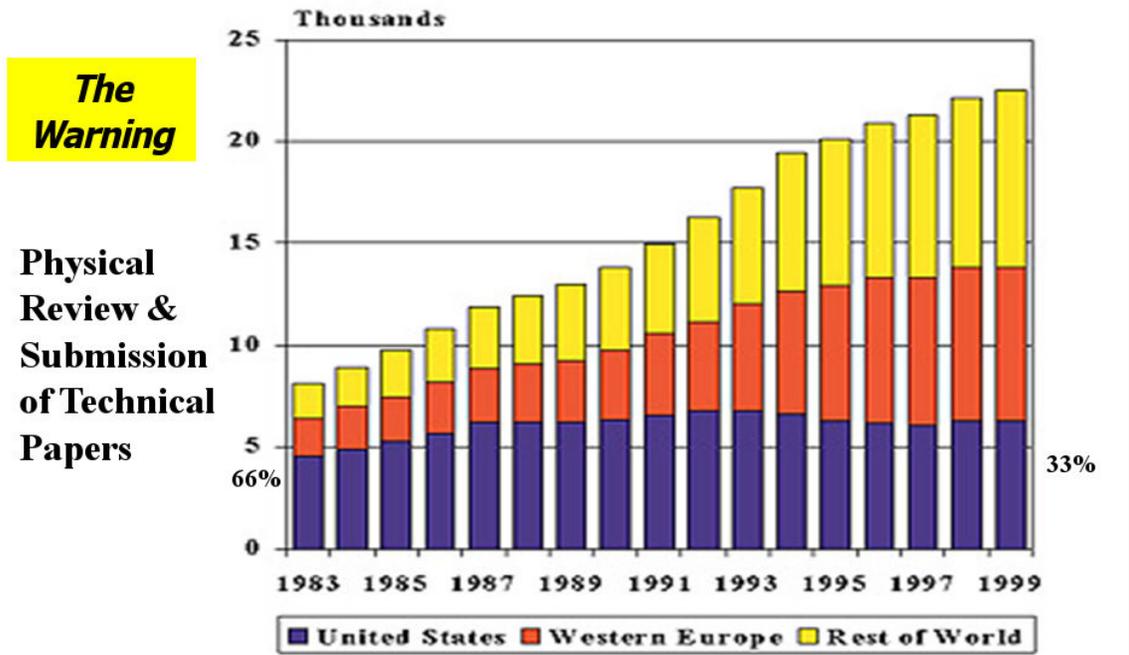


Figure 75

This is an interesting chart (Figure 75) if you're going to develop metrics to track the return on investment for funding we send to universities to perform research in science, math & engineering. The chart shows the percentage of 24 year olds in the U.S. with a degree in science and engineering. A lot of people point out to me there are a lot fewer people in Finland than in the U.S., but the lower percentage is an indicator of the value a 24-year-old in the U.S. puts on a degree in science and engineering; something that is a real concern to us. These numbers comes from *Money Magazine* back in 2004, but the trend has not changed.

U.S. No Longer Leads the World in the Generation of New Scientific Knowledge



Source: American Physical Society - *APS News August/September 2000*

22

Figure 76

What impact has this trend had on the development of technical papers? This chart (Figure 76) shows that in 1983, the U.S., which is purple down at the bottom, created about two-thirds of the reports published around the world. This represents the discovery of new scientific information. If we then take that all the way out to 1999, the U.S. remained constant, but now we're down to about a third, instead of two-thirds of the information that is being discovered.

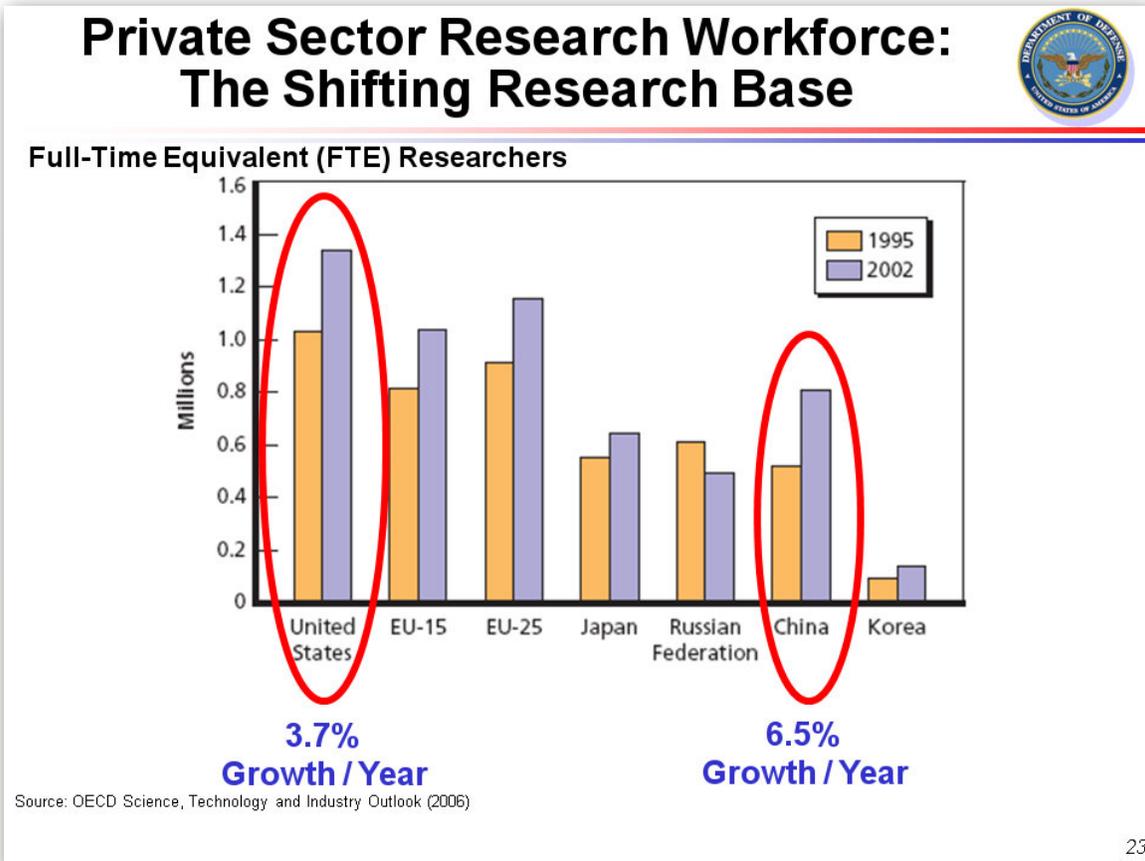


Figure 77

This chart (Figure 77) shows the growth rate of full-time equivalent researchers from 1995 to 2002 for various nations. In the U.S. we see our growth rate is only about 3.7 percent where China’s growth rate is 6.5 percent, another very disturbing trend.

The Challenge from the Rest of the World



- **KAUST (King Abdullah University of Science and Technology) - IEEE Spectrum – September 2009**
- **CSTDC (China Science and Technology Exchange Center) – September 2009**



- **CITDC (China International Talent Development Center)**

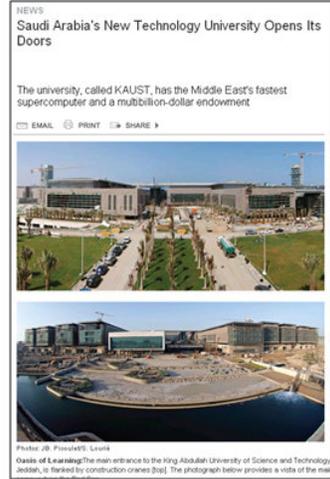


Figure 78

The information on the next chart (Figure 78) was alluded to by Jim in his talk about the development of graduate students overseas. At the Saudi Arabia King Abdul University, they are attracting a lot of U.S. professors and U.S. students. They search the world for the cream of the crop. The same thing is going on in China. Many times students can go to these schools and pay absolutely no tuition. These institutions are just looking for the best students to get involved in development of science and technology.

So that's the world challenge. What's the DoD doing about it? We actually have a STEM strategic plan that's being prepared at the urging of Congress, because Congress is concerned that we are spending a lot of money and they want to know what we are getting for the dollar. We think there are a lot of initiatives underway and all are not necessarily coordinated and tied together. Congress wants us to develop a strategy and plan to ensure all the moving parts are complementary and not duplicative.

DoD DDR&E Response



- DoD STEM Strategic Plan is being developed
- Working group (~160) led by Dr. Laura Adolfie
- Contact information
 - laura.adolfie@osd.mil
 - 703-588-1479
 - 703-588-1423 (fax)
 - Assistant: Michelle Walker
 - michelle.walker.ctr@osd.mil
 - 703-588-1405
 - STEM@osd.mil

25

Figure 79

The person leading our STEM program is Dr. Laura Adolfie. Marty invited her to attend this meeting today and provide a presentation, but she unfortunately was involved in another meeting. She has a group of about 160 folks she works with, and she said anybody who wants to join her group is welcome. Here is her contact information (Figure 79). She has an assistant, Michele Walker, and if you would like to write to her website it's STEM@OSD.mil. Laura is developing the DoD strategy and plan. It should be completed sometime in November, so look for something coming out of DoD on what we hope will be a common sense approach to address the STEM issue.

We do have a funded program called the National Defense Educational Program, put in place by Dr. Ron Sega, the Director of Defense Research & Engineering in 2004. It started out at \$10 million a year and is very similar to the National Defense Education Act the country put in place when the Russians launched Sputnik. Dr. Sega was able to get this program started at \$10 million per year and you can see that the request for 2009 is \$69 million. In 2008 we requested \$42 million and the 2010 budget request on the Hill is for \$90 million. So that too is a program that has a significant funding slope that Congress has supported. It has the goal of creating scientists and engineers and is only available for U.S. citizens.

The DoD not only funds colleges, universities, and graduate schools; but we also have a program for K to 12 because we find students make their decisions back in middle school regarding what they are going to do in terms of pursuing a career in science and engineering. DoD laboratories and bases execute the K to 12 program. Both military and civilian folks go out into the schools and talk to students. We also provide the schools with tutors. So the DoD has outreach programs in the community as well the universities.

If you'd like to tap into some of this money, here are some of the websites for specific programs. There's the SMART program that's under National Defense Education Program. It's looking across many scientific and technology disciplines. If you would like to apply for a grant or scholarship, the application date is 15 December 2010. Here's the website you can go to. We also have the National Defense Science and Engineering Graduate Fellowship, and this chart shows 15 specific disciplines we're looking into at the graduate level. There is a cutoff date of 4 January 2010, and there's the website you can go to. Many times when we talk about this program, people in the audience ask "How can I apply for this money?" That's how you do it. It is fairly competitive because Laura tells me for every one scholarship or fellowship that is awarded, there are probably 10 applicants.

So that in a "nutshell" is what's going on in the DoD in terms of R&D, plus a little bit about the STEM program and who you can ask for more information.

The Census Bureau's New American Community Survey Enables Major Improvements in the Coverage, Content, Timeliness, and Accessibility of STEM Workforce Data

Presented by Mr. Richard Ellis, Ellis Research Services

MR. RICHARD ELLIS: *(1) This presentation began with the following handout:*

What's in DOE's ACS Data Archive?

This is the initial draft version of an archive for the U.S. Department of Energy, containing statistics on the entire STEM workforce from the 2005-2007 editions of the Census Bureau's new American Community Survey (ACS). This new annual survey provides data that were previously available only from the decennial Census, or from a variety of other less timely sources or sources which were less useful in other ways (for example, smaller samples). This changes the usefulness of such data from mostly a matter of historical interest to much more timely information for persons interested in recent trends in rapidly evolving professions in technology and the sciences.

In addition to these major improvements in the frequency, rapid release, and depth of statistical information on STEM professions, a separate development makes access to such information much easier than has been the case in the past. Internet services such as the IPUMS site operated by the University of Minnesota can be used to either extract entire datasets from the ACS or to create many types of statistics from those data online, without any need to use local data processing specialists at all. Virtually all of the data in this archive were generated with the IPUMS online systems, although we have also begun to experiment with direct tabulations of whole IPUMS data extracts because this may add access to some datasets and variables which are not yet accessible online.

Greatly improved access to useful STEM statistics should substantially increase the use of these resources. It will also substantially reduce costs associated with the production of similar statistics in the past. At the same time, it may also justify local budget increases for such work because there is now much more to examine than has been the case before.

IPUMS output from its online database processing system comes in the form of standard HTML files. We have converted all such output to pure spreadsheets to facilitate calculations, consistent presentations, preservation of formulas or other calculations, and other user conveniences. In particular, everything in this archive is comparable to the reports for preceding years done by the Sloan Foundation-supported STEM Workforce Data Project, also available at www.cpst.org.

The ACS is not without some weaknesses, but in general those weaknesses are shared by most other sources of information on STEM professions. For example, rapid shifts in specializations now mean that the largest group of engineers reported by most federal source of such data is the set of miscellaneous "Other engineers" not reported in any other published category. Since all other reported engineering specialties are smaller than this one, it is very likely that it includes many different types of classifiable occupations. Later editions of these notes will expand on this topic and suggest ways to deal with it, and will also comment on other strengths and weaknesses of STEM data sources.

Specific statistics in Version 1.0 of the archive

For this initial version, the “archive” is simply a standard computer directory or “folder,” suitable for most hardware available today. All materials are provided in the common Microsoft Excel 2000/97/XP “.xls” file format and can be used on virtually all PC hardware platforms available today. Indeed, all of the archive’s files were constructed on a 64-bit Linux system running Open Office, which is available at no cost for Microsoft or Unix platforms (the latter include Apple’s OSX). Spreadsheets are used in place of less volatile HTML, text or PDF versions of the ACS results because they retain hidden data such as cell formulas and thus contribute to the archive’s transparency and openness to the correction of any errors users may discover; in such a case, please notify raellis@earthlink.net.

In the future, the archive can be distributed in formats such as self-executing ZIP or other archival tools if this is likely to save meaningful amounts of download time. Such files contain source materials in compressed formats and will be substantially smaller than their originals. Version 0 of this archive designates its status as a draft. Version 1 will consist of a completed draft (presently expected to go through at least two more rounds of substantial additions) that has been reviewed and accepted by our sponsors at the U.S. Department of Energy. Expansion of the archive will include many new kinds of information on people in the STEM workforce; see below for more details.

The author wishes to comment on the present usage of the term “STEM.” It seems absurd to stick the mathematical occupations in with computer science; they should be grouped with the rest of science. This is why this archive does not include a separate subtotal for the common “Computer and Mathematical Occupations” subgroup treated in most applications of the current federal Standard Occupational Classification (“SOC”) coding system. If the “M” in “STEM” should stand for anything, it should be for medicine, which is the largest available example of an applied scientific realm like engineering or information technology that is not otherwise treated here (there are other candidates for inclusion in statistics on STEM professions, including elementary and secondary science teachers; current data also miss postsecondary faculty, a problem we will address in future updates).

This initial draft version of the archive - the version 0.2 update is nearly complete and will be available shortly-- includes the following subdirectories:

(1) STEM Occupations - 2005-07 Time Series and Combined Dataset

Table 1 provides the complete employment times series from 2005, 2006, and 2007 for almost 50 specific STEM occupational classes. In addition, numerous subtotals are provided for selected groups of these occupations. Data for 2008 are currently being added to the archive and will be included in version 0.3, expected to be available by early 2010. Note that this is the first use of the ACS as a resource for these kinds of STEM data; all future updates will be easier to handle and so the annual time lag from data collection to user availability is likely to be able to be reduced by at least another couple of months.

In addition, results are also provided for a combined dataset that merges the ACS samples from all three years (2005, 2006, and 2007), yielding three times as many cases for any analysis examining this period as a whole. This combined dataset is then used as the source for many of the other materials in the archive, particularly for such purposes as the examination of age, gender, and other questions where very large samples offer new capacities to generate details for smaller STEM occupations.

(2) Characteristics of STEM Workers

This subdirectory contains five files providing results for all of the above occupational categories in the combined three-year 2005-2007 ACS dataset, for:

- sex;
- age (in five-year groups);
- ethnicity;
- citizenship (not available in other annual compendia of STEM data); and
- highest degree (ditto).

Note that control of age is essential for the examination of gender effects on participation in STEM occupations, because until the 1970's, women only rarely joined many of these professions,

particularly those in engineering. As a consequence, the women's share of STEM occupations tends to decline as one examines more experienced groups of workers, although exceptions to this trend can be observed. Version 0.2 of the archive will add complete breakdowns of all of the reported STEM occupational groups by gender and five-year age groups. Later versions of the archive will also add in

earned income medians for the entire set of age by gender tabulations.

(3) Employment and Unemployment

Table 3 adds information on unemployment rates to the data from the combined 2005-2007 three-year ACS surveys in Table 1. It also includes information on persons who have been identified as members of STEM occupations but who are NOT in the labor force (have not worked for at least five years), as well as the numbers of such persons who state that they are still available for work. Version 0.2 will add more recent (3rd quarter 2009) unemployment rates from the Current Population Survey (CPS).

(4) Geographic Distributions

Table 4.1 provides the distribution of the set of STEM occupations by states (including the District of Columbia). Note that data is available from a separate survey, similar to the ACS but for persons in Puerto Rico; those data have been retrieved and will be added to this tabulation in version 0.2. That update will also add data on the makeup of STEM occupations in a set of 35 major metropolitan statistical areas.

(5) Occupations by Industry Sectors

Table 5.1 distributes the set of STEM occupations by major industry employer sectors. A separate tabulation to be added in version 0.2 will provide similar information on a selected set of more detailed industry groups where STEM professionals are particularly likely to work. In addition, later updates will include a subdirectory containing special runs on the characteristics of selected occupation-and-industry combinations (for example, electrical engineers employed by electrical utilities companies).

A sixth subsection of the archive will be added in version 0.2: measures of differences in economic demand for each of the reported STEM occupations.

What happens next

Further updates of the archive are likely to emphasize three types of additions: detailed

examination of workforce characteristics for selected combinations of occupations and industry sectors; additional details for states and other geographic divisions; and the addition of data for 2008 to the entire archive.

Suggestions for additional tabulation possibilities will be welcome, as will be potential contributions to this archive from other users of the ACS. Users should be aware that the ACS contains a host of additional items that have not been reported here, including information on housing, households, family structures, several other measures of income, national origins, and more.

Richard Ellis (December 5, 2009)

Ellis Research Services

125 Walnut Street

Carlisle, PA 17013

raellis@earthlink.net

(717) 218-9818 (voice and fax)

(717) 386-7931 (cell)

[Handout ends]

(2) Selected additional comments made by the author during the presentation:

The Department of Energy finds itself in the interesting position of having to place a large amount of stimulus money in a hurry. Work had dried up for the type of stuff I do [assembling STEM statistics], because nonprofits and foundations have been hit by the current national economic unpleasantness, just like everybody else. This project has rescued my own STEM-intensive business (although that result probably hasn't been included in the government's job preservation numbers),...

This project will include the use of advanced computer graphics to get this information out in forms where people will pay attention to it, rather than simply producing materials that sit in somebody's filing cabinet and never get used, which is the fate of much of the information about the whole STEM enterprise... I will remind you all that for a long time the Congress has supported efforts to encourage women and minorities to participate in American science and technology, The track record show that current trends are actually going in the opposite direction. So rules and policies don't mean much if nobody pays attention to them...

With the ACS, we have all of the following: much larger databases, meaning that we can dig down to levels we were never able to approach before. New variables, not previously available in any annual source of information... And incredible improvements in accessibility. These data are available to everyone in this room, at no cost, anytime you feel like going online and generating them. You do not need to be a programmer, although some experience with databases probably helps. We used the University of Minnesota's IPUMS web site, which includes the capacity to tap more than a century of Census results with a single click of a mouse... Nothing like this has been available in the past.

(3) Updates:

Since the presentation, DOE's archive has grown. It now includes all of the added information noted above. In addition, data for 2008 have been added to all time series. The final version of this initial baseline archive of STEM data from the American Community Survey will be released this coming Spring.

Towards Data Driven STEM Policymaking

Presented by Dr. Ron Hira, Associate Professor of Public Policy Rochester Institute of Technology

DR. RON HIRA: I want to thank Marty for inviting me to speak today, and I really am quite excited about Richard Ellis's presentation of this ACS data. We can finally maybe make some progress in the discussion about the science and engineering workforce for both supply and demand. Demand measures have really been absent not only in the discussion but absent for analysts to examine.

I'm going to talk about something a little bit different, not analytic work, but instead I'll tell a story of what I think is a lesson I learned along the way in terms of how data is used in the policy making process. I'm going to look at the case of off-shoring.

I'm an engineer by training and so I'm steeped in policy analysis, but one thing I learned being involved in the public discussion about the off-shoring of high skilled jobs is how important the role of politics is not just in what we'd assume it would inject into the policy process — where policy choices are being made, selection of different policy proposals as in the healthcare debate now where you talk about politics — but how important it is in terms of framing the debate in terms of data gathering. Thinking about what data we need to be collected, and I'll talk about off-shoring. But we could use this in terms of talking about other workforce issues such as immigration policy.

Offshoring

- Offshoring of White Collar Jobs is the “*Next Industrial Revolution*”
 - Prof. Alan Blinder, Princeton University & former Vice-Chair of Federal Reserve

- “Is The US Killing Its Innovation Machine”
 - Harvard Business Review Discussion
 - How does the offshoring of R&D and manufacturing affect America’s competitiveness?
 - In response to Pisano & Shih summer HBR article

Figure 80

Off-shoring, what is it? Most people in the room know what it is now but let me pull out a couple things I think is important. Alan Blinder about two years ago wrote a pretty provocative piece in *Foreign Affairs Magazine* and said “Off-shoring is the next industrial revolution” (see Figure 80). That’s strong words from somebody who’s a sober, mainstream economist, Clinton’s head of Council on Economic Advisors, Princeton University professor, former vice chair of the Federal Reserve. Frankly if you talk to him, he got a lot of pushback by his community of economists. He has laid out the case this is a structural shift in the economy equivalent to the industrial revolution. Think about how important that is in terms of all aspects of the economy, the workforce, and national security.

The last couple of weeks there’s been a blog going on in the *Harvard Business Review*, quite fascinating, with an article by two Harvard business school professors, Gary Pisano and Willy Shih in a special issue of HBR about restoring America’s competitiveness. Pisano is an academic and Shih worked as an executive at IBM Silicon Graphics and was president of one of the divisions at Kodak, not radical folks, and they came out questioning whether outsourcing was good for both business and American competitiveness, questioned migration of manufacturing and what they call the “industrial commons”, those ramifications not just for what goes on now but creating the next levels of technology whether battery technology in green jobs, those kinds of things.

There's been an interesting back and forth on this blog. Go to *Harvard Business Review* website and see the comments of people like Clyde Prestowitz, Laura Tyson discussing this issue I think for the first time at that kind of level. It's interesting how much data plays a role in the way people interpret what's going on, i.e. Shih and Pisano present a graphic about advanced technology product trade, the fact we run a trade deficit in high tech products, something a lot of people don't realize. It seems odd that we are specializing in the high tech but run a trade deficit with the world and especially with China. This data series goes back to the mid 1980s. The Census Bureau has collected foreign trade statistics.

Laura Tyson, also a chair of the Council of Economic Advisors with the Clinton Administration, is attacking that data saying it's really U.S. multinationals doing export processing in those countries, so we should discount this trade deficit in high tech products. Why can't we answer this question? Does it matter or does it not?



Figure 81

I like to start out my presentations on off-shoring with this dramatic slide, the cover story from *Business Week* in February 3, 2003, which kick-started the debate about outsourcing (Figure 81). So, we've debated this six and a half years, a long time for policy debates. They ask the right question, the subtitle is your job next? Is globalization

sending upscale jobs offshore including chip design engineering, basic research and even financial analysis. Even back in 2003 there were flagging the fact these weren't low skilled, low tech jobs moving offshore. These were high wage, high tech jobs, and they asked: Can America lose these jobs and still prosper?

A lot of mainstream economists said, this is ridiculous, of course America is going to prosper. Free trade always guarantees us a better outcome. But the reality is, to peel back the arguments and theory, it's much more ambiguous. It could be a win/win or a win/lose and we really don't know. That was a subject of a 2004 article by Paul Samuelson, the Nobel Laureate from MIT pointing out what neoclassical trade theory can show and cannot show.

What really happened in response to this discussion? We got the America Competes Act in 2007 and I'll go through the rationale behind it, history of it. The National Academy's *Rising Above the Gathering Storm Report*, most people in the room are aware of, and I was a reviewer on that, there was little to no data gathering, used secondary sources, and there was no analysis in the report. Their diagnosis was straightforward that we have an under-capacity in technology investments and the solution is improve K-12 science and math, increase amount of R&D spending by the government and produce more scientists and engineers domestic and foreign, import some and produce more.

There were no recommendations for better and ongoing data gathering, analysis or intelligence gathering from a very august group that included Norm Augustine, Craig Barrett, that high a level.

What were the origins of this report? In the summer of 2003 IBM was getting bad press in the *Wall Street Journal*, *NY Times* about their employment practices of off-shoring work, forcing their U.S. workers to train foreign replacements as a condition of severance and unemployment, or muzzling those workers. IBM wanted to get ahead of the game and funded the Council on Competitiveness, an inside the Beltway group that didn't do a lot in the late 1990s but was prominent in the 1980s and early 1990s when John Young from Hewlett Packard headed it. They did the National Innovation Initiative, staffed with a lot of IBM and Morgan Stanley folks at the sessions. They purposely excluded U.S. workforce representation. The labor union folks said, "we're not going to be involved because we don't believe what they are doing will go anywhere," unlike what happened in the 1980s when the Council on Competitiveness included the unions and workforce representation.

Fast forward to the Summer of 2005 the National Academy of Sciences did *Rising Above the Gathering Storm (RAGS)* report, Augustine, Barrett, Steven Chu, circumvented the normal National Academy's process to get the report out within six months. They had a directive from Senators Bingaman and Alexander to give them 10 nice off-the-shelf kinds of policy actions that could be done. Again there was no U.S. worker representation on the study panel, which is fascinating if you think about even the way Tom Freidman presents the world is flat and off-shoring and globalization. It is about workers competing across borders, and there's no workforce representation in this study process.

The report assumed the U.S. national innovation system looks like it did back in 1957 responding to Sputnik. By summer of 2007 the COMPETES Act passed and the science and engineering coalition in Washington, many represented here, got behind RAGS because it was about getting more R&D money for the STEM Enterprise, producing and giving more money to universities to produce more scientists and engineers.

From a policy process point of view it was very smart because it took competitiveness off the agenda. Any time anybody raised an issue about off-shoring or globalization, “We already passed the COMPETES Act so we’re done with this.” We just need to fund COMPETES and we’ll be done, and that’s the solution.

R·I·T David Goldston in *Nature* August 2007

“Congress is poised to pass legislation authorizing the approach called for in the *Gathering Storm*.

What needs to happen next is one of those rare, but essential periods when Congress is perplexed enough to scan the full horizon for new diagnoses and prescriptions — including some that are yet to be formulated. The next consensus will have to rely less on a reflexive turn to politically safe, time-honored ideas if the United States is to keep enough high-value jobs to sustain its standard of living.”

Ron Hira, RIT

rhira@mail.rit.edu

8

Figure 82

The politics didn’t go unnoticed. Dave Goldston, chief of staff of the House Science Committee for many years wrote a commentary in *Nature* in August 2007 just before the COMPETES Act passed and said, “Congress is poised to pass legislation authorizing the approach called for in the *Gathering Storm*.”

What needs to happen next is one of those rare, but essential periods when Congress is perplexed enough to scan the full horizon for new diagnoses and prescriptions — including some that are yet to be formulated. The next consensus will have to rely less on a reflexive turn to politically safe, time-honored ideas if the United States is to keep enough high-value jobs to sustain its standard of living” (see Figure 82). He had been chief of staff of House Science Committee that passed the Competes Act, but had stepped down when he wrote this commentary pointing out this was a political process, not about analysis or thinking outside the box or coming up with new policy ideas and alternatives.

What was missing was the kind of discussion we had in the 1980s when we had a competitiveness debate and passed many different acts, Stevenson/Wydler Act, Bayh/Dole Act, Technology Transfer Act, created Omnibus Trade and Investment Act in 1988, and there was a long discussion in the 1980s and early 1990s about how to address competitiveness. Instead, we short-circuited that whole policy dialog and process for political reasons.

Let me turn to some different narratives about offshoring. The dominant way of framing off-shoring in terms of the workforce is that there is a division of labor by skill level. The story goes the U.S. keeps high-skill, high-wage jobs and industry and offshore is low-skill, low-wage jobs. We don't want the low-skilled, labor-intensive stuff, so we'll offshore that and free us up to do the higher level things. So off-shoring becomes a win/win, creates a guaranteed win/win, to quote Diana Farrell who probably made more money than anyone in this process as a management consultant selling off-shoring and is now the number two person in the Obama administration and National Economic Council. Contrast this with Obama's election campaign comments about off-shoring.

What Diana Farrell based this off-shoring support on is the idea that we are a job creation machine here in the U.S. We are in a bad cycle right now, but it's questionable over the last decade, even outside this downturn, if we've really been a job creation machine. We've not created 3.5 million jobs a year over that period in any of those years. America's competitive advantage, as the narrative goes, is innovation, so there's a simple formula, move up skill and move to better industries.

Blinder and a number of other people offer a different narrative, maybe not about skill level but about tradability, whether things can be done across borders or need to be done face to face. Blinder argued that work that can be done remotely is vulnerable but face to face will be geographically sticky and those will stay here. He did estimates, looked at all 838 SOC codes in the BLS data and used the judgment that said "Can this work be done remotely or do you need face to face contact?" He estimates a third of all U.S. jobs are vulnerable to off-shoring, meaning they're newly tradable, and wage competition will be the primary fact, not that all these jobs will move offshore, but we will see lowering wages as you compete against your cousins, in my case literally my cousins in India who can now do that work remotely. He concludes that most STEM occupations are vulnerable to this wage competition and tradability and the policy solution would be to specialize in sticky jobs and industries.

Can we test these theories? Blinder's analysis has been attacked because it's speculative, but so is the other theory about just moving up skill. Without data you really can't test theories. What types are being off-shored, how many, where, what are the wage impacts, what happens to displaced workers, do they get reemployed quickly? Do they take significant wage cuts, get pushed out of particular occupations into others, go from engineering to mortgage brokers? Where is the government here in collecting the data? Nobody has paid attention to that. How do we test which theory is right, and to what end? More importantly, it's not just an academic exercise. We need to give the right kinds of labor market signals to workers so they don't train in fields that are going to be rendered obsolete by trade globalization?

One reason we don't have this data is because companies have a strong interest in keeping offshore hidden from view. These companies know what type of jobs will be moved offshore and which not, and i.e. IBM's headcount in India went from 6,000 in 2003 to an estimated 95,000 in 2009, the last solid data we have is from 2007 when they had 74,000. They have grown 16-fold in six years. If they had hired 90,000 in the U.S. over that period of time, you'd see ads all over. This is a very significant increase in their headcount. They have 115,000 in the U.S., aren't announcing layoffs anymore, and now call them "resource actions," the new euphemism for layoffs in the

U.S. There's much dispute about what types of jobs are laid off, knowledge transfer going on, and to what extent they are training replacements.

Where did *Rising Above the Gathering Storm* come from? The two co chairs of that national innovation initiative back in 2003 were Sam Palmisano, the CEO of IBM and Wayne Clough president of Georgia Tech at the time. It's not as though they didn't have a conflict of interest in terms of the process and outcomes of the policy solutions.

In terms of the narrative, if you believe the first theory that this is just a matter of skill level, that we'll keep the high-tech, high-wage, high-skilled jobs, what happens to that narrative if R&D and innovation is being off-shored as we are starting to see? We already see low-cost countries can attract R&D and innovation and investments, R&D site selection experts say India and China are competitive for those investments. This is not low-level, mind-numbing coding in India or low-level manufacturing in China. This is high tech R&D types of investment.

RIT

Microsoft

- Microsoft in India
 - Employs more than 4,000 workers in India.
 - The Microsoft India Development Center (an R&D center) was established in 1998.
 - 120 people in 2003
 - 1,500+ workers in 2008 – ten-fold increase
 - Developed key components of BING search

Ron Hira, RIT rhira@mail.rit.edu 16

Figure 83

Microsoft

- Microsoft in China
 - China R&D Group >10 yrs old w/1,500 workers
 - Localization & serve global markets
 - May 08 announces \$280 million R&D campus in Beijing
 - Nov 08 - expanding its China R&D operations investing an additional \$1 billion over the next three years
 - largest R&D center behind US

Figure 84



General Electric

- GE's R&D Headcount Distribution as of 2007
 - NY Research headquarters = 1,900
 - Munich = 150
 - Shanghai = 150
 - **Jack Welch Center in Bangalore = 3,000**
- Jeffrey Immelt, CEO of GE
 - Increase U.S. Manufacturing employment to 20%
 - Oct 2009 HBR Article promoting "Reverse Innovation"

Ron Hira, RIT

rhira@mail.rit.edu

18

Figure 85

Intel

- Intel in India
 - 1988 Establishes sales office
 - 1998: Establishes R&D center
 - 2008: ~2,500 R&D headcount
 - 2007 Bangalore center did half the work towards “teraflop research chip”
 - Sep 2008 first microprocessor designed entirely in India, and first time 45 nm technology designed outside of the U.S.
 - Xeon 7400 microprocessor is used for high-end servers

Figure 86



Intel

- Intel in China
 - Building a \$2.5 billion 300mm semiconductor fabrication facility in Dalian, China, its first in Asia
 - Intel Corp's global investment organization, Intel Capital, established a second China investment fund. The \$500 million Intel Capital China Technology Fund II will be used for investments in wireless broadband, technology, media, telecommunications, and "clean tech."
 - "The establishment of our China Technology Fund II, is more than double the size of the original China Fund is the ideal way to celebrate 10 years of Intel Capital activity in China's vibrant economy," Arvind Sodhani, president of Intel Capital

Ron Hira, RIT

rhira@mail.rit.edu

20

Figure 87

Multinationals have established 1,160 research institutions in China up from 100 in 1999, and the Ministry of Commerce in China has some criteria for measuring that. Cisco claims to already be doing half its core R&D in India. Microsoft (see Figure 83 and Figure 84) is increasing R&D in India significantly, the recent Bing search engine had significant parts developed in India. In China they have increased investments in R&D, in May 2008 a \$280 million announcement and by November, six month later up to \$1 billion. GE (see Figure 85) has a higher headcount in Jack Welch center in Bangalore, with an R&D workforce R&D of 3,000, more than all the other centers combined including the U.S. center. This is particularly interesting since Jeff Immelt's, current CEO, recent comment and ads on Sunday talk shows of Rebuilding America (America's Renewal, Rebuilding Manufacturing in America) Immelt has spoken out that we need 20 percent of our employment in manufacturing in the U.S. at 11 percent. Intel (see Figure 86 and Figure 87) is doing a lot in low cost countries, not just building up headcount, but startup funds, venture funds, in India and China.

There's lots new in this round of globalization, employment relations - we talked about going from lifetime employment at IBM to being forced to train the replacement. CEO Palmisano talks of globally integrated enterprise in a Foreign Affairs article that everyone should read to understand where business strategy is going in thinking

about globalization. U.S. universities are going global in ways very different than prior patterns. This calls into question our R&D investments. Everyone in this room wants to increase them without thinking of what's happening to the structure and downstream benefits. We don't invest in R&D as ends in themselves but do the investments/ tax credits to create the downstream benefits, design, development and production jobs, and hope those will stay in the U.S.

So there's a structural shift in the nature of the U.S. national innovation system, but you can't just look at that but look that politics are different this time around in the discussion of competitiveness, and it shapes the policy process. This last slide, What Should We Do? – collect additional, better, timelier data is not a whole lot different than what other people would say, but we really need an independent institute to study the implications of globalization if for no other reason than national security, now absent in the discussion on globalization and its impact on the industrial base, innovation and future technologies. Last, we need to think about facilitating work representation in all these panels. You can't have the National Academies with their kind of influence and power not have any workforce representation. Thank you.

QUESTION: (Question on H1B visas and off-shoring)

MR. HIRA: To understand the policy debate within H1B you can't understand it without understanding the politics of the various interest groups, and it's amazing how new data revealed that becomes transparent can shift the debate. One of the key arguments people like Bill Gates and people in this room make is that unless we import and increase the number of H1Bs, the cap, companies will simply outsource. The argument goes that by keeping the cap where it is, we're forcing companies to go offshore because they can't find enough people. This is their argument. Well, the reality is, the top four firms getting H1B visas are the four major India and IT offshore outsourcing firms. These are companies whose sole purpose is to try to shift as much work offshore as possible, outsource as much work as possible. It runs completely counter to the arguments Gates and others been making about the H1B program. Senators Durbin and Grassley were able to extract at least the data on H1Bs by employers, and it became very obvious what was going on. That I think shifted the debate quite significantly. But they can have data bottled up for political purposes. As much as academics, people in this room act as though STEM Enterprise is devoid of politics, particularly the analysis in the data, they are fooling themselves or choosing to fool you.

An Overview of Federal Government Innovation Metrics Initiatives & Related Efforts: Why They Matter

Presented by Mr. Robert S. Boege, J.D., Executive Director
The Alliance for Science & Technology Research in America (ASTRA)

MR. ROBERT S. BOEGE: You're probably wondering why I have titled my presentation an "Innovation Bestiary." The graphic (see Figure 88) is from the renowned Aberdeen Bestiary, a beautiful medieval manuscript that describes all sort of creatures — both real and (it turns out) fictitious. There are illustrations of animals. There are the usual things like giraffes and elephants — as well as unicorns and sea serpents. In reference to the past presentations, where we referred to "metrics" as animals — that's why we can say that some of these metrics are like animals that might be selected for Noah's Ark. Well, some of these "zoo animals" called "metrics" now being brought before us will not get a ticket for boarding the Ark — unless we can prove that they have 10 and 20-year track records. At least, we need lots of time-delayed data to make good conclusions, according to the gatekeepers who don't seem to understand the time scales of the innovation process.

Workshop on Science, Technology, Engineering and Mathematics (STEM) Enterprise: Measures for Innovation & Competitiveness

An Innovation Bestiary: Measuring U.S. Innovation in an Era of Policy Incoherence, Economic Discontinuity, and Opportunity

Robert S. Boege
ASTRA Executive Director

www.usinnovation.org and www.aboutastra.org

October 21, 2009

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Figure 88

And that's one of the points I want to make today. Our statistical underpinning for what we are calling the U.S. "Innovation Ecosystem" is flawed. It's great to measure the U.S. economy of the 1930s very effectively, but what was constructed generations ago probably reflects about 10 or 15 percent of what we now "do" as a nation. And it has little linkage to the much larger global economy. There's constant concern about whether or not policy makers understand the services economy, intangibles, as well as things like transborder transactions conducted by complex multinational entities. Simple issues become complex. For example, how does one categorize eBay activities under the antiquated product codes that still reign supreme within our government apparatus? Is it really just a Yellow Pages marketing company? Is Yahoo the same as Google?

My point is: there's a disconnect between the economists and statisticians' view of reality, something they are being tasked to measure, and the market's understanding of the same things. By extension, I think that most consumers would be baffled by the complex and arcane nature of our statistical nomenclature and taxonomies, and this in turn makes it very difficult to measure many innovation-related activities. And that all gets back to policy. How do we make good policy decisions without good information?

Moreover, one point I'd make, having been in many a discussion like this... I always look for the innovators in the audience, or on the panels on which I am asked to opine. Generally speaking, I find few real innovators, entrepreneurs or small business owners — individuals who ought to have input into these discussions. Why would we not solicit the input of those who are most familiar with the subject matter, especially when survey instruments are being drafted and/or important policy conclusions are being drawn that affect their core interests?

Defining “Innovation”

- Innovation is “the commercial or industrial application of something new—a new product, process or method of production; a new market or sources of supply; a new form of commercial business or financial organization.” (Schumpeter, *Theory of Economic Development*)
- Innovation is the intersection of invention and insight, leading to the creation of social and economic value. (Innovate America, *National Innovation Initiative Report*, Council on Competitiveness, 2004)
- Innovation—the blend of invention, insight and entrepreneurship that launches growth industries, generates new value and creates high value jobs. (Ahead of the Curve, The Business Council of New York State, Inc. 2006)
- Innovation covers a wide range of activities to improve firm performance, including the implementation of a new or significantly improved product, service, distribution process, manufacturing process, marketing method or organizational method. (European Commission, *Innobarometer 2004*, November 2004)
- An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations. Innovation activities are all scientific, technological, organizational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. (*Oslo Manual*, 3rd Edition, OECD).
- Innovation success is the degree to which value is created for customers through enterprises that transform new knowledge and technologies into profitable products and services for national and global markets. A high rate of innovation in turn contributes to more market creation, economic growth, job creation, wealth and a higher standard of living. (21st Century Working Group, *National Innovation Initiative*, 2004)



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Figure 89

Which leads me to another point: Why does measuring innovation seem to be so difficult? I guess because the process of identifying “Innovation” itself is (see Figure 89). You have some of the materials passed out earlier, and I’ll make reference to them now.

IVS: What We Think We Learned



ASTRA's Innovation Vital Signs Project

Key U.S. Innovation Elements: What are they and how do they interact?

U.S. innovation indicators tend to focus on measurable data sets which have been readily collected by governmental and private entities for many years. While policy makers have traditionally looked at patent production, R&D spending, science & engineering degrees conferred and scientific article citation, the U.S. "innovation ecosystem" is a more complex series of interrelated phenomena. ASTRA has created a **Periodic Table of Innovation Elements** suggesting how key innovation elements interact and seem to affect one another. The more recognized innovation elements depicted below are organized according to eight "element" groups: **Inputs, Process, Outputs, Impact, Macro-Economy, Policy, Infrastructure** and **Mindset**. The key innovation elements selected by ASTRA are organized and color-coded depending upon their primary role.



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Figure 90

At ASTRA, we tried a modest project in 2005 and 2006 -- the Innovation Vital Signs Project (see Figure 90). In it, the team we assembled (thanks to a grant with the former Technology Administration at the U.S. Department of Commerce) tried to start from scratch in identifying key innovation metrics. We wanted to see if we could establish some sense of priority or importance to certain of these innovation benchmarks. One of the participants, Burk Kalweit, is in this room. Burk is with the ASTRA staff. He's also an economist, as was Dr. Egils Milbergs of the Center for Accelerating Innovation. Burk and Egils went through a good 3,500 to 3,700 potential innovation indicators. These "vital signs" were both international, local, and regional in scope — in other words, they ran the gamut.

Our Innovation Vital Signs Team then winnowed the high priority "candidates" down to about one hundred indicators that were the result of a consensus developed through several user workshops we held. They answered the question we posed to users: "If you had to look at what's critical, what matters in innovation, what vital signs would be most important in the innovation space?"

If you read the Period Table of Innovation Elements, it is simply the beginning of a discussion as to what should belong there. That's why I was so fascinated by Katy Börner's presentation earlier. It suggests there's a much larger reality out there that can be "mapped" through much improved data visualization techniques.

The question is obvious: How should we map innovation or innovation subsystems? What sorts of templates would we use? Geospatial? Networking? Hybrids? What would you look for, what would the patterns look like, how would we know it?

I think that now, with the general diffusion of so-called "cloud computing," that these mapping technologies can become the atom smashers of innovation. Soon, assuming we have adequate data and consistent theories of the innovation process, we may be able to actually measure U.S. innovation capacity, or other aspects of innovation, with a high degree of granularity. We will be able to discern geospatial and networking relationships that have been obscured heretofore.

The important results may be to discover underlying and previously undocumented patterns. Or, we will see innovation with greater dimensionality — I'm sure we will have arguments about things and patterns that we did not see before, or debate whether what we are seeing has some causation that is also in the visualization? I think it's a fascinating area and there's a great need for future research in this area.

We won't have time for my presentation if I go through every slide, so please trust me — we tried to look at definitions of innovation and incorporate them into the final product.



IVS: What We Think We Learned

ASTRA's Innovation Vital Signs Project

- **Nomenclature and Taxonomy Possible**
- **Private Sector Data Availability Problematic in U.S.**
- **Dash Board, Other Data Visualization Possible**
- **More Research and Tweaking needed**
- **See IVS Final Report at www.usinnovation.org**

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Figure 92

Here are some “takeaways” from what we learned about the ASTRA Innovation Vital Signs Project (see Figure 92):

1 – A nomenclature and taxonomy are possible, (nomenclature meaning terms we can agree on that define the innovation space). It would be possible for development of an “Innovation” user’s manual of sorts that would instruct us about what to look for in innovation, and patterns that have significant for policy makers especially.

2 - The collection of private sector data is problematic. We think that this is because in the U.S. there is a strong concern about business confidentiality, loss of proprietary methods or IP, and the fact that a significant private industry already exists around the areas of business intelligence, investment management, market analysis, etc. U.S. laws protect the confidentiality of much of the data that probably is significant for innovation and there is a high value to such data that many entities do not want to see in the public domain.

3 – It is possible to create something akin to a dashboard or other data visualization graphics based upon the data we had. While we came to the realization that a lot more research and tweaking was needed, we concluded that in the first stage we need more support and connectedness with other organizations to complete the preliminary

research in this area. It's clear that since our Phase One Report was issued in 2007 there have been hundreds of parallel or more advanced accomplishments in this area. This is a growing space and growing area of interest.

4 - We developed a Regional Innovation Index tool which is on our website. The good news is, it more or less works if you know what you're looking for. You can access it for free. My caveat is, as the Kauffman Foundation recently mentioned to us, it's truly a "beta," populated with data that ends around 2005 and 2006. ASTRA is currently seeking partners to help us populate it with more current data. I think you'll find that — if you want to compare your state or region's economy with another state or region — the Index works quite well. It is focused on U.S. innovation data, doesn't have much in terms of global and was an experiment to see what we could get out of it.

Another question I'd have, acknowledging the richness of what's going on across the world in this space — why don't we use or learn from comparative examples from abroad? Furthermore, why does our U.S. policy apparatus not seem very receptive to the fine work being done by entities like the OECD and so many others, including universities, NGO's, and government entities everywhere? We've mentioned the European role previously, and we should not overlook East Asian and South Asian examples either.

I'm a bit baffled as to why there is resistance to adoption of innovation models that can be tested in the U.S. Some say this is because we as a nation have never developed a serious academic discipline out of innovation economics — because there has heretofore been no incentive and no academic infrastructure to do so. What makes us incapable of looking at comparative models from abroad and learning from them? I don't know the answer, but I think that I am correct in detecting a dismissive attitude that somehow the rest of the world "just doesn't understand innovation in the same way we do." That's fatal thinking, folks.

Observations

- Robust innovation indicators will require working within industry definitions and structures (e.g. NAICS).
- Manufacturing industry data is readily available at levels of detail that are most likely more than adequate.
- Service sector is much more problematic:
 - service industries are significant innovators but little data available.
 - service industries more difficult to evaluate due to lack of data.
 - non-manufacturing industries are much less tangible and therefore less susceptible to measurement.
 - there is no accepted framework for non-goods producing industries available for reporting to capture innovation activities.



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Figure 93

Other observations we've come up with, in no particular order (see Figure 93):

1 - Robust innovation indicators will require working within industry definitions and structures including the NAICS codes that are in my opinion hopelessly outdated. The manufacturing industry data is readily available at many levels of detail, and that is adequate enough for what they need. But the service sector is still problematic.

2 – The “Regime Change” in Washington is unfolding and a fascinating, if evolving, Innovation Agenda is being implemented across many federal agencies. So much is going on... I know that Kei Koizumi of the OSTP couldn't talk about many of the details this morning... for example the creation of an innovation and entrepreneurship office at the Department of Commerce is a very encouraging sign, but we are uninformed about the specifics until they become public.

Ron Hira, you might remember that in the *America COMPETES Act of 2007* Congress actually defunded *and* deauthorized the Technology Administration (TA) at the Department of Commerce. I find this ironic, in that TA was about the only crosscutting agency that could look at things like innovation in a holistic sense. So it is with some satisfaction (I think) that all of a sudden we going to re-create that function again be located at Commerce

and apparently will be reporting directly to Commerce Secretary Gary Locke. That's good news. Who knows how that's going to be done. Obviously there are appointments in the process, but I think all of us should look at that space and see what develops.

There are so many other major initiatives going on in innovation space. The President in September gave a wonderful exposition of why we need to accomplish a 3% of GDP R&D goal. And there is strong support (so far) within the Executive Branch for "doubling" science R&D budgets over a ten-year period. Never mind that inflation may eat up the actual growth, we'll take it for now.

ASTRA has actually published a paper discussing whether this 3% R&D goal is doable. The President's speech was visionary in many ways. It explained a laudable goal, but if you look at where the proposed money will come from, it will be only from the private sector — the very part of the economy that is under duress and is rapidly sending R&D offshore for many reasons. Right now, between 2.6 percent to 2.7 percent is already coming out of private industry. These companies are leaving, and they are sending the high-paying jobs abroad as well. "In-sourcing" also is important, but that's not our focus here. The "off-shorers" may be making themselves more attractive to stock investors, but a higher stock price may be a short-term goal if companies lose control of their own innovation space.

Overall picture: Where's the new money going to come from, given the fiscal situation? There is no proposal in here for government to have an increase in the 3 percent figure. It is true there is a 10-year commitment to a doubling of general overall science budgets, but that's a pretty risky proposition to talk about with \$1.4 trillion deficits in front of us. Finally, there's little or no Congressional will to do much in this area, at least in my opinion. And to sustain such an effort, on the scale of the Manned Space Program or winning the Cold War — I doubt there will be a parallel long-term effort that matters.

We mentioned the Science of Science & Innovation Policy (SciSIP) Program at NSF. This is a fascinating area. SciSIP's Julia Lane and others, some of whom are in this room, are involved in some of those projects. SciSIP has all sorts of potential. There are many projects that could be intensified and rolled out, much that's being discovered, and I believe there's a monthly newsletter that Julia and the group just published can be found over on the table. They have an engaging blog, and you ought to log on and see the discussion. This connectedness, ability to communicate across many disciplines silos, institutions, individual researchers, economists, everybody seems to be involved in a very interesting dialog, and that ability didn't exist a few years ago. That's good news.

The National Science Board has a BRDIS effort. That stands for "Business R&D Innovation Survey." Finally they are starting to ask industry, at least a few representatives of industry, what questions should we ask them about innovation processes. BRDIS hopes to get neutral data back from you — information that you'd agree to provide and that is directly related to your innovation ecosystems.

Interesting effort. I don't know where it's going but if you look at the advisory board one member is our ASTRA chairman Dr. Mary Good who's at the U of Arkansas now, as Dean of the Donaghey School of Engineering & Information Science. Dr. Good's background includes career stints in private industry, places like Allied Signal, as well as several other private companies prior to that.

It sounds good that we'll get some input from industry, but we're still not going to get input from smaller entities. It's fair to say that "Innovation" in this country is overwhelmingly created by smaller enterprises, even if it begins with fundamental research funding by government, universities and industry. Many of you would translate the face of my comment to mean the Small Business Innovative Research (SBIR) or equivalent STTR programs. These are about the only set-asides that exist within the federal budget for science and engineering spending. SBIR/STTR receives about 2.5 percent of certain agency budgets, and these trickle down to smaller business entities and start-ups. That is a tremendous place for innovation, creativity, discovery, and commercialization of technologies that come out of academe. SBIR also results in significant job creation.

That shouldn't be overlooked. Yes, even as we stand or sit here, the SBIR Act has yet to be reauthorized after years of fiddling around and perpetually extending it. It's not a good situation, and failure to renew the Act has gotten so bad that there's now an effort to split off DoD's 6.1 SBIR efforts from the whole package. That move is not being met very well by the Committee staff who are at loggerheads over certain provisions of the SBIR reauthorization bill. But something should be resolved, and soon.

Speaking of which. The IRS and Census are emblematic of incredible data-rich environments that can provide all sorts of information about innovation indicators. If confidentiality is maintained. But that's a huge "if, if, if." There have been tests on certain defined and confidential datasets, but they will not be released to the general public. But a great deal more about how this process works, trends and patterns could be teased out of that data if possible. I'd urge each of you to look at some under ways to measure innovation through use of government data. Just go to agency Web Sites and look at the size of their efforts, and you'll see what I refer to. There's no time to get into it right now.

There are many other cross-agency activities. There's some confusion (as well as Congressional concern) about creation of 45 so-called Czardoms within the Executive Branch. While not a new development, Congress is concerned about the accountability of the many trans-agency directorates working on topics like climate control and global warming, things on manufacturing, green energy, etc. The area of nanotechnology is one that sticks out. The nanotechnology initiative has 27 agencies or so involved, and this seemed to be the most effective way to bring it together. One of the lead agencies is NSF, but it has separate reporting structures, but it's interesting and nanotechnology is an area where we should look for innovation mapping and metrics as well.

Within the private sector, The Ewing Marion Kauffman Foundation stands out among others for its work on innovation metrics. Nationally it's held several workshops. I commend one held in March or April this year. The bibliography they developed for this event alone will boggle your mind, there's so much going on in this area in the academic space in areas, economists, presentations were super and you can find those online. Kauffman has stepped up to the plate and looked at this and also looked at how innovation space affects entrepreneurship and other entities. There's also the Alfred P. Sloan Foundation, the Milking Foundation and many others.

Finally, private consulting groups have many studies out there. Google "innovation" and you will probably get more than 6 million entries, like I did. Of course, who has time to see what the links lead to?

I didn't reproduce one of the McKinsey studies on business innovation because I was concerned about copyright permissions, but there are several recent articles you can find right on the Net that talk about business innovation metrics that we should be measuring.

Well, we have talked about some key policy issues and we talked about the innovation policy agenda. The S&T budget situation is another story. There's a paper available to you from ASTRA in which we actually analyze some of the budget implications of the "doubling effort." There's no way the government can pay for 10-year doubling of science budgets unless something changes with either entitlements, or a renewed commitment is made by Congress to fund such efforts.

If you look only at the America Competes Act agencies, by FY 2011, we may have a so-called Year of the Cliff. This means that science budgets at NSF, DOE and NIST may just fall off the precipice, much like NIH did after its doubling. Except, these agencies never got "doubled."

Everyone's talking about how we ramped up Stimulus spending at agencies like NSF or Department of Energy or NIST each of which had a sizeable temporary increase in their FY 2009 and FY 2010 budgets, but suddenly we are realizing that we have stressed all those systems by trying to get money out the door, performing requisite peer review, and the tripling workloads of people without increasing the competence or number of staff who can do it. Then, suddenly, the funding just ends, unless it's continued in some way. As Ron says, the authorizations are there but there's not much appetite in the Appropriations committees of Congress to keep funding until they see a direct return on the public investment in scientific R&D. Ergo, Katy's comments this morning of why it's important to see what's sticky about innovation, i.e. how are we getting jobs out of this process and how do we detect these results in a timely manner — not twenty years from now?

Most of you would say that's fine but it might take 3, 4, 10 years to figure out what this means. That's not how Congress is seeing this. It wants immediate return. I suppose they would give you a 12 to 18-month window. That's why it's so important for you to be cognizant of any results that might matter to policy makers. If you look at the reporting and feedback mechanisms available, if you're aware of jobs being created, it's important to respond to these survey instruments.

Well, I've overstayed my welcome. I'd be happy to go into taking any questions you may have, even if I don't pretend to have the answers. What I do hope is that my review of the situation and ASTRA's materials have stimulated your thinking.

We have great attention being paid to this topic, a new blossoming of expertise within the Executive Branch. Unfortunately, we probably have less attention on this topic in Congress — especially the Senate — and therefore adequate funding will remain a perplexing issue for as long as most of us will be around.

Like it or not, Congress will remain the place where the serious money is, at least most of the money in the federal sector. Our individual States are doing things, as are many institutions and companies within the private sector.

What is the number actually? If you ask economists who know this, I guess you'd get estimates between \$425 billion to half a trillion dollars — that's what they say ought to be what this economy is spending on overall R&D. So, we are spending only about thirds of that, but the math gets fuzzy. If you have a better number, tell me.

Finally there are other questions afoot here. The taboo of the last 20 or 30 years has been the mention of "industrial policy." Somehow that's "evil, crazy, or socialistic." Meanwhile, with a smirk and a wink, most of the world's governments, regardless of their ideological penchants, whether capitalist or socialistic or whatever, methodically test the merits of industrial policy. Many are targeting our smaller businesses, or scooping up the patents riches

we taxpayers have paid for, or copying the breakthrough thinking, the special talents we develop for the rest of the world through our prestigious academic system...

Such efforts are directed squarely at what used to be proudly called “the American jobs (and innovation) machine.” Our R&D and academic systems are generally porous, open and designed to promote rapid and broad diffusion of knowledge. Just read our patents, we seem to say, take our talent, merge with our companies if you want... if the invisible hand of the market does not incentivize Americans to keep their companies here, come on in and buy them. Make them an offer.

So of all the technologies that have migrated offshore, how will the U.S. continue to innovate without a manufacturing base? Sector by sector, areas like aerospace, semiconductors, propulsion, automotive, manufacturing, photonics, optoelectronics, nanotechnologies of all sorts — all are “leaving” or at least transforming other countries’ economies.

Regarding market share, it’s even more daunting. Nanotechnology patenting is down to about 28 percent of world market share. Photonics and optoelectronics products are down to about 4 or 5 percent. It’s astonishing. We have an open economy and the rest of the world is delighted to take it.

Finally there was talk today about how to do this. There’s been serious discussion about a National Innovation Foundation (NIF) or some equivalent that modified would look like the Smithsonian, or perhaps the National Academies on steroids. The first budget estimates for such an endeavor were about \$3 billion in the bill introduced last year by Senators Clinton of New York and Collins from Maine. Interestingly, everyone said why did you do that (introduce the bill) so soon? Some were irked because they didn’t want a government option for this. They were hoping it could look like a private sector thing but others wanted to inject the topic into the 2008 Presidential Campaign, and I guess they did. Well, trial balloons being what they are, this one got popped very quickly by scores of government agencies that felt uneasy about their own turf and budgets.

Bottom line — the discussion about a National Innovation Foundation is ongoing, and it’s problematic. But it’s beneficial to keep discussing it.

So in closing I’d like to thank everybody, and say are enough real innovators involved in the innovation metrics policy debate? Have you talked to them and do you know them? Think about it. Government policy experts, statisticians and most economists detect innovation in the data they process. But what models of innovation work, and why?

Is there a normative model of innovation that could work everywhere? Perhaps and perhaps not. Could proprietary and confidentiality concerns be addressed? As compared to what? What are we comparing ourselves against? What is the goal of innovation in general, why the effort? Is it to have constant disruptive technologies destroying profitability in companies? What is it? Think about that, please, and help contribute to finding some answers.

That concludes my remarks and a review of several of the special animals in my Bestiary of the innovation system.

Thank you very much.

Citation Metrics: Using Citation Analysis of Journal Data to Measure Research Productivity and Impact

Presented by Ms. Ann Kushmerick, Manager, Research Evaluation and Bibliometric Data, Global Sales Support, Healthcare & Science Business of Thomson Reuters

MS. ANN KUSHMERICK: Thank you, Marty. I'm very happy to be here, and thank you IEEE for bringing us all together to talk about this very important topic.

My task is to talk about the bibliometric aspect and the indicators we commonly use to measure R&D based on the journal data.

Luckily, most of the speakers today already talked about this a little bit, so I don't need to talk much about the background. For those of you not that familiar with bibliometrics, it's important to know the foundation and premises we're working with here. The application of statistical methods to the journal, patent and other types of literature is the main method for quantitatively tracking research outcomes. So we're trying to apply numbers to the R&D enterprise.

The publications give us a very nice proxy of R&D activity going on, and as they are the primary way most research is disseminated to the wider community. The citations to the articles give us a nice gauge of the impact of that research because citations are the way researchers acknowledge the relevance of impact, importance or utility of work that has come before. There are of course exceptions but in general they are the coin of the scientific realm as Robert Merton famously called them.

The metrics we can derive from the citation data are transparent, repeatable, and easily understood once you have some background. That's one reason they become adopted as good metrics for tracking these phenomena.

We talked already of how there are many methodologies and data sources when we talk of research assessment, so I won't dwell on that. But this type of data is one piece of the picture and we do encourage people to look at it in conjunction with other data types because they are complementary. Some people are afraid bibliometrics is meant to replace peer review, which is something we would not advocate for. We think these are approaches that make up for deficits in the other, and they are complementary.

We could talk a lot about guidelines for how we should apply this data, but don't have time today. I brought some white papers, put them on the table, that go into more detail. We also have them on the web. General principles to think of if you use this data, comparing "like with like", which we call our Golden Rule. A key thing to remember is that citation activity varies greatly among disciplines, so citation rates in economics or engineering are very different from those in physics, or biology. So for this reason we create "relative impact measures," to help us normalize for differences in the fields.

And knowing the parameters of your data, and all who work in statistics know this is important. Another factor to consider when you use citation data is the time period. Citation behavior works in such a way that older papers will generally be cited more than newer ones, since they have been around longer. The way you categorize your data is essential to the outcome of your analysis. Issues with the way we deal with author or institution names is another area, even document types dealing with different types of scientific outputs, proceedings papers, patents, review articles.

Citation relationships

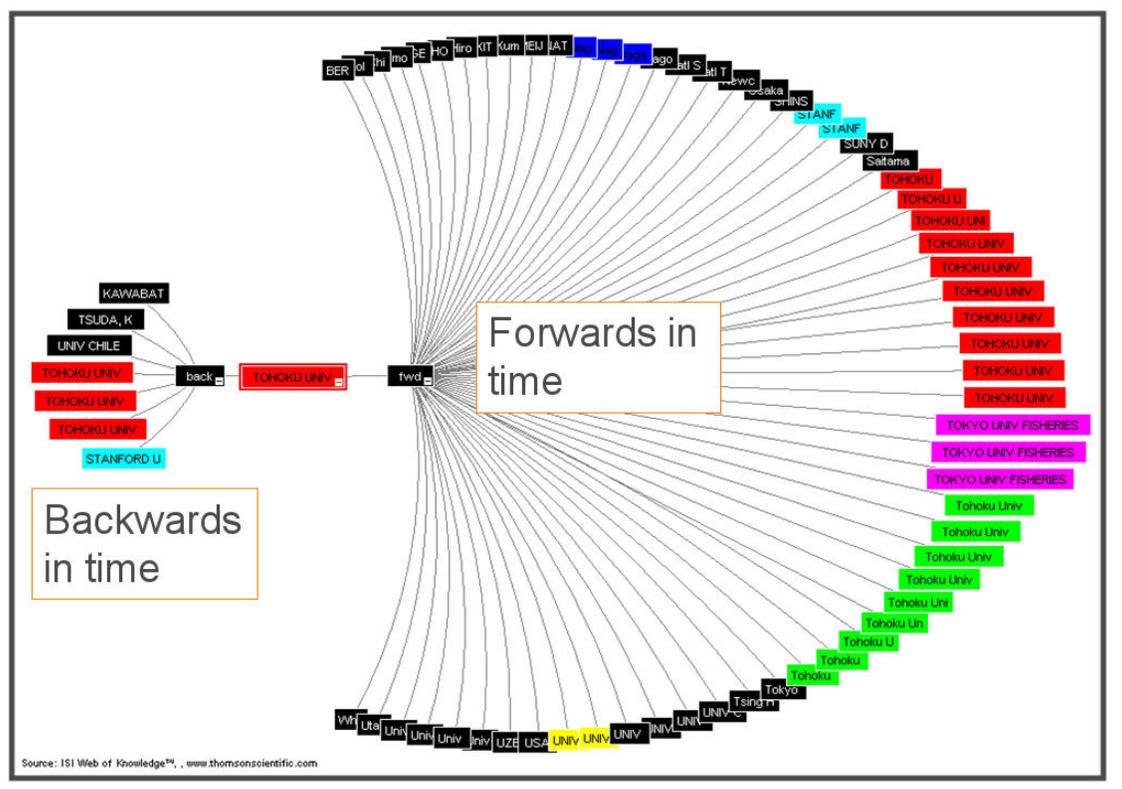


Figure 94

For those not familiar, this is a nice graphical representation of what we're talking about (Figure 94). This is a citation map, a tool that helps us visualize the citation activity, and in the middle is one individual paper. Here papers are labeled by institution and on the left side we see the backward citations, so the items, whether books or papers, that are cited in this paper's bibliography, and on the right side we see the dozens of papers that have gone on to cite this one paper. So you can see we can generate this gigantic network of inter citation relationships among all the scientific literature.

Thomson Reuters (formerly ISI) has been the authority on citation data for over 50 years.

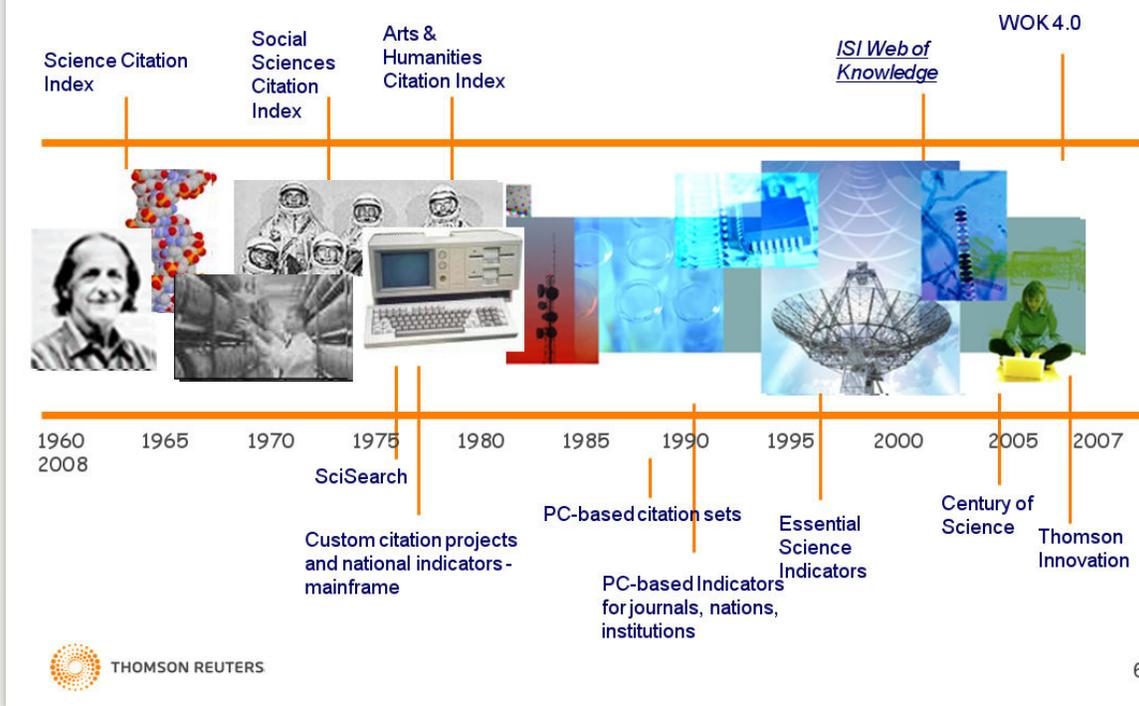


Figure 95

Thank you, Marty, for explaining that we've been doing this for a long time (Figure 95). Earlier some mentioned ISI. That is us, the Institute for Scientific Information, although now we are known as Thomson Reuters, part of a larger organization. Going back to the late '50s, early '60s, Dr. Eugene Garfield was the pioneer of the idea of creating the citation index so you can track the relationships, particularly among different disciplines, so no longer just having an index of engineering or medicine but bringing everything together in a multidisciplinary context.

Uses of bibliometric data

Web of Science data have been used in major research evaluation initiatives around the globe for decades.



- **US National Science Foundation**
Science & Engineering Indicators
- **European Commission**
European Union Science & Technology Indicators



- **US National Research Council -- Doctoral Program Ranking**



Figure 96

Also some of this was mentioned earlier, the various applications of bibliometric data (see Figure 96). We talked of the NSF S&E Indicators at length. Our data are certainly part of that. European Commission does a similar type of report. The National Research Council does a ranking of doctoral programs and incorporates bibliometric indicators. Certainly as we discussed around the world, in Europe, Asia, Australia, there are many more types of activities that rely on bibliometrics even more so than here in the States. We have relationships with all these different policy bodies, ministries of research, et cetera, who have been working in this area for a very long time.

Uses of bibliometric data

Research institutions:

- strategic planning
- benchmarking performance
- peer comparisons
- faculty reviews
- grant applications
- collaboration analysis



Number of citations compared to peer institutions

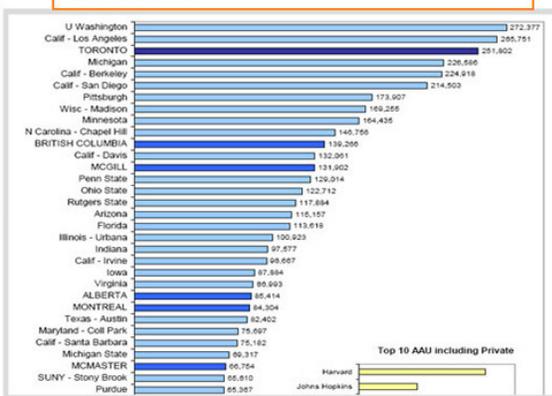


Figure 97

Institutions also use this type of data. We can go from the highest level down to the lowest in terms of how people use the data (see Figure 97). As far as strategic planning goes, reviewing individual researchers and their performance, doing peer comparisons et cetera. This is just one example from the University of Toronto in how they apply citation data when they tried to develop indicators for their own organization.

Here's another example, we're working with the NIH on the ESPA system, electronic Scientific Portfolio Assistant, which helps to bridge the gap between the grant funding and the outcomes. That's essential. The bibliometric indicators, the output indicators should be combined with the input indicators as well. We are working with a group called Discovery Logic on this type of technology to pull together all these types of data related to the research activity. There will be an event next month in D.C. where we'll talk about this in more detail.

The Web of Science has been thrown around today quite a bit, but for those not familiar for what it is as a data source, allow me to go through a couple points. In the Web of Science Citation Index, we are indexing over 11,000 peer-reviewed journals from around the world in many languages. Many countries are represented, and the data are multidisciplinary. We are talking here of science but we also we do index social science and arts and

humanities to an extent. The data we have goes back over 100 years including the citation data, which gives us a unique data source for tracking changes in thought over time through the citation activity to see how the newer research has been affected and grown out of the older research.

We're selective about the content. People like the fact that we do have standards to be included in this body of data and we're very consistent on how we index it. When you work in statistics you'll know this is important, that you have a consistent and reliable data source on which to generate the baselines and statistics I'll talk about.

We also index conference proceedings, which I know is important to areas like engineering and computer science. We capture funding acknowledgements, so if someone wanted to see which papers have been funded by DoD or Homeland Security or NIH, we have those datapoints now.

Types of citation metrics and what they measure

	Metric	Calculation	Evaluator questions
Productivity	-# papers -share of papers in field	-# papers -# papers in field/ papers in field	What is the research output of X? (a country, institution, researcher, etc.)
Total influence	# citations	# citations	What is the overall impact of a body of work?
	H-index	Number of papers (N) with at least N citations each.	What is the impact and productivity of a body of work?
Efficiency	Average citation rate	Total citations/Total papers	What is the rate at which a body of work is cited?
	Percent of papers cited	# papers with at least one citation/ Total # papers in population	How many papers get cited? Never get cited?

Figure 98

Types of citation metrics and what they measure

	Metric	Calculation	Evaluator questions
Relative Impact/ Benchmarking	Journal performance ratio	Sum of citations/sum of journal expected citation rates Expected citation rate calculated for a journal, for each year and document type combination (e.g. <i>JAMA</i> , 2001, review)	Has this body of work performed better than average vis-à-vis the journals represented?
	Category performance ratio Aggregate Performance Index	Sum of citations/sum of category expected citation rates Expected citation rate calculated for a journal category, for each year and document type combination (e.g. Physics, 1995, article)	Has this body of work performed better than average vis-à-vis the specific disciplines represented?

Figure 99

Types of citation metrics and what they measure

	Metric	Calculation	Evaluator questions
Relative Impact/ Benchmarking	Percentile in category and mean percentile	Percentile placement of article within a journal category (e.g. oncology, 2002)	How has this body of work performed compared to the disciplines represented?
	% papers in top x% of their field	e.g. 10% of Dr. Lopez' papers are in the top 1% of their fields	What proportion of a body of work achieves a specific level of performance?
Emerging areas of research	Research Fronts	Clusters of highly cited papers identified via co-citation analysis	What are the emerging areas of research in chemistry?

Figure 100

Types of citation metrics and what they measure

	Metric	Calculation	Evaluator questions
Specialization	Disciplinary index	$\sum_{i=1}^N s_i^2$ where s is the share of papers in category i and n is the number of categories	How multidisciplinary is a body of work?
	Interdisciplinarity index	$-\left(\sum_{i=1}^n p_i \log_{10} p_i\right) \div \log_{10} n$ where p is the share of papers in category i and n is the number of categories	How dispersed is a body of work across disciplines?
Indirect impact	Second generation citations	Citations received by a paper's citing papers	Did the papers citing a body of work go on to have impact?

Figure 101

One of my main goals is to give you an idea of the kind of metrics out there because many times people think there are only a few. There are many ways we analyze this data, and you will have this PowerPoint in the e-book, so we don't have to talk about all of this (see Figure 98 through Figure 101). I put here areas of what the metrics measure, and these are not hard and fast rules, but to give you an idea of what kind of measure we're talking about. In terms of gross productivity, we look at papers, the share of papers in the field, so called "market share" that either the U.S. has in a discipline or an institution might have within its country.

For total influence, we look at the gross citation count, how many times you've been cited. There's also something called H-index developed recently that physicists and others use, to measure both productivity and impact in one number, so it takes into account both the number of papers and their citation count. It boils down in a calculation of the number of papers with at least n citations each, so if your H-index is, say, 20 it means 20 of your papers have received at least 20 citations each, a bit of a new approach and has its limitations like every other bibliometric statistic.

In terms of efficiency, we can look at average citation rates, citations divided by papers, we can look at the percent of papers cited, citedness or uncitedness rate, to see how many times does the U.S. or an institution produce papers that never are cited by anyone else.

More interesting are these relative impact measures you might not be familiar with. I mentioned we need to compare like with like, we need normalization. We create baselines on various levels, we calculate these expected citation rates for journals, and also do it for journal categories, groups of journals on a specific topic like electrical engineering. By doing this we can then compare a paper to that norm, to that expected rate, to really see if it's highly cited. Most people don't know just by looking at a citation count what it really means, if it's good, average, etc.. We can then create these ratios and say overall the U.S. is twice the average as far as all the papers it's produced across all disciplines.

We can also calculate percentiles, place a paper within a discipline based on a citation count, so maybe your paper's in the top 1 percent of all electrical engineering papers from the year 2000. So this gives us a way to put context around a citation count.

As to emerging areas of research or innovation, we can use this type of data to help identify these. One way we do this is by research fronts, the clustering of highly cited papers based on what we call "co-citation analysis." This means you might have two different papers with no apparent connection but if they've been cited frequently by other papers in common then maybe there's a connection, so we can see the patterns, areas of research coming together by looking at the literature.

This is an example of one of the maps we create to show these relationships. Our chief scientist, Dr. Henry Small, was really a pioneer in this area of co-citation analysis and mapping. This is a map we created recently on oxide super-conductors, and all the circles you see are the highly cited papers in this cluster. The relationships between them, the co-citation relationships are indicated by the lines, they have different strengths, and the size of the circles is related to how highly cited each paper is.

On to the metrics. We also have ways to measure specialization or interdisciplinary, and this is another thing we know is very much on everyone's mind. Two different approaches I've shown here, called "disciplinary index" and "interdisciplinary index." The calculations are here. Disciplinary is based on what's called the Herfindahl index used in economics that's used to assess market share, except we apply it to the share of disciplines within a body of work to try to show how concentrated it is or how diverse it is among different disciplines.

Interdisciplinary index is similar. It's based on the Shannon entropy model, again trying to look at how equally dispersed you might be over various disciplines versus more concentrated in certain ones. So it's a way to look down on the data and assess the composition of a body of work.

We can call "indirect impact" things like second generation citation counts. So if you go back to that map I showed, we can bring it back generation upon generation and look at downstream how many times the paper that cited your paper has gone on to be cited. So it's starting to apply these kind of Google page-rank iterative ways of looking at the data.

What is a researcher's impact?

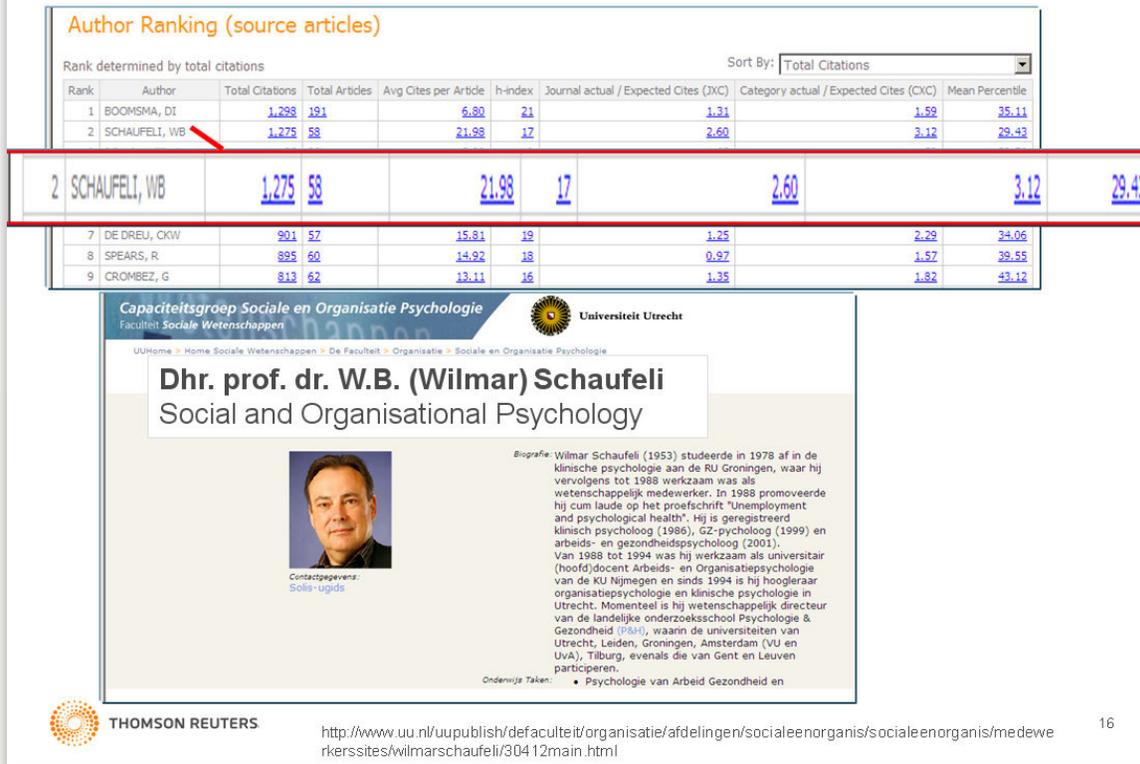


Figure 102

Just to give you an idea of how this would work, I did a couple examples and did it in the context of a researcher because I wanted to get down to the most granular level and then we can build up to a larger level. Really all these metrics can be applied to anything, a researcher, a country, an institution, a topic, et cetera. So if you take a look at this one example (Figure 102), I took a researcher who happens to be a psychologist Dr. Schaufeli, it doesn't matter who it is or what they work in but as an example, we can look at one of this researcher's papers, this is an article on burnout, which I'm very glad is being researched, a very important topic, and if you allow me to go through the metrics as an example I think they might become more clear.

One of Dr. Schaufeli's papers

Job Burnout, *Annual Review of Psychology*, 2001

Total Citations	2nd Generation Citations	2nd Generation Citations per Citing article	Journal Expected Citations (JXC)	Category Expected Citations (CXC)	Percentile in Field	Journal Impact Factor	Publication Year	Field View Ranking	Article Type View Ranking
434	2,107	4.85	111.19	65.29	0.08	13.40	2001	PSYCHOLOGY	REVIEW

2nd generation citations: indirect, long term impact. Citations received by the papers that cited this paper



Figure 103

Here as I just mentioned, second generation citation count (Figure 103), this article he produced received 434 citations but those papers have gone on to receive over 2,000 citations, so if you're wondering did the papers that cite me or cite our country have any impact, this is away to gauge that.

One of Dr. Schaufeli's papers

Job Burnout, *Annual Review of Psychology*, 2001

Total Citations	2nd Generation Citations	2nd Generation Citations per Citing article	Journal Expected Citations (JXC)	Category Expected Citations (CXC)	Percentile in Field	Journal Impact Factor	Publication Year	Field View Ranking	Article Type View Ranking
434	2,107	4.85	111.19	65.29	0.08	13.40	2001	PSYCHOLOGY	REVIEW

- Average citations specific to journal, year of article, and document type.
- Baseline for journal performance.
- Schaufeli- ratio of actual cites to expected: 3.9 (434/111.19)

Figure 104

What you see here labeled as this JXC is the Journal Expected Citation Rate, so this gives us a baseline, a frame of reference for the journal this article was in (Figure 104). In this case it's *Annual Review Psychology*. We also take into account the age of the paper, and as I said age is very important, and the document title, in this case a review because of the journal. We can see on average up to the last year of citations, review articles from 2001 in this journal received about 111 citations, and this allows us to compare his 434 citations to this baseline and see indeed it's received four times what's expected for this journal.

One of Dr. Schaufeli's papers

Job Burnout, *Annual Review of Psychology*, 2001

Total Citations	2nd Generation Citations	2nd Generation Citations per Citing article	Journal Expected Citations (JXC)	Category Expected Citations (CXC)	Percentile in Field	Journal Impact Factor	Publication Year	Field View Ranking	Article Type View Ranking
434	2,107	4.85	111.19	65.29	0.08	13.40	2001	PSYCHOLOGY	REVIEW

- Average citations specific to category, year of article, and document type.
- Baseline for category performance.
- Schaufeli- ratio of actual cites to expected: 6.65 (434/65.29)

Figure 105

Then on the category level (Figure 105), this journal is categorized into the psychology category which makes sense in this case, and we see the baseline is about 65, so all the psychology papers from the hundreds of psychology journals we index from 2001 that are reviews receive on average about 65 citations. So we see that on the category level this paper is even more highly cited, over six times what we'd expect for that cohort.

One of Dr. Schaufeli's papers

Job Burnout, *Annual Review of Psychology*, 2001

Total Citations	2nd Generation Citations	2nd Generation Citations per Citing article	Journal Expected Citations (JXC)	Category Expected Citations (CXC)	Percentile in Field	Journal Impact Factor	Publication Year	Field View Ranking	Article Type View Ranking
434	2,107	4.85	111.19	65.29	0.08	13.40	2001	PSYCHOLOGY	REVIEW

- Percentile position specific to field and year. The closer to zero, the more highly cited.
- Schaufeli's paper falls into the top 1% of all psychology papers from 2001, more specifically top 0.08%.

Figure 106

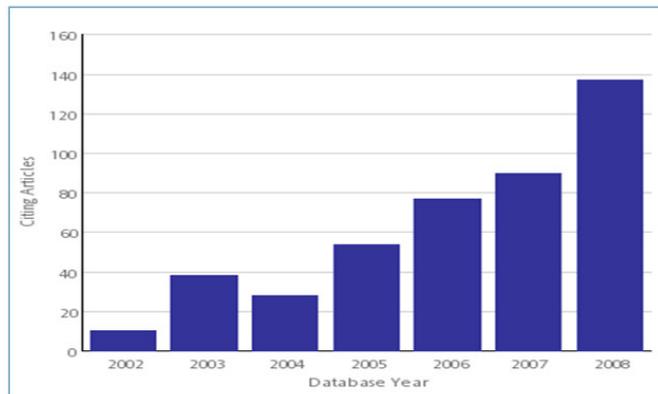
The percentile I mentioned, this paper actually falls within the top 0.08 percent of all psychology papers produced in 2001 (Figure 106). The way our percentiles work, actually zero is the best, so the smaller the number, the more highly cited. So it's confirming what we suspected that this paper is indeed a highly cited paper.

One of Dr. Schaufeli's papers

Job Burnout, *Annual Review of Psychology*, 2001

Total Citations	2nd Generation Citations	2nd Generation Citations per Citing article	Journal Expected Citations (JXC)	Category Expected Citations (CXC)	Percentile in Field	Journal Impact Factor	Publication Year	Field View Ranking	Article Type View Ranking
434	2,107	4.85	111.19	65.29	0.08	13.40	2001	PSYCHOLOGY	REVIEW

Annual breakdown of citations received



21

Figure 107

We can then of course look at the breakdown of citations received annually (Figure 107). A lot of people want to know is this paper is still accruing citations, has it plateaued, has it decreased?

Dr. Schaufeli- Summary metrics

Productivity	# papers	68	Relative Impact/ Bench- marking	Journal actual/expected	2.57
Total influence	# citations	1,327		Category actual/expected	3.01
	Self-citing papers	56		Mean percentile	29.76
	H-index	18		% papers in top 10% of their field	32.81
Efficiency	Avg. citation rate	19.51		% papers in top 1% of their field	9.38

- Journal and category performance ratios compare this researcher's citation counts to the norms or "expected" rates in his discipline. Schaufeli is performing above average on both the journal and category levels (2.57, 3.01).
- Mean percentile reflects the percentile performance of the researcher's work, on average. e.g. in top 29.76 percent

Figure 108

We can then roll these numbers up to look at this person's body of work, and think of this also, we can look at the entire country's body of work or any other entity as well. Particularly I wanted to mention these relative impact measures. Here you see what we can call the journal performance ratio which in this case comes out to be about 2.5 (Figure 108). So he's doing two and a half times the average citation rate for the journals he's publishing in. If this came out to be one, he'd be right on average with the journals he's publishing in. On the category level, he's performing at three times what's expected.

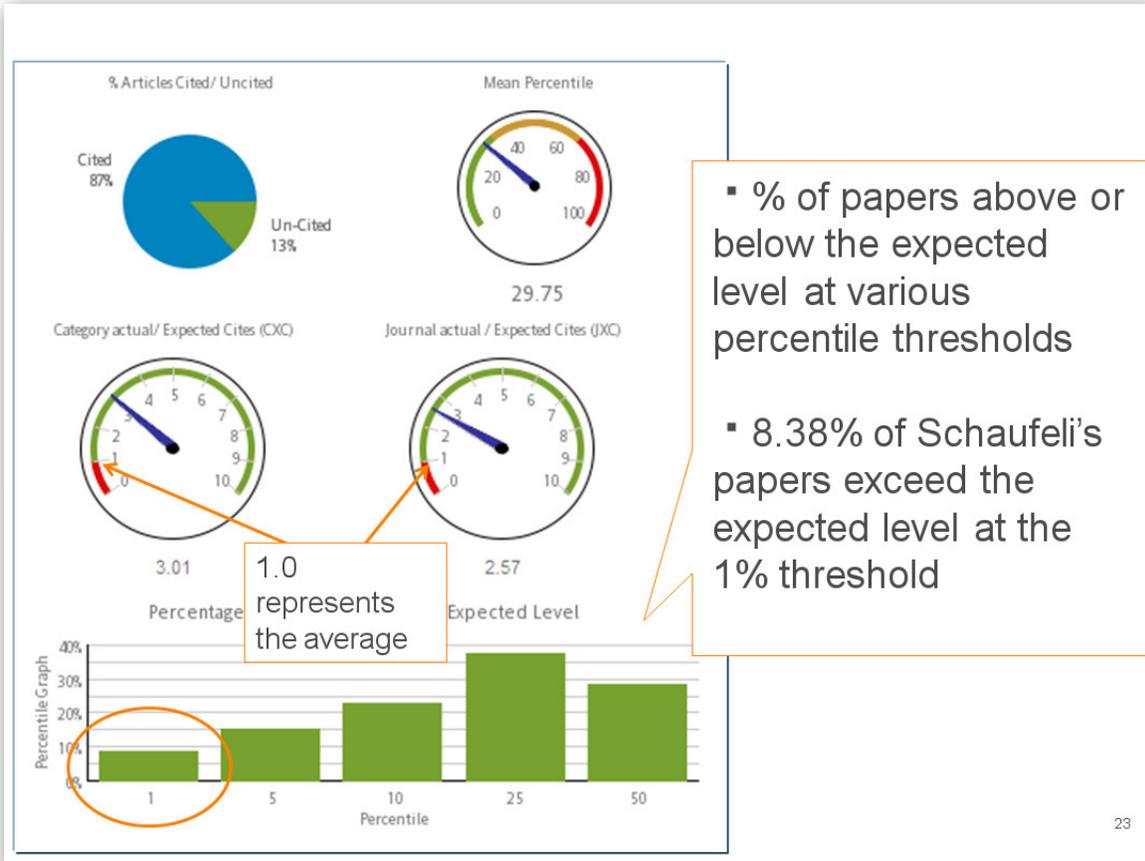


Figure 109

And if you look at a multidisciplinary set of papers like an entire country this is a nice way to normalize for the differences in all those fields.

Mean percentile, we can take all the percentiles for all of his papers and take a mean of those to see that in this case he is performing in about the top third regardless of whatever discipline those papers happen to be in (Figure 109).

Normalized measures are key to understanding performance: compare researchers, units, etc.

	Total Papers	Total Cites	Avg. Cites per Paper	H Index	Journal actual/expected	Category actual/expected	Mean Percentile
Dr. Smith (Chemistry)	110	853	7.75	16	1.03	1.18	44.53
Dr. C Adams (Chemistry)	40	354	8.85	12	1.01	0.91	30.84
Dr. M Jones (Economics)	19	75	3.95	5	1.43	1.25	62.27
Chemistry Dept	172	1,242	7.22	19	1.00	0.98	45.64
Univ ABC	24,231	133,007	5.49	91	1.20	1.02	54.14

These metrics normalize for field, age, and size differences.



Figure 110

We have ways to visually understand this data as well (see Figure 110). I won't get into it in the interest of time, but one key here, the takeaway message of this slide is that the relative measures enable us to compare across disciplines, and to compare across size. When we look at citation counts or even an H index, the size of the entity will affect it. The bigger the entity, you'll have more papers, more citations. And also the time factor, so the H index for example or even a citation count for a younger researcher is not comparable to an older person who's been researching much longer. So in this case we have a couple chemists, a couple economists, and we're able to compare them using these measures.

Comparison of selected NCI cancer centers

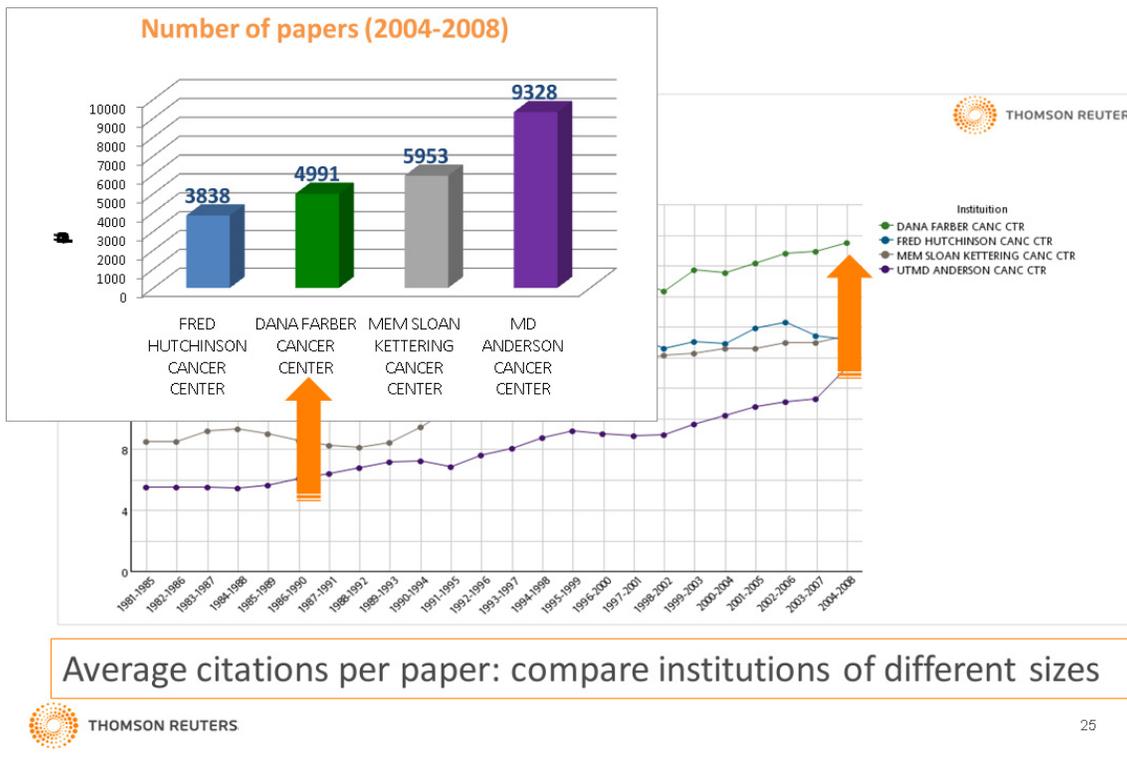
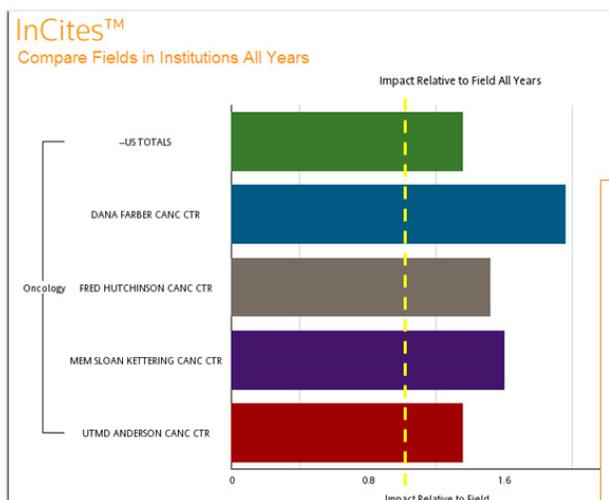


Figure 111

I did a couple of institutional level comparisons as well. These are more of a biomedical area but of course we can apply this to any other type of disciplines: physics, computer science, et cetera. This particular analysis you can see here (Figure 111), looked at a couple of the NCI designated cancer centers and a trend over time for their citation rate. So this is normalized for size because we're not looking at just a gross count of citations but really your impact, your citations per paper. You see Dana Farber is the one that comes out on top here in the green, and when I looked at the actual output it's interesting that Dana Farber doesn't produce nearly as many papers as some of these other entities but on average it's receiving many more citations.

For example, in the country level we see this for a lot in these small countries. We mentioned Finland where they have this high concentration of engineers versus their population. Well, a lot of those countries, Scandinavia and Switzerland, don't have a huge population and don't produce a lot of research, but whatever they do produce is very high impact. So the different measures can tell us different things about the data.

Peer comparison using relative impact in oncology



Relative citation impact: comparing performance to the discipline's average performance.

All of these institutions outperform the average citation performance in oncology (represented by 1.0)



Figure 112

Here for example, taking the same institutions and doing the relative impact in oncology, which is what they focus on, we can easily see in this graph (Figure 112) I've highlighted the baseline for oncology, average citation rate across the world which is in the yellow, so they are all performing well above that average. So it validates their research and the funding they are getting, and they can say this funding is going to be used effectively, the extra Recovery Act funding in the future from NIH. In the green bar here is the U.S. average, so these institutions are performing above the U.S. average, so we can look at different baselines of comparison.

Institutional level analysis: # papers, # citations, relative citation impact

Cold Spring Harbor Lab: Neurosciences and Behavior

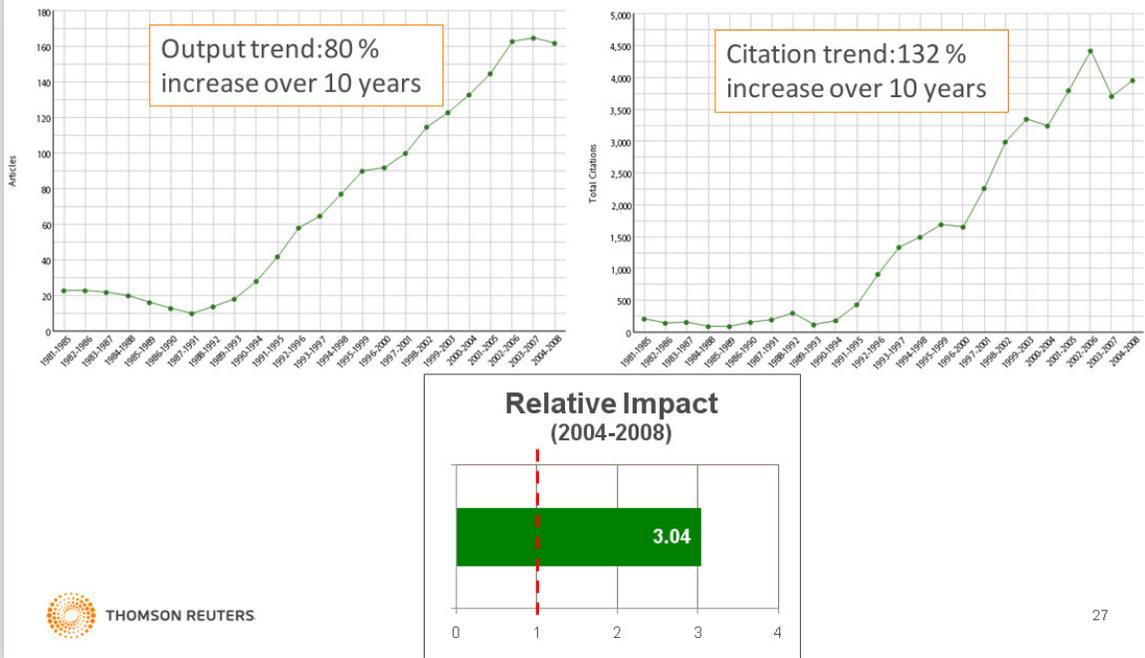


Figure 113

This is another example, looking at both output, and citations and the relative impact (Figure 113). You can look at these at your leisure later.

Analyze countries: Netherlands Specialization: top 6 fields

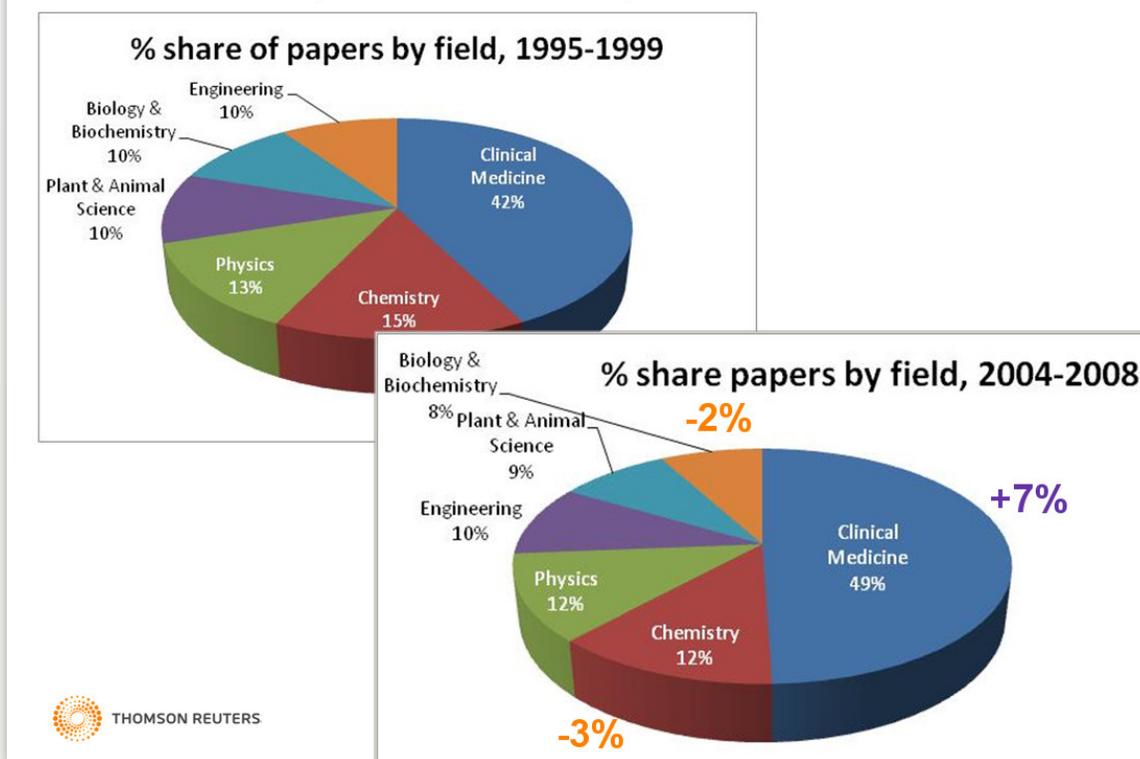


Figure 114

A couple country level examples, since I know that's of interest, here's one example of specialization in the Netherlands and looking at the percent share of their papers across the different disciplines in an older period versus a newer one (Figure 114). What's interesting is that they are producing a greater share in something like clinical medicine and a lesser share in biology and chemistry. People would try to correlate perhaps the policy decisions made or funding changes to see what the actual outcome was a couple years down the road.

Analyze National trends in paper output/production

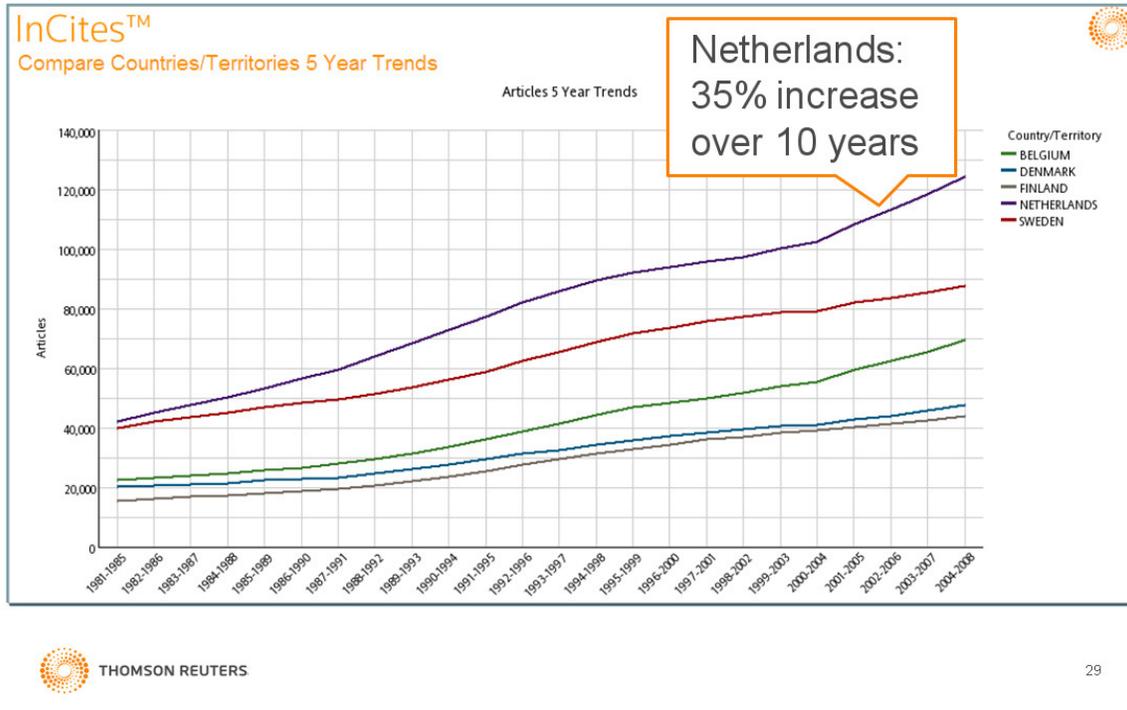


Figure 115

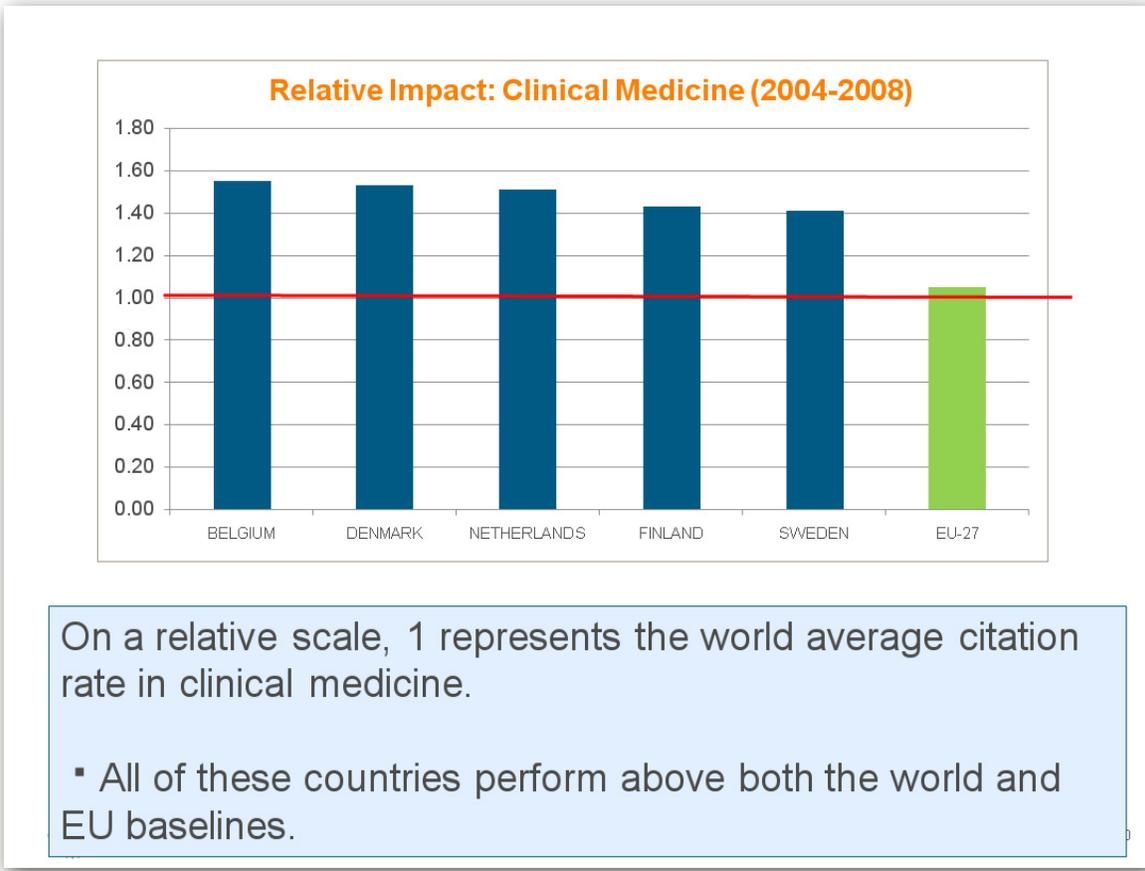


Figure 116

Another trend of the output in Netherlands and other neighboring countries (see Figure 115 and Figure 116).

USA- share of world's publications

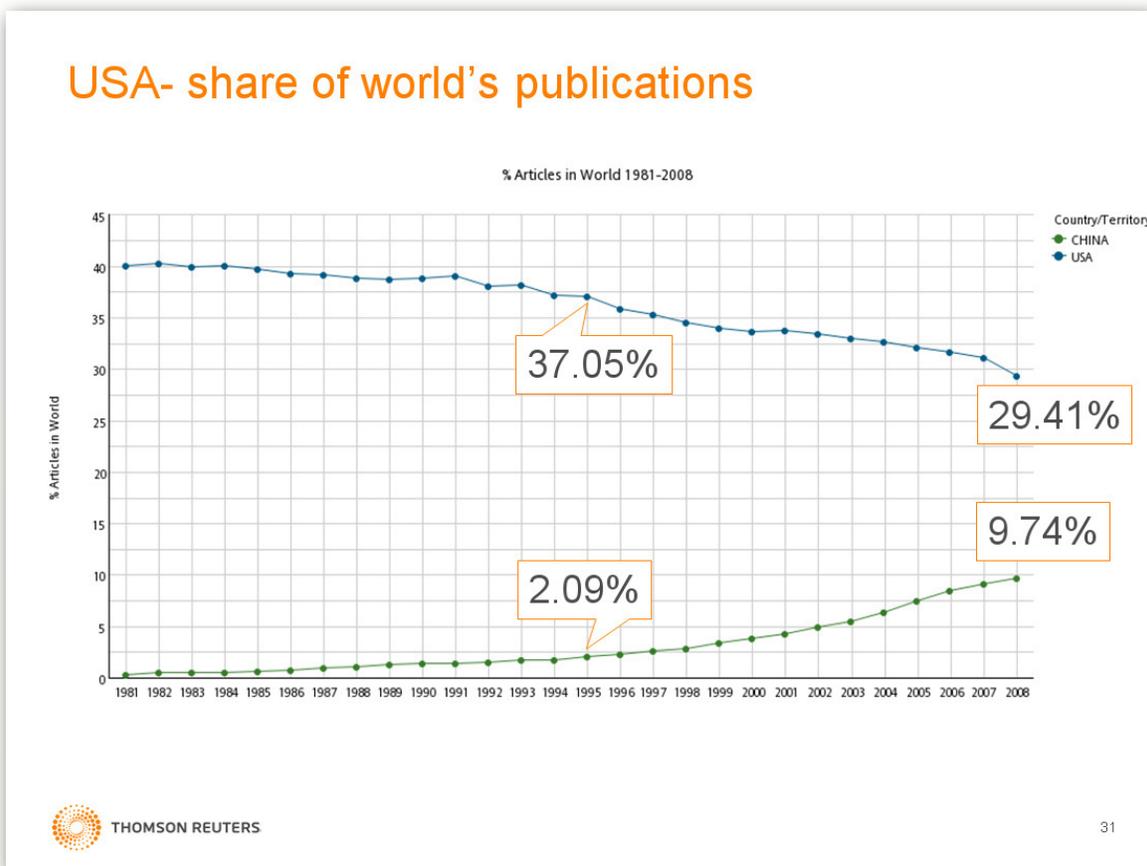


Figure 117

I included this as well, which goes nicely with all of this *Gathering Storm* on everything that's been discussed today about the U.S., and this type of data, one reason why people are very interested in this idea of the U.S. and its standing in the world, you see here a trend in the share of the U.S. articles in the world, so the U.S. back in 1995 contributed 37 percent and now it's about 29 percent (see Figure 117). One reason you can see, China is in green, and China and some other countries really weren't players before, and suddenly are having rapid growth of production in science, and now China accounts for 10 percent of all the scientific output, at least in the 11,000 journals we're capturing. Of course as other countries emerge our share will decrease even though our gross numbers might be increasing. That's a simplified explanation to let you know these are the kinds of data points from the bibliometric perspective people are looking at when they make these conclusions and decisions.

Journal-level metrics

	Calculation	Researcher Questions	Librarian Questions	Evaluator Questions
Journal impact factor	<p>A= total cites in 2008</p> <p>B= 2008 cites to articles published in 2006-2007</p> <p>C= # of articles published in 2006-2007</p> <p>D= B/C = 2008 impact factor</p>	<p>What are the most highly cited journals in my discipline?</p> <p>Where should I submit my new paper?</p>	<p>What journals are most important for my library's collection?</p>	<p>Does this researcher publish papers in journals with impact factors in the top quartile of their fields?</p>
Immediacy Index	<p># of citations to articles published in 2008/ # of articles 2008</p>	<p>Do articles in this journal receive citations quickly after publication?</p>		<p>Should I expect a paper in Journal X to receive citations quickly?</p>

Figure 118

Journal-level metrics

	Calculation	Researcher Questions	Librarian Questions	Evaluator Questions
Eigenfactor™ score	Measures journal impact in terms of embedment within the entire citation network. -scaled so that the sum of the scores of all JCR journals is 100.	How influential is a journal, weighted by the influence of the journals citing it?	Which journals are most important to my stakeholders?	How important is this journal within the research network?
Eigenfactor Article Influence™ score	Per article measure using Eigenfactor™ score - Normalized so the mean JCR journal's article influence is 1.0.	Compared to other journals, how influential is this journal?		

Figure 119

I'll skip over this. We use journal level metrics as well (see Figure 118 and Figure 119). Some of you might be familiar with things like the journal impact factor which are specific to journals. A lot of times they are inappropriately applied to researchers or other entities, but you should use a journal level metric for a journal and use the other metrics I mentioned for other entities.

So links and white papers are here if you're interested in learning more about bibliometrics, we have a newsletter as well as a blog if you want to comment and be involved in a discussion about these issues. If the white papers and other information I brought are already gone, contact me and I'll give you those as well. Thank you.

Experiencing Innovation in College Curricula

Presented by Dr. Ralph W. Wyndrum, President, IEEE-USA Innovation Institute

DR. RALPH W. WYNDRUM: The IEEE-USA Innovation Institute has a key focus on helping its USA members adapt and, I might say, survive in the changing world we're facing from globalization. We are trying to promote innovation in U.S. industry. In fact it is a core purpose of the IEEE Institute to do this, to foster technological innovation and excellence for the benefit of humanity.



IEEE-USA INNOVATION INSTITUTE www.innovation-institute.org

The purpose of the IEEE-USA Innovation Institute

In response to the *Rising of the Gathering Storm Report*, that identified globalization challenges facing the technology sector, IEEE-USA established the Innovation Institute. The IEEE-USA Innovation Institute's key focus is to help IEEE members adapt to the changing world of engineering and promote innovation to private industry.

In addition the Innovation Institute supports IEEE-USA's Core Purpose: "*To foster technological innovation and excellence for the benefit of humanity*"

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Figure 120

As I go through **slide 2** (Figure 120), you can scan this data. I think we've heard enough information today to have a certain degree of alarm raised among us from the speakers we've heard from. Indeed, we saw some of the information that the *Harvard Business Review* by Greg Pisano and Willy Shea, that was presented. It became very clear, as indicated there, that innovation is America's wealth generation machine. Developing and manufacturing high-tech gear, high-tech services and products is what is generating much of the wealth in this country, and that generation mechanism is being very, very rapidly eroded. There is no question about it. Slide 2 shows only a few instances of the facts.



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IS INNOVATION IN THE USA STILL IMPORTANT?

- From 1990 to 2008, hi tech innovation driven jobs fell from 2.2M to 0.9M/year
- Hi tech Mfg Goods trade balance moved from \$33B (1990) to \$(-31)B (2006)
- 2007 USA Patents granted: 79,526 of US origin, 77,256 of foreign origin. 2200 US edge.
- 2008 USA Patents granted: 77,501 of US origin, 80,271 of foreign origin. 2700 US deficit
- Only 3 US companies on the list of 10 top patent grantee companies
- % share foreign patent origin: 2008, 50.9%; 1996, 44.3%.
- Information system patents produced very few jobs, exports.
- Invention is the front end of innovation. USA disinvestment is both is well supported by data and continues today. Focus is on products and services yielding immediate revenue streams




Figure 121

Slide 3 (see Figure 121): The capacity to make and design and manufacture everything from lithium batteries to Amazon's Kindles has gone offshore. And it's not coming back. And the rate that it's leaving is much faster than most of us recognize, and we need to do something to reverse that.

I personally spent considerable time overseas with products that we developed at Bell Laboratories that were manufactured in Europe and China. I can assure you from personal experience that running an operation that separates research from development is an unnatural act. Manufacture and R&D go together like love and marriage. They cannot be easily separated. So we can expect to find this continual erosion, and the offshoring of the R&D to follow the manufacturer.

If I take a look at some of this data which I suspect you've looked at, the first one points out a rather frightening piece of data, that high-tech innovation driven jobs have fallen by a factor of 2 from 1990 to 2008. We also note that the trade balance has moved from a positive \$33 billion to minus \$31 billion in high-tech goods in that period of time. And more than that, the estimates are that in this year 2009 it's moved to minus \$50 billion. Look at the numbers, let them sit in firmly in your view. \$50 billion negative!



It's not just plastic toys and clothes that we import from Asia. The patent situation reached the tipping point this year. Without going to these numbers, let me tell you that it flipped from a case where less than half of the patents had been coming in from foreign applicants from overseas, foreign companies. The year 2008, for the first time, more than half came from foreign companies, U.S. patents granted to patent grantees from outside the United States. That is likely to continue, and the best estimates for 2009 are that there will be 84,000 patents granted from overseas and 75,000 to American patentees!

The snowball is going down the hill and gathering lots of snow and gathering it at a rapid rate.

One last point. Only three U.S. companies remain on the list of the 10 top patent grantee companies in the U.S. This should alarm those who fear high unemployment in the U.S.A. over the next decade!

Okay. That was meant to give a sense of urgency to what you've been hearing, and we'll now start to talk about ways we might reverse and slow down that trend. The United States IEEE Innovation Institute, formed for the purposes that we mentioned before, has been working with a set of cutting-edge industry leaders, and we have met with groups of these, most recently in Atlanta, Denver and Austin, Texas. We have chosen to focus on university engineering students prior to graduation to infuse in them the ability at the senior year to bring innovative thinking to whatever design segment they move into. Innovative products are always the ones that get the greatest profit margin early in the game, cost cutting is not something that has high returns. It's a defensive mechanism. It's not something you want to set up a business to do. So it's important for this to be understood and absorbed by our engineering graduates.



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The IEEE-USA Innovation Business Plan, 2008-09

- Developed through a series of industry roundtables through May 2009 in Atlanta, Denver and Austin.
- Focus on university engineering students prior to graduation to infuse them with the ability to bring innovative thinking to whatever design assignment they undertook in their careers.
- Plan was dubbed "Senior Project.com"
- Collaborative design projects, spanning multiple engineering disciplines, and even schools, would "seed" innovation widely in future USA Industry and prepare graduates to lead global industry teams.
- Plan would be leveraged over several years to an increasing network of engineering schools in the USA, beginning with a 2010 pilot effort, probably in the Austin TX area. Industry and academic support is indicated.



Figure 122




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Progress on 2008-9 Innovation Business Plan

- Subsequent meeting in Austin TX (8/09) indicated continuing industry and academic support, with industry volunteers and academia participating in a pilot project.




Figure 123

Slide 4 & 5 (see Figure 122 and Figure 123): We've dubbed our project SeniorProject.com, and the notion is that we will begin teaching, for example, electrical engineering students to work on collaborative projects in the senior year with their counterparts in the mechanical engineering department, in the physics department, in the chemical engineering department. If you were going to be designing a new transportable water desalinization facility for example, for a developing world that was inexpensive, it would have to be very innovative, not the sort of thing that costs about a billion a pop in Turkey or Saudi Arabia and the like. But to really open up that market, you'd have to put in an enormous amount of innovation and use local power sources or so for power, and do a lot of new things.

Our argument is, let's get the seniors on their senior projects, and most schools have these, working as they later will at industry, with other departments, learning and sharing the understandings from the other disciplines and develop collaboratively on a software development platform, as is often done in industry today, a single project with many collaborators.

So we plan to introduce that collaborative design activity working with various schools in the United States and we're already discussing this with the University of Texas-Austin, and the University of Pittsburgh.

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2010 Implementation

- The Innovation Institute will be focusing its attention in 2009-2010 on partnering with industry and universities to foster innovative projects
 - **Mash-up: online collaboration tool**
 - Webinars
 - eBooks
 - Online case studies
 - Industry sponsored forums

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Figure 124

Slide 6 (see Figure 124): We also are developing webinars in our programs, e-books such as today's e-book that was described which will be part of our output, online case studies, and industry sponsored forums.

What is the IEEE-USA Mash-Up?

- The Realization of *Collaborative Design*
- IEEE-USA led *collaborative online design workspace for industry, students, faculty, universities and IEEE members.*
- Intended to solve interdisciplinary and real world technical problems *through innovative social & technical networking.*

Figure 125

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How This Mash-Up Works

- Participants: Industry, Faculty, Students and IEEE members
- Participants pose technical problems to be solved, stressing new and innovative solutions
- Industry provides collaborative tools & resources
- Additional cash funding is being actively sought

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Figure 126

Slides 7 & 8 (see Figure 125 and Figure 126): Overall, our program will be to have what we call a mash-up. You've heard the term "mash-up" at least once before today. You're overlaying various levels of expertise from various disciplinary areas on to the problem so that you get a much better handle and grasp of where you can go and much more innovation in the interaction you have.

Basically we are looking to make some significant changes in the way our students are educated. Some of us have heard long enough that there are only 140 course credits in engineers' curriculum, and that that number is inviolate and there's no space for anything outside the silo that the students are studying in. We don't believe that. And we are going to take this to try to make some breakthroughs there.

So the participants will represent a full spectrum of disciplines that need to participate. Industry will be there looking expectantly at the results but helping us as mentors, faculty are crucial to this, and getting top rated faculty to become involved here is going to be a key effort. Students and IEEE members should be served well by this. Industry probably will be posing the technical problems to be solved, but we are likely to be bringing some of the best technical minds in USA academia across department lines to solve important problems with innovative American solutions.



Figure 127

Slide 9 (see Figure 127): I think you've pretty much got the idea now of how this works.



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Next Steps

- Build and Assess support from Industry and Academia
 - Industry offered financial aid “in kind” but pilot will also require a software platform for collaborative design, academic leadership, and heavy volunteer effort.
- IEEE-TAB (humanitarian project) and ASME (Engineering for Change, “E4C”) each offered use of their s/w platforms.
- Proceeding with pilot of “senior Project.com” in 2010.



Figure 128

Slide 10 (see Figure 128): The next steps are going to be to build and assess support from industry and academia. Industry so far has suggested financial aid in kind and mentoring. In fact they’ve been quite generous in their suggestions. But we are going to need more than that. We’ll need software platform support and two candidates have volunteered so far. We’ll need academic leadership, a heavy volunteer effort, and frankly cash. This is going to involve certain administrative expenses and organizational expenses, and in these times that’s hard to come by too.

What are the returns?

- The Nation and its industry
 - Innovative technical solutions and innovative leadership
 - Innovative workforce and potential employees flow to business
- Faculty
 - A new and important experience
 - Industry visibility and linkages
- Students
 - Real world innovative designs with course credit
 - Innovation process skills and collaborative engineering skills
 - Enhanced employment preparation and opportunities
 - “Trickle-up” from students to industry
- Issues for Study
 - IP rights and web security

Figure 129

Slide 11 (see Figure 129): The returns as we see them for the nation and for our industry, include new innovative technical solutions and we see essentially the creation of an entire generation of innovatively trained students. This has not happened before. If it catches on, we see an innovative workforce and employees that flow to business with a lot more talent for what business needs than what they’ve seen to date. For faculty this should be a fun experience. I teach at Rutgers, and I believe that. It will bring industry visibility and linkages to them that have not existed before perhaps. For students it will bring a very practical calling card when they go looking for a job. It will bring them skills, it will bring them interactions on a personal level that they have not, as students, had in the past. And they will suddenly begin to understand how to work in a collaborative design group.

And we believe, and I say this seriously, there will be a good deal of trickle up from the students into industry.



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Is Innovation Still Important?

- In President Obama's first nationwide presidential address, he declared the dawn of a new era guided by American ingenuity, and defined not by the magnitude of the current economic crisis but by an innovative response to it.
- IEEE-USA views The Innovation Institute as a serious response to Obama and the Nation.



Figure 130

Slide 12 (see Figure 130): Now is innovation still important? We think it is. We believe Obama thinks it is. We hope the U.S. government thinks it is.

But not everyone in U.S.A. leadership believes this. A strategic planning director from a company said to me, "You know, it's really bad policy to set aside (as we used to do at Bell Laboratories) X percent of your revenues for R&D. That's a level of faith you shouldn't have. It's bad business. We have to take essentially the expected returns of that R&D and we have to play them against returns that we can get from other sources." So the investments we make in R&D, he said, "really have to be weighed against the investments returns we might get if we spent the same dollars expanding our West Coast sales force or advertising our products more widely which would get earlier and perhaps greater sales."

Now what I'm trying to say here, folks, is that discussions in the 21st C are very difficult to have when you are not even on the same page and don't have the same value systems. And there are a lot of people out there who do not have the same value systems that at least I feel I and my colleagues have and I hope some of you have. I'll leave it on that note. Thank you.

Bring Them In: Improving STEM Recruiting by Working with High School Teachers

Presented by Dr. David Alan Grier, Associate Professor of International Science and Technology Policy; Associate Dean of International Affairs, George Washington University

DR. DAVID ALAN GRIER: I'm very pleased to be here, very pleased to welcome you here to our school. The IEEE is a very important organization to us and to me personally. I think many of you know I'm the head of magazine publications for the IEEE Computer Society and I write regularly for those periodicals. The IEEE has been an important part of our engineering school and an important part of how we think about science and education.

About six or seven weeks ago Maxine Singer, who is a tireless advocate for STEM education, for Science, Technology Engineering and Mathematics education, published an opinion piece in *Science*. She made her usual arguments that we need to do more with STEM education. We need to improve it and to invest in it so that we can develop the next generation of scientists and engineers. At the end of the piece, she ended with a little dangling idea. She stated that real scientists, thought that was not her phrase, professional scientists will need to do more to engage high school education.

That statement only gets at the very beginning of an issue that is large and needs to be addressed by organizations like the IEEE. We need to take a careful look at how we treat high school science teachers and make the honest professionals. By doing this we will get a better grade of teachers, more connected teacher, and a better approach to STEM education.

For two years I worked as our primary recruiter from George Washington University at the high school level. I traveled from high school to high school, big and little, some famous and most not. I would talk generally with two people at each school. I would do a passing thing of course with the principal or associate principal to say hello, the teacher who taught calculus and the teacher who taught physics. At many schools there was only one, at most there were two, and at a few big ones there were actually four. They were lovely people, devoting a great deal of time and energy to deal with students who are still quite high on hormones and gets them focused and able to understand some elementary aspects of science. These teachers are our prime recruiters. They are the people who try to convince students that science is fun, that it's interesting, that it engages the wider world, that it is an issue to which they can devote their lives. Yet for the most part I found these teachers to be an oddly isolated group, dedicated to their classes, dedicated to their charges, and dedicated to science, but often feeling distant from the scientific world.

These teachers often had limited control over their lives. Local school boards would impose curriculum on them. Experts from the state would show up and tell them what to do. Parents didn't quite grasp what these teachers needed to do, especially the parents who desperately wanted their children to become doctors someday.

There was one incident that remains vividly in thought even though six years have passed since I met this teacher. I'd driven quite some distance to find his high school. After class ended, he invited me to sit in on his computer club, which I was glad to do. I sat around with them for awhile listening to what they did with their programming projects. They were clever students, sophomoric at times, but engaging. They broke up early for the usual things, the soccer practice, some going off for ballet, other things.

Yet the teacher wanted to sit and talk further. He talked about his interest in science. He had been educated abroad, had come to the United States and found that he did not have enough resources to pursue an advanced degree in science. Instead, he got high teaching accreditation. He found that he loved high school teaching. He loved these kids. He loved working with experiments. He loved thinking of new ideas. But he also felt isolated. The other teachers didn't appreciate what he did, and often students to avoid science classes. He had no friends who were engaged in science, none that he knew were involved in scientific pursuits. Still, he soldiered on. He felt the great resentment, that is common to all teachers, when the evil hand of administration comes crashing down and a stern voice says, this is our curriculum, teach it. He had faced such demands, not once or twice, but three times, each with curricula that seemed to vary little but for some detail that he found irritating.

As we walked out to the parking lot where his car was parked, he stopped and in a voice that almost broke said, how grateful he was that I was there. This was the first contact with a real scientist that he had had in a long time. He wanted to know what I did and who were my colleagues. He was aware of my writing for and wanted to know how I keep informed about new developments in computer science. He wished he had time to follow the scientific literature more, but he didn't.

That was the most dramatic incident I faced but the spirit of that evening was repeated again and again.

We sometimes forget that when we build a strong professional society for science, a strong professional organization for engineering, that we build it on rejection. We talked about how many papers we reject and how grateful we are when we finally get our acceptance rate down to 18 or 15 percent or 12 percent. I have been an editor for an IEEE journal, and I've seen papers from high school professors pass our desk, and I know that I can't accept them. They are not as closely tied to literature as they need to be. You'd like to reach out a hand and say, this was a good effort, there may be something we can do with it, and it was nice to hear from you. But we don't. We don't bring them in. We don't have a way to make these professional scientists. They are high school scientists to be sure, high school teacher scientists, but there has to be a way that we can make them a professional so that they are part of the professional group. In this way they can be part of the scientific process, in touch with people who work in research, in engineering, in business, and so they know what science is like.

Not that long ago high school teachers were regularly part of the scientific endeavor, particularly for work that involved gathering large data sets. Until the computerization of the weather in the 1950s high school teachers regularly collected weather data. It is a task roughly as much fun as milking cows without the cow. At least with a cow you have a nice friendly face that may or may not want to see you twice a day. When you college weather data, you have a lonely walk to get the barometric pressure, the amount of rain, the high and the low temperatures. Certain amount of environmental work in the 1950s was the same. Before tidal statistics were computerized in the 1960s, coastal teachers would collect high and low tide, whatever else you needed for hydrology. Those opportunities are gone and replaced by automatic sensors. We have very few ways right now to engage high school teachers in scientific research, yet engage them we must because such work makes them professionals. That kind of work brings them in. Most importantly it gives these teachers a story that is directly connected to what you do and what I do and what professional scientists in business do and what research scientists do. It makes them part of the process and ultimately connects their students to the scientific endeavor.

This is one idea that needs to be considered by the professional societies. What's a high school engineer? A lot of people who teach physics at high school are former engineers now in retirement. How do we make sure they are still part of the professional societies? The teachers who have connections beyond their schools are often the

least frustrated and the most contented. Yet how do we connect these teachers to our professional communities. That's the issue we need to address. That's what we need to do if we are going to have a strong seamless link between high school and college. That has to be part of the process that brings the best people into science and engineering and make sure we get the engineers and scientists and mathematicians for tomorrow.

Q&A:

QUESTION: I'm Robert Boege, ASTRA, the Alliance for Science and Technology Research in America. I'd like to get a bigger focus. Did you have a reaction to the recommendations of the recent report about putting I guess you'd call it engineering back in STEM education in the K through 12 curriculum?

MR. GRIER: I read it somewhere but I didn't read the whole report. The argument, I feel quite positive toward that in the sense that engineering and particularly the task many high school students have of taking things apart is one of the first ways they move from the elementary interests in science which are largely space and dinosaurs in things that teach them going from basic mechanics into the fundamental concepts of physics. I think the idea of it's something that you postpone until later is a mistake. As we know, shop class which was another way people got started in it, has long been watered down, and it doesn't exist in the same form it did when any of us, judging by our hair or lack of it, went to high school. I think there's something there that does desperately needs to be revised.

QUESTION: As a follow-up, I thought there was a fascinating matrix, a report that described program after program some of which was at middle school level and high school that showed relative success but failure to communicate best practice or communicate across geographic areas, which was shocking. The other omission I saw was failure to recognize the role of parents whether single household or not, to engage parents. I actually served as a volunteer at the Thomas Jefferson High School, public school, fantastic science school, and it has absolute commitment from the cohort of parents who are not necessarily engineers or scientists, just very concerned parents who somehow have been endowed with this passion for getting their kids adequately trained. Comments?

MR. GRIER: Oh, yes. I recruited at Thomas Jefferson a lot. They are an extraordinary school, praised for what they do. Like most science magnet schools, they don't begin to have 100 percent placement in science or engineering. I recall 35 to 45, but still that's better than most schools, unusual. Most schools don't begin to have the assets, the parents or the commitment.

The issue of transmitting best practices I think is part of the point I'm trying to get at. Best practices are tested by those in the front lines and we need to bring them in as a sense. I'm not saying make them full members of IEEE or American Physics Society. We give them a class that clearly appreciates what they are and what they do and what they can give us, and one of those is transmitting best practices.

As a parallel, at this university there's a period in my wandering career that I ran our honors program for the best students, and the goal was straightforward, keep them from leaving, from transferring to Penn or Georgetown. It's a small group of programs like that and a very targeted kind of problem, but we had a conference where we exchanged best practices. It's actually going to be in Washington in a couple weeks. That was an important way not only for exchanging among practitioners but raising them to the higher level. What do we have for high school math and physics teachers, the two primary groups. Chemistry sometimes was helpful, sometimes not. But always math and physics were. How do we engage them in the bigger questions, make them feel they are part of the process, get their ideas to spread?

Workshop Conclusion

MARTY SOKOLOSKI: We need to get some metrics going here to show people that we need to put our hands around STEM Enterprise because we need to find out what the health of it is as I showed in my first slide. The fact that the workforce of R&D is slowly dissipating off our shores is something that we need to do something about. I remember back in the 1950s and 1960s it wasn't unusual to see a very basic benchmark article, for instance in Physical Review, B, which is the bastion of solid state physics, wasn't unusual to see an article by GE or Westinghouse or one of the industrial laboratories. Matter of fact, it was par for the course. If you look back in that time period industry was funding more basic research than the government. What has happened since that period of time?

The thing that has happened is that the business model has changed. Now businesses want to get short-term returns on their investments. Businesses like we'd said before don't want to listen to something that's going to have a return 10 years from now. That's not the business plan. I don't know how to change this around. I don't know what to do. If you look at that and look at globalization, the factoring out of R&D offshore fits the business plan because you get R&D offshore cheaper.

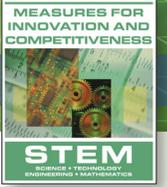
Because of the information technology and how we can transmit information back and forth, that's not a problem anymore. So this is a real problem in the workforce area.

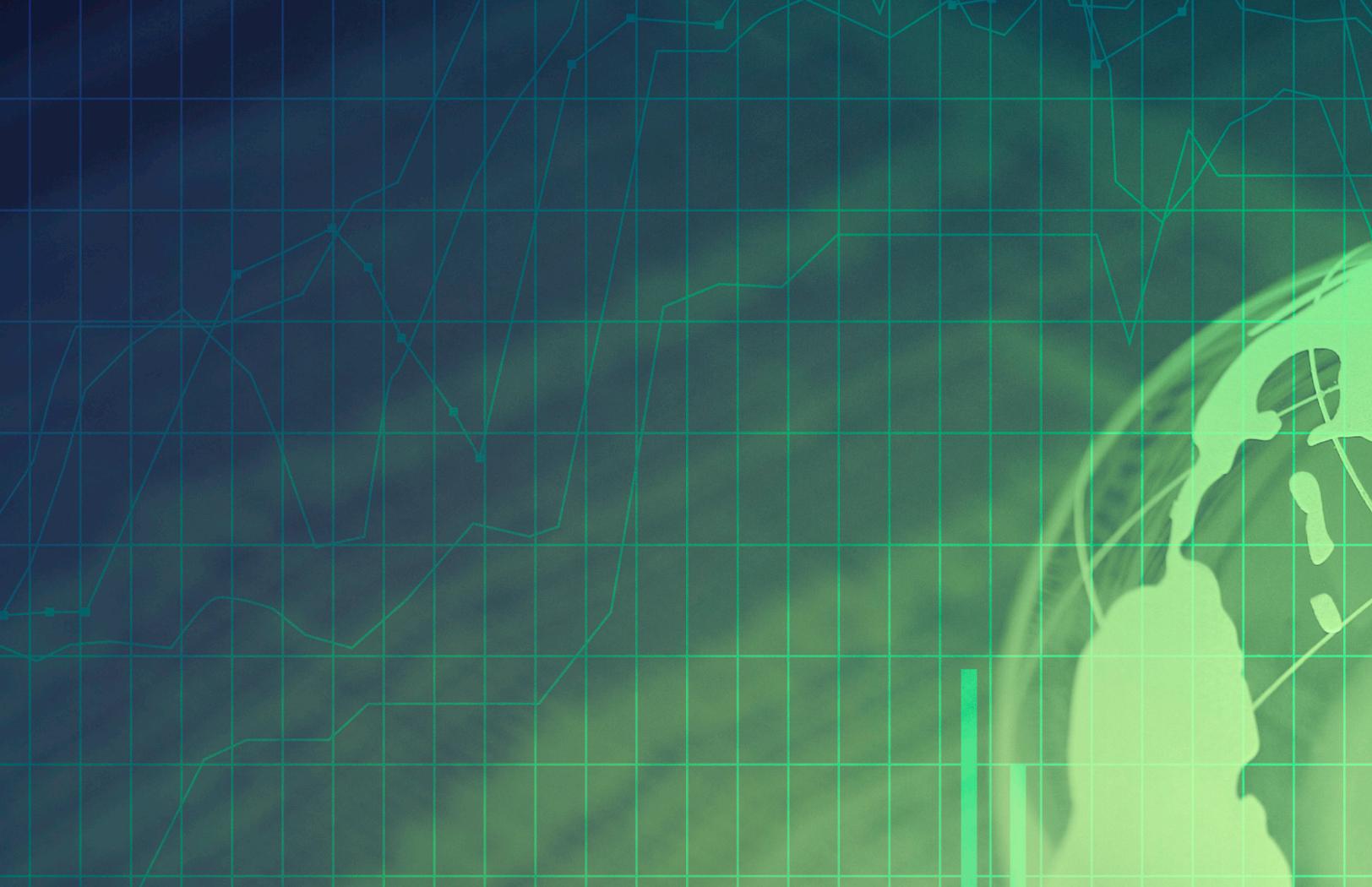
Ron Hira expressed the fact that the American Competes Act really did not address this. It says we're going to put more money over here. That's fine because I think in the federal sector there's enough constraints that it's very difficult to take your R&D and offshore it. If you have an R&D grant, perhaps maybe one person is from a foreign institute but the work maybe is done here. I know the work NASA does contracting out for the space missions, the work has got to be done in the U.S. However, foreign entities can have experiments on this mission, but they have to pay for it. And we encourage that as well.

So I think in the federal sector, the feds funding R&D, I think we can put constraints on that. The fact is that industrial R&D is another bag of worms. Somehow we've got to get this message across to somebody before it's too late. It might even be too late now.

So I hope everybody is pleased with what took place, all you registrants. If you have any comments about the conduct of this workshop please send them to one of the planning members. I think we have our e-mail addresses on there. Send them to any person on the planning committee. Hopefully we might have another workshop two years from now come back. I hope you don't have to commiserate like I did now. I hope there's something positive to talk about. But we need to tell policy makers what the problem is. And I hope we have enough ammunition, enough metrics, and enough of an advocacy position to bring this across, not only people in the federal sector but to our industry colleagues.

I want to thank everybody here and hopefully we'll meet in two years. This concludes our workshop. Thank you very much.





2001 L Street, NW, Suite 700
Washington, D.C. 20036
+1 202 785 0017
www.ieeeusa.org