THE SCIENCE OF SCIENCE AND INNOVATION POLICY

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED ELEVENTH CONGRESS

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CONTENTS

September 23, 2010

THE SCIENCE OF SCIENCE AND INNOVATION POLICY

THURSDAY, SEPTEMBER 23, 2010

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
Washington, DC.

The Subcommittee met, pursuant to call, at 2:07 p.m., in Room 2325 of the Rayburn House Office Building, Hon. Daniel Lipinski [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
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COMMITTEE ON SCIENCE AND TECHNOLOGY

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Subcommittee on Research and Science Education
Hearing on

The Science of Science and Innovation Policy

September 23, 2010
2:00 p.m. – 4:00 p.m.
2325 Rayburn House Office Building

Witness List

Dr. Julia Lane
Program Director of the Science of Science and Innovation Policy program
National Science Foundation

Dr. Daniel Sarewitz
Co-Director of the Consortium for Science, Policy & Outcomes
and Professor of Science and Society
Arizona State University

Dr. Fiona Murray
Associate Professor of Management
Technological Innovation & Entrepreneurship Group
MIT Sloan School of Management

Dr. Albert H. Teich
Director of Science & Policy Programs
American Association for the Advancement of Science

HEARING CHARTER

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION
U.S. HOUSE OF REPRESENTATIVES

The Science of Science and Innovation Policy

THURSDAY, SEPTEMBER 23, 2010
2:00 P.M.–4:00 P.M.
2325 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, September 23, 2010, the Research and Science Education Subcommittee will hold a hearing to examine the current state of science and technology policy research, how this research informs policymaking, and the role of the federal government in fostering academic research and education in this emerging interdisciplinary field.

2. Witnesses

- **Dr. Julia Lane**, Program Director of the Science of Science and Innovation Policy program, National Science Foundation.
- **Dr. Daniel Sarewitz**, Co-Director of the Consortium for Science, Policy & Outcomes, Arizona State University.
- **Dr. Fiona Murray**, Associate Professor of Management in the Technological Innovation & Entrepreneurship Group, MIT Sloan School of Management.
- **Dr. Albert H. Teich**, Director of Science & Policy Programs, American Association for the Advancement of Science.

3. Overarching Questions

- What is the "science of science policy?" How can science and technology (S&T) policy research contribute to and inform evidence-based local and national policy decisions? To what extent are science and technology policies in the United States being shaped by what has been learned from S&T policy research?
- What new and continuing areas of research in this area could significantly improve our ability to design effective programs and better target federal research investments? What are the most promising research opportunities and what are the biggest research gaps? Is the Federal government, specifically the National Science Foundation, playing an effective role in developing the science of science policy?
- What is the state of education in science and technology policy at U.S. universities? What are the backgrounds of students pursuing graduate degrees in S&T policy? What career paths are sought by science and technology policy program graduates? What are the fundamental skills and content knowledge needed by science and technology policy practitioners? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy programs at U.S. universities?

4. Background

During his keynote address in 2005 at the American Association for the Advancement of Science's Science and Technology Policy Forum, Dr. John Marburger, then science advisor to President Bush, called for the establishment of a "science of science policy." The "science of science policy" (SoSP) as described by Dr. Marburger and others includes the development of scientific theories, analytical tools, and rigorous datasets that will assist policymakers in science policy decisions. The SoSP is an interdisciplinary field that draws together researchers from economics, political science, and the social and behavioral sciences to improve our understanding of the science and engineering enterprise, including the process of innovation in an effort to establish a more quantitative approach to science and technology policy decisions.

While most believe that science, technology, and innovation are critical to the competitiveness and prosperity of the United States, we lack the rigorous tools to quantify that relationship. Therefore, it remains difficult to actually *measure* the economic impact, social benefits, and effectiveness of federal research and development (R&D) investments. In addition to improving our ability to target federal R&D investments, research in the area of SoSP holds the potential to provide insight into the effect of globalization on the U.S. science and engineering workforce, increase our understanding of technology development and diffusion, communicate the social and economic benefits of R&D spending to the general public, and shed light on the process of creativity and innovation.

In 2006, in response to Dr. Marburger's call to action, an interagency working group, co-chaired by the National Science Foundation (NSF) and the Department of Energy, was formed within the Subcommittee on Social, Behavioral, and Economic Sciences under the National Science and Technology Council. The interagency working group conducted an assessment of the state of SoSP research and surveyed the Federal agencies about the tools, methods, and data they were using to make investment decisions. This work resulted in the release of a Federal SoSP research roadmap [1] in 2008. The roadmap outlines three broad themes and poses 10 research questions to be addressed by federally-funded SoSP research.

Theme 1: Understanding Science and Innovation

Question 1: What are the behavioral foundations of innovation?

Question 2: What explains technology development, adoption, and diffusion?

Question 3: How and why do communities of science and innovation form and evolve?

Theme 2: Investing in Science and Innovation

Question 4: What is the value of the Nation's public investment in science?

Question 5: Is it possible to "predict discovery"?

Question 6: Is it possible to describe the impact of discovery on innovation?

Question 7: What are the determinants of investment effectiveness?

Theme 3: Using the Science of Science Policy to Address National Priorities

Question 8: What impact does science have on innovation and competitiveness?

Question 9: How competitive is the U.S. scientific workforce?

Question 10: What is the relative importance of different policy instruments in science policy?

Role of the National Science Foundation

In 2006, NSF's Directorate for Social, Behavioral and Economic Sciences (SBE) held three workshops to ask for recommendations and guidance from the research community about the breadth of activities that should be supported under an NSF-funded SoSP program. In 2007, NSF allocated $6.8 million for a new Science of Science and Innovation Policy (SciSIP) program. SciSIP supports both single investigators and collaborations in two areas. First, the program supports research on data and the improvement of science metrics, including research to improve our ability to identify, characterize, and measure returns on federal R&D investments. Second, the program supports research directed toward the development of models and other statistical tools as well as qualitative studies that will improve our understanding of the process of innovation and science outcomes, both societal and economic. In addition to supporting research, the program supports workshops, conferences, and symposia to help foster a community of researchers in the SciSIP area.

NSF's SciSIP budget request for fiscal year 2011 was $14.25 million, of which $8.05 million will be devoted to SciSIP research and community building activities through SBE's Office of Multidisciplinary Activities and $6.2 million will be for the development of data survey tools through SBE's Division of Science Resource Statistics (SRS). The data compiled by SRS for the biennial Science and Engineering Indi-

[1] *The Science of Science Policy: A Federal Research Roadmap http://www.whitehouse.gov/files/documents/ostp/NSTC%20Reports/39924_PDF%20Proof.pdf*

cators report serve a vital role in the SoSP as a long-term source of unbiased information about the science and engineering enterprise.

NSF's current efforts in SciSIP are not its first. From the 1970's through the early 1990's NSF had a modest-sized staff carrying out policy research and analysis. These analysts worked in the Office of Research and Development Assessment, later the Division of Policy Research and Analysis (PRA), on specific tasks requested by the Office of Management and Budget, the Office of Science and Technology Policy, the Congressional Office of Technology Assessment, and other federal agencies. Additionally, PRA had a small budget to support academic research in areas directly relevant to their policy analysis tasks. In 1992, PRA was involved in a scandal over the faulty assumptions used to predict a looming shortage in engineers. The scandal led to an investigation by the Committee on Science & Technology and the dismantling of PRA.

STAR METRICS

The National Science Foundation and the National Institutes of Health are currently collaborating on a project known as STAR METRICS (Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science), which is the first federal-university partnership to develop a data infrastructure that documents the outcomes of science investments for the public. An initial pilot project was recently completed with a handful of regionally and otherwise diverse institutions of higher education through the National Academies' Federal Demonstration Partnership. The pilot project validated the initiative's concept and its ability to collect relevant data from existing university databases. The full-scale project will proceed in two phases: Phase I will develop uniform, auditable and standardized measures of job creation resulting from science spending included in the American Recovery and Reinvestment Act; Phase II will develop measures of the impact of federal R&D spending on economic growth, workforce development, scientific knowledge, and social outcomes.

International Efforts

The Organization for Economic Cooperation and Development (OECD) has been developing and collecting science and technology indicators from their member nations for nearly 50 years. In 2004, the Science & Technology Ministerial called for a "new generation of indicators which can measure innovative performance and other related output of a knowledge-based economy" emphasizing "the data required for the assessment, monitoring and policy making purposes."[2] Since that time the OECD has continued to refine its science and technology indicators, and improve the tools they use for analyzing the impact of science and technology. Earlier this year the OECD released a report entitled, "Measuring Innovation: A New Perspective."[3] The report identifies five areas for which international action is needed: the development of innovation metrics that can be linked to aggregate measures of economic performance; investment in a high-quality and comprehensive statistical infrastructure to analysis innovation at the firm-level; the promotion of innovation metrics in public sector and for public policy evaluation; the identification of new approaches to understand knowledge creation and flow; and the promotion of the measurement of innovation on social goals.

On April 14, Dr. Julia Lane spoke to the European Parliament about the STAR METRICS effort, emphasizing the global nature of science and engineering and the common need for better tools to assess and predict the impact of science, technology, and innovation. During her speech, Dr. Lane indicated that creating a universal researcher identification system could be an important first step in a global effort to understand and measure the return on scientific investment. Niki Tzavela, a Greek Member of the European Parliament, who serves as Vice-Chair of the European Parliament Delegation to the United States, and sits on the Parliament's Industry, Research, and Energy Committee (ITRE), has been a leader on the issue of improved science metrics in the European Union. Having indicated that the EU 8th Framework Program represents an opportunity to evaluate and improve science policy, Mrs. Tzavela introduced an initiative to the ITRE Committee proposing that the EU collaborate on this topic with the United States. The EU is now considering initiatives that would complement the STAR metrics project, and the Scientific Tech-

[2] What Indicators for Science, Technology and Innovation Policies in the 21st Century? Blue Sky II Forum—Background *http://www.oecd.org/dataoecd/9/48/37082579.pdf*

[3] *http://www.oecd.org/document/22/0,3343,en_41462537_41454856_44979734_1_1_1_1,00.html*

nology Options Assessment Panel within the EU has been designated to provide an in-depth analysis on Science Metrics.[4]

Education in Science & Technology Public Policy

According to the AAAS Guide to Graduate Education in Science, Engineering and Public Policy[5] there are more than 25 U.S. universities that offer a graduate degree in the interdisciplinary field of science and technology public policy. These degree programs draw from a number of fields, including economics, sociology, political science, and engineering; however the coursework associated with each program varies and is dependent upon the academic department or school that houses the program.

5. Questions for Witnesses

Dr. Julia Lane

1. Please describe NSF's Science of Science Policy and Innovation program, including a description of the Foundation's overall vision and strategy for research and education in this area.

   Specifically,

   How is NSF fostering collaboration between social and behavioral scientists and researchers from other disciplines, including computer scientists, engineers, and physical scientists, in science and technology policy research?

   How is NSF fostering the development of science and technology policy degree programs and courses of study at colleges and universities? What is the current scope and level of support for such programs?

   How is NSF encouraging the development of a community of practice in science of science policy and the dissemination of research results to policy makers?

2. As a Co-Chair of the Science of Science Policy Interagency Group under the National Science and Technology Council, please briefly describe the work of that group and how the various federal science agencies are collaborating on the development and implementation of science of science policy tools to improve the management and effectiveness of their R&D portfolios and other science and technology-related programs.
3. Please provide a brief description and update on the status of the OSTP led project on science metrics, known as STAR Metrics, including a description of international engagement and interest in this effort.

Dr. Albert Teich

1. How can research on innovation and the scientific enterprise also known as the science of science and innovation policy (SciSIP) be used to inform the design of effective federal programs and the management of federal research investments? Do you believe the results of science and technology policy research are being effectively incorporated into national policy decisions?
2. What are the challenges to the incorporation of science and technology research in the decision making process? What is AAAS's role in mitigating those barriers? Specifically, how is AAAS helping to build a community of practice in the SciSIP? What recommendations, if any, do you have for the National Science Foundation's SciSIP program? Do you believe SciSIP research is being effectively coordinated across the federal agencies? If not, what if any recommendations do you have regarding interagency coordination?
3. As you know there are more than 25 U.S. universities that offer graduate degrees in science, engineering and public policy. In your opinion, are these programs having the intended effect of producing graduates with the skills necessary to shape science and technology policies? What type of education and training should science and technology policy practitioners receive? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy programs at U.S. universities? If

[4] *http://www.euractiv.com/en/science/eu-looks-to-us-model-for-measuring-rd-impact-news-448950*

[5] *http://www.aaas.org/spp/sepp/*

not, what recommendations, if any, do you have for NSF and/or the universities with such programs?

Dr. Daniel Sarewitz

1. Please provide an overview of the research activities of the Consortium for Science, Policy, and Outcomes. How are you facilitating interdisciplinary collaborations within the Consortium? What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? What are the most promising research opportunities and what are the biggest research gaps?
2. Is the Federal government, specifically the National Science Foundation, playing an effective role in fostering SciSIP research and the development of a community of practice in SciSIP? What recommendations, if any, do you have for the National Science Foundation's SciSIP program?
3. Please describe the education and outreach activities of the Consortium for Science, Policy, and Outcomes.
4. How can the dissemination of SciSIP research findings be improved so that policymakers are better informed of the current state of research? Are there best practices that can be implemented by the Federal government and/or the research community to improve the incorporation of science and technology policy research into the decision making process?
5. What are the fundamental skills and content knowledge needed by SciSIP researchers and practitioners? What are the backgrounds of students pursuing graduate degrees in science and technology policy and what careers paths are sought by these graduates? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy degree programs at U.S. universities? If not, what recommendations, if any, do you have for NSF and/or the universities with such programs?

Dr. Fiona Murray

1. Please provide an overview of your research. What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? What are the most promising research opportunities and what are the biggest research gaps?
2. Is the Federal government, specifically the National Science Foundation, playing an effective role in fostering SciSIP research and the development of a community of practice in SciSIP? What recommendations, if any, do you have for the National Science Foundation's SciSIP program?
3. What are the fundamental skills and content knowledge needed by SciSIP researchers and practitioners? What are the backgrounds of students pursuing graduate degrees in science and technology policy and what careers paths are sought by these graduates? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy degree programs at U.S. universities? If not, what recommendations, if any, do you have for NSF and/or the universities with such programs?

Chairman LIPINSKI. This hearing will now come to order. Good afternoon and welcome to today's Research and Science Education Subcommittee hearing on the Science of Science and Innovation Policy, also known as SciSIP. For those of you who may not be familiar with the phrase, the Science of Science Policy is a field of interdisciplinary research that focuses on understanding how our policy decisions impact innovation and science and engineering research. Given the magnitude of the federal investment in science and technology, there is a need for objective analysis and evaluation of federally funded R&D programs. And given the size of the budget deficit, Congressional decision makers need the best information possible to make sure we are spending taxpayer dollars optimally.

Today we will be hearing from a diverse panel of witnesses about the current state of research and education in this emerging field. This topic is of particular interest to me since it goes to the core of why I joined the Science and Technology Committee when I first came to Congress. Like most members of this committee, I believe that science and engineering research, and education have driven long term economic growth and improved the quality of life for all Americans. I have viewed science and innovation policy as critical for maintaining our international competitiveness and creating jobs.

But the best policies are not self-evident. As someone who was trained as an engineer and a social scientist, I believe we need data and proper analysis of this data to be able to determine as best we can the optimal policy. We are going to hear today about some of the research that is being done on science policy. I am eager to hear to the panel's thoughts on what is being found, how well these findings are being disseminated, and whether research in this area is actually helping policymakers.

While many of us would agree that science has had a positive impact on our lives, I think we know very little about how the process of innovation works. What kinds of research programs or institutional structures are most effective? How do investments in R&D translate to more jobs, improved health, and overall societal wellbeing? How should we balance investments in basic and applied research? With millions of Americans out of work it becomes more critical than ever that we find answers to these questions.

We will also take a closer look at the state of education in science and technology policy and how these degree programs and courses of study are contributing by educating the next generation of researchers and science policy practitioners. There are a variety of science and technology programs that are popping up across the country. They can be found in public policy schools, economics departments, business schools, and other places, even philosophy departments. I am looking forward to hearing more about these programs, including what kinds of students they attract and where those students go upon graduation.

Finally, I hope to hear recommendations from today's witnesses about how the Federal Government, particularly the National Science Foundation, can foster interdisciplinary research in this area, and how it can continue to improved education and training for students who want to pursue a career at the intersection of science, technology, and public policy. I thank the witnesses for being here this afternoon, especially as we have had to move this hearing back from the morning. I look forward to your testimony.

Now before I recognize Dr. Ehlers, I—this will likely be the last hearing of this subcommittee, the last meeting of this subcommittee. It may not be, but just in case it is the last for this Congress, I wanted to say that I think we should all recognize Dr. Ehlers for his contributions in Congress and especially on this committee through the years. It has been certainly—I have had a great partner working on this as I have chaired the Subcommittee for the last two years. He is someone who really, truly is dedicated to the issues that we are facing here and we deal with here in the Committee. Too many things right now are becoming partisan footballs, and Dr. Ehlers really has kept his eye on what is best and trying to find what is best for our country. And I want to thank you for the years that you have put in here and wish you the best in your next endeavors, but it has been a pleasure to work with you, especially over these last few years.

[The prepared statement of Chairman Lipinski follows:]

PREPARED STATEMENT OF CHAIRMAN DANIEL LIPINSKI

Good afternoon and welcome to today's Research and Science Education Subcommittee hearing on the science of science and innovation policy, also know as SciSIP. For those of you who might not be familiar with the phrase, the "science of science policy" is a field of interdisciplinary research that focuses on understanding how our policy decisions impact innovation and science and engineering research. Given the magnitude of the federal investment in science and technology, there is a need for objective analysis and evaluation of federally funded R&D programs. And given the size of the budget deficit, Congressional decision makers need the best information possible to make sure we are spending taxpayer dollars optimally. Today we'll be hearing from a diverse panel of witnesses about the current state of research and education in this emerging field.

This topic is of particular interest to me since it goes to the core of why I joined the Science and Technology Committee when I came to Congress. Like most Members of this committee, I believe that science and engineering research and education have driven long-term economic growth and improved the quality of life for all Americans. I view science and innovation policy as critical for maintaining our international competitiveness and creating jobs.

But the best policies are not self-evident. As someone who was trained as an engineer and a social scientist, I believe we need data and proper analysis of this data to be able to determine—as best we can—the optimal policy to implement. We are going to hear today about some of the research that is being done on science policy, and I am eager to hear the panel's thoughts on what is being found, how well the findings of this research are being disseminated, and whether research in this area is actually helping policy makers.

While many of us would agree that science has had a positive impact on our lives, I think we actually know very little about how the process of innovation works. What kinds of research programs or institutional structures are most effective? How do investments in R&D translate to more jobs, improved health, and overall societal wellbeing? How should we balance investments in basic and applied research? With millions of Americans out of work, it becomes more critical than ever that we find answers to these questions.

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Finally, I hope to hear recommendations from today's witnesses about how the Federal government, particularly the National Science Foundation, can foster interdisciplinary research in this area and how it can contribute to improved education and training for students who want to pursue a career at the intersection of science, technology, and public policy.

I thank the witnesses for being here this afternoon and look forward to their testimony.

Chairman LIPINSKI. And with that I will now recognize Dr. Ehlers for an opening statement.

Mr. EHLERS. Thank you for those kind words, Mr. Chairman. I think my biggest challenge will be learning how to sleep in, but I very much appreciate those comments. I always just try to do a good job wherever I am. It is a trade I learned from my parents and I never, never, never, ever expected to be in the Congress or in politics. My mother never quite got over it. As she put it, what are you doing with all those nasty people? But it turns out my colleagues are not nasty people, and I appreciate your leadership on the Subcommittee. And you have done a great job of leading us in the right direction, and it has been a pleasure to work with you. Thank you.

With that I will proceed to the opening statement. Today we will explore the current state of science and technology policy research and the role it plays in informing our policy decisions. And I have to insert a little comment in here, that is, when I first arrived here and was assigned to the Science Committee, which made obvious sense since I was at that time I think one of the very few, if the only, scientist in the Congress, at least on the Republican side. And at the first meeting of the Science Committee I asked the Chair, how many scientists do you have on staff? And the answer was none. And I said really? How can you function without—and he said well, we don't really need people who understand science. We need people who understand science policy.

Well, as a scientist I had never thought much about science policy and little did I know that in conversation with Newt Gingrich where I commented that I thought it a bit strange that the science policy we were operating under in the government and in the Congress was by Vannevar Bush's 1945 book, and I said that is a little out of date. Things change rapidly in science. It is a great book, "The Endless Frontier". Vannevar Bush was a great man. He had done a lot of good works especially during World War II. But I talked to Newt Gingrich about that, that that was the latest science policy book that was guiding the Government, so he did as Newt Gingrich always did and said hey, it is time to get another one. Why don't you do it? So I learned after a couple of years never to suggest anything to Newt because he always dumped the burden on me.

In any event, I did proceed to work on a book, which just walked in the door with my aide, and some of you have seen it already. It is called "Unlocking Our Future". Now this is not a great science policy book. I knew absolutely nothing about science policy when we proceeded to write it but it seemed to me that there were certain things that were obvious and we put them in here. And I deliberately said "Unlocking Our Future" because I felt we had so much to do and I was not able to do it in this thin little volume. It did get some notice, and it inspired some science policy individuals to engage more seriously in this. And some of them, many of them are represented here. But it was a real education to me. You should try that sometime, writing a book about something you know nothing about. It is a great way to learn and fortunately as a child I was homeschooled because of illness, so all the learning I did was things that I learned and learned on my own. So that was good preparation for this.

We clearly, badly need something like this again and it is one case where the author is delighted to say this is too old now. It is time to get busy. Someone else better start writing a better thing.

Let me continue with my opening statement. When Dr. John Marburger, who was science advisor to President Bush, called for the establishment of a Science of Science Policy in 2005, we embarked on a new journey into this emerging field of interdisciplinary research by establishing an interagency working group, the Science and Science of Innovation Policy program at the National Science Foundation—the shorthand for it was SciSIP—and most recently, the Science and Technology for America's Reinvestment, which is the emphasis that I and others, including the authors of "The Gathering Storm," have been emphasizing, because it is important for us to measure the effects of research and innovation competitiveness and science which has come to be called STAR METRICS. I hope this hearing will provide us with a detailed measurement of how far we have come on that journey as well as an encouraging picture of the progress we have made.

I have spent many years on this Committee working to strengthen U.S. innovation and science education, and I have been a long time advocate of increased federal funding for basic research. I wish the entire Congress was receptive to that notion as they—but this funding produces the technological innovations that will keep America competitive in the global market and it is essential for us to educate American workers in the skills needed for 21st century jobs.

As with any program, sustained Congressional oversight is required to insure that the Science of Science Policy Programs are effective and that they progress in a timely and fiscally responsible manner. I am encouraged by efforts which seek to maximize our current investments in scientific research, and I believe it is very important that those are the investments that provide us with measureable returns. And that is why I have worked so hard to try and make the research and development tax credit permanent, because that is one good way to encourage industry to work on these issues. We must be mindful of that fact as Congress deliberates the best ways to use American taxpayer funds in this difficult economic climate.

To that end I am very interested in learning more about the progress and potential of the STAR METRICS program and its recently completed project. I hope—I look forward to learning more about the status of science affecting science policy and the advancements which have been made since 2005. And I wanted to thank our panel of witnesses for being here today, for accommodating our last second scheduling change, and I look forward to hearing their insights on this topic. There is much work to be done to help our nation recover its lead in technological development, and in manufacturing, and in science in general.

And so I am looking forward to the testimony today and I hope you can enlighten us, and out of this will come first of all a new version of this, and secondly there is some improvement in our judgments about science and also science education in this Nation. Thank you very much.

[Statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Today, we will explore the current state of science and technology policy research, and the role it plays in informing our policy decisions. When Dr. John Marburger, then science advisor to President Bush, called for the establishment of a "science of science policy" (SoSP) in 2005, we embarked on a new journey into this emerging field of interdisciplinary research by establishing an interagency working group, the Science of Science and Innovation Policy (SciSIP) program at the National Science Foundation (NSF), and, most recently, the Science and Technology for America's Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science (STAR METRICS) project. I hope this hearing will provide us with a detailed measurement of how far we have come on that journey, as well as an encouraging picture of the progress we have made.

I have spent many years on this committee working to strengthen U.S. innovation and science education, and I have been a long time advocate of increased federal funding for basic research. This funding produces the technological innovations that will keep America competitive in the global market, and it is essential for us to educate American workers in the skills needed for 21st-century jobs.

As with any program, sustained Congressional oversight is required to ensure the SoSP programs are effective, and that they progress in a timely and fiscally responsible manner. I am encouraged by efforts which seek to maximize our current investments in scientific research, and I believe it is very important that those R&D investments provide us with measurable returns. We must be mindful of that fact as Congress deliberates the best ways to use American taxpayer funds in this difficult economic climate. To that end, I am very interested in learning more about the progress and potential of the STAR METRICS program and its recently completed pilot project.

I look forward to learning more about the status of science affecting science policy and the advancements which have been made since 2005. I want to thank our panel of witnesses for being here today, for accommodating our last-second scheduling change, and I look forward to hearing their insights on this topic.

Chairman LIPINSKI. Thank you, Dr. Ehlers. Maybe we can make that a best seller now. Now if there are Members who wish to submit additional opening statements, their statements will be added to the record at this point. And at this time I want to introduce our witnesses. Dr. Julia Lane is the Program Director of the Science of Science and Innovation Policy program at the National Science Foundation. Dr. Daniel Sarewitz is the Co-Director of the Consortium for Science, Policy & Outcomes and Professor of Science and Society at Arizona State University. Dr. Fiona Murray is an Associate Professor of Management in the Technological Innovation & Entrepreneur Group at MIT Sloan School of Management. And Dr. Albert H. Teich is the Director of Science & Policy Programs at the American Association for the Advancement of Science.

As our witnesses should know, you will each have five minutes for your spoken testimony. Your written testimony will be included in the record for the hearing. When you all have completed your spoken testimony we will begin with questions. Each Member will have five minutes to question the panel. And before we begin I just want to mention that we will be having votes coming up soon, so probably what the most important thing is if everyone could hold to their five minutes it will help us so we don't have—hopefully won't have an interruption in the—at least in the testimony part here. But with that, we will start with Dr. Lane.

STATEMENT OF JULIA LANE, PROGRAM DIRECTOR OF THE SCIENCE OF SCIENCE AND INNOVATION POLICY PROGRAM, NATIONAL SCIENCE FOUNDATION

Dr. LANE. Chairman Lipinski, Ranking Member Ehlers, Members of the Subcommittee, it is my distinct pleasure to be with you here today to discuss NSF's Science of Science and Innovation Policy Program, the activities of the Science of Science Policy Inter-Agency Group, and the STAR METRICS program, the last of which is a new federal and university partnership to document the scientific, social, economic, and work force outcomes of science investments to the public. I am Dr. Julia Lane. I am the Program Director of the SciSIP program at NSF and Co-Chair of NSTC working group on the Science of Science Policy.

I submitted a written statement to supplement or to accompany my oral testimony. So the focus of these three efforts is to provide, as you noted, better methods and data to inform science—federal science investment decisions. They represent the first efforts to construct a scientific framework that is supported by multiple agencies and multiple institutions, all jointly engaged. It represents a true all-out effort to providing an evidence basis for U.S. science policy. Its success is important for policy makers because, in a nutshell, you can't manage what you can't measure, and what you measure is what you get.

Developing a scientific framework involves several things. It requires the engagement of scientists from many disciplines to address science policy issues. The NSF does this through the SciSIP program. The overarching goal of this effort is to conduct basic research that creates new objective models, analytical tools, and data sets to inform our nation's basic research, and to inform public and private sectors about the processes through which investments in science and engineering work their way through the outcomes we have mentioned. It funds researchers from a wide range of disciplines and it funds students to study science policy issues in a scientific manner. As you also know, it supports the redesign of surveys undertaken by the National Science Foundation's Science Resource Statistics. It is the statistical agency charged with describing the science and innovation enterprise. For example, the new business and innovation survey, the BRDIS [Business R&D and Innovation Survey] survey, has been completely redesigned from a 1950s structure to something that captures the new R&D innovation activities.

So it is not just the academic community that is advancing the Science of Science Policy. It is also policymakers in the Executive and Legislative branches who recognize that we need these better approaches. That is why the National Science and Technology Council established the Science of Science Policy Inter-Agency Task Group. That task group, the science policy Agencies that were represented on that, created a road map that characterized our current system of measuring the science and engineering enterprise as inadequate. We can do better. There is enormous potential to do better. The first step to doing better is to get better data. Just as good bricks need straw, good research in an empirical field like science and innovation policy requires good data. So to that end, the SciSIP Program and the Science of Science Policy Inter-Agency Group initiated the development of the STAR METRICS program to which you have already alluded. The benefits of this program is that rather than having organized data sets that different agencies and different institutions use to answer the types of questions that the American people are asking, we can develop a common, bottom-up, empirical infrastructure that will be available to all recipients of federal funding and to science agencies to quickly respond to state, congressional, and OMB requests. It is critical that we take a bottom-up effort in order to develop these approaches—one that is domain specific, generalized, and replicable.

Phase one started in March, jointly sponsored by NIH, the lead agency, NSF, and OSTP. And that is collecting the data required to, with no burden, respond to questions about the jobs associated with science funding. Phase two, which is trying to collect broader data on a wide range of outcomes--not just jobs, but social, scientific, economic, and work force outcomes—is beginning this fall with formal consultations with research institutions.

Furthermore, science is fundamentally an international endeavor. We have engaged with the European Union, with the Japanese, with the Brazilians, with many countries in order to document the impact of science investments. In fact, the Japanese Government has recently set aside funding for a Japanese equivalent of a SciSIP program. The European Union has also shown considerable interest in what we have been up to, and is considering emulating the bottom-up, no burden endeavor that the SciSIP, the Science of Science Policy, and the STAR METRICS Program have pushed forward. And the Brazilian Government has also requested briefings on the SciSIP, Science of Science Policy, and STAR METRICS Program.

This concludes my testimony, Mr. Chairman. I look forward to answering any questions you or the Members of the Committee might have.

[The prepared statement of Dr. Lane follows:]

PREPARED STATEMENT OF JULIA I. LANE

Chairman Lipinski, Ranking Member Ehlers, and Members of the Subcommittee, it is my distinct privilege to be here with you today to discuss NSF's Science of Science and Innovation Policy (SciSIP), the activities of the Science of Science Policy Interagency Group, and the STAR METRICS program—a new federal effort designed to create a scientific quantifiable measurement of the economic and social impacts of federal research spending. I am Dr. Julia Lane, the program Director of the SciSIP program at the National Science Foundation, and co-chair of the NSTC working group on Science of Science Policy (SOCP).

At the outset, I would like to express my appreciation to all the Members on the House Committee on Science and Technology for their unstinting support to advance both the cause, and the frontiers of science. This Committee has long held steadfast in the knowledge that America's present and future strength, prosperity and global preeminence depend directly on fundamental research.

The National Science Foundation has always believed that optimal use of limited Federal funds relies on two conditions: Ensuring that research is aimed—and continuously re-aimed—at the frontiers of understanding; and certifying that every dollar goes to competitive, merit-reviewed, and time-limited awards with clear criteria for success. When these two conditions are met, the nation gets the most intellectual and economic leverage from its research investments.

Yet our portfolio keeps changing. We have a minimal vested interest in maintaining the status quo, and pride ourselves on an ability to shift resources quickly to the most exciting subjects and most ingenious researchers.

Moreover, we regard it as an essential part of our mission to constantly re-think old categories and traditional perspectives. This ability is crucial now, because conventional boundaries are disappearing—boundaries between nations, boundaries between disciplines, boundaries between science and engineering, and boundaries between what is fundamental and what is application. At the border where research meets the unknown, the knowledge structures and techniques of life science, physical science, and information science are merging.

Additionally, our scope is extremely wide, extending across all the traditional mathematics, science and engineering disciplines. That is a major advantage in today's research climate, where advances in one field frequently have immediate and important applications to another. The same mathematics used to describe the physics of turbulent air masses may suddenly explain a phenomenon in ecology or in the stock market, or the changes in brain waves preceding an epileptic seizure. The same algorithms used by astronomers to discern patterns in the distant heavens can aid radiologists to understand a mammogram, or intelligence systems to identify a threat. Only an agency that sees the "big picture" can assure this kind of interdisciplinary synergy.

For all of these reasons, the National Science Foundation is fostering the development of the knowledge, theories, data, tools and human capital needed to cultivate a Science of Science and Innovation Policy program. The program has three major aims: advancing evidence-based science and innovation policy decision making; developing and building a scientific community to study science and innovation policy; and developing new and improved datasets.

The overarching goal in this effort, however, is to conduct basic research that creates new objective models, analytic tools, and datasets to inform our nation's public and private sectors about the processes through which investments in science and engineering research may be transformed into scientific, social and economic outcomes.

We need to better understand the contexts, structures, and processes of scientific and engineering research, to evaluate reliably the tangible and intangible returns from investments in research and development (R&D), and to predict the likely returns from future R&D investments.

It is not only leaders in the scientific and engineering fields, but policymakers as well in the Executive and Legislative Branches who recognize that we need better approaches for developing science policy, which is why the National Science and Technology Council established the Science of Science Policy Interagency Task Group. That task group's roadmap characterized our current systems of measurement of the science and engineering enterprise as inadequate. There is enormous potential to do better.

To begin to create a scientific, quantifiable measurement of the economic and social impacts of our federal research investments, this Administration has initiated an innovative new program, STAR METRICS (Science and Technology in America's Reinvestment—Measuring the EffecTs of Research on Innovation, Competitiveness and Science). This initiative is led by the National Institutes of Health and the National Science Foundation under the auspices of the White House Office of Science and Technology Policy. The goal is to develop a system that can be used to track the impact of federal science investments. I will return to the topic of STAR METRICS later in my testimony.

1) The overall vision and strategy for research and education in the 'Science of Science and Innovation Policy.

Federally funded basic and applied scientific research has had a significant impact on innovation, economic growth and America's social well-being. We know this in the broad sense from numerous economic analyses but it is difficult to disentangle the impact of Federal investment versus private, state and industrial investments. We have little information about the impact of individual projects and programs, whether federally or privately funded. We have little information about the impact of science agencies. Thus, although determining which federally funded research projects yield solid results and which do not is a subject of high national interest, since American taxpayers invest more than $140 billion annually in research and development (R&D), there is little evidence to support such analysis. In short, although Congressional and Executive Branch policy decisions are strongly influenced by past practices or data trends that may be dated, or have limited relevance to today's economic situation. A deeper understanding of the changing framework in which scientific and technical innovation occurs would help policymakers decide how best to make and manage limited public R&D investments to exploit the most promising and important opportunities.

The lack of analytical capacity in science policy is in sharp contrast to other policy fields that focus on workforce, health and education. Debate in these fields is informed by the rich availability of data, high quality analysis of the relative impact of different interventions and computational models that often allow for forward-looking analyses with impressive results. For example, in workforce policy, the evaluation of the impact of distinct education and training programs has been transformed by careful attention to issues such as selection bias and the development of appropriate comparison groups. The analysis of data about geographic differences in health care costs and health care outcomes has featured prominently in guiding health policy debates. And education policy has moved from a "invest more money" and "launch a thousand pilot projects" imperative to a more systematic analysis of programs that actually work and that promote local and national reform efforts.

Each of those efforts, however, has benefited from an understanding of the systems that are being analyzed. In the case of science policy, no such agreement currently exists. NSF's Science of Science & Innovation Policy (SciSIP) program is designed to advance the scientific basis of science and innovation policy.

Vision

The principal goal is to advance the scientific basis of making science policy decisions, particularly those involving budgets, through the development of improved data collection, theoretical frameworks, computational models and new analytic tools.

A major component of the SciSIP program is the funding of investigator initiated research. Through direct engagement of the federal policy community with the research community, it is hoped that future policy decisions can be informed by empirically validated hypotheses and informed judgment. Our aim, as noted in the program's description, is to "engage researchers from all of the social, behavioral and economic sciences as well as those working in domain-specific applications such as chemistry, biology, physics, or nanotechnology in the study of science and innovation policy. The program welcomes proposals for individual or multi-investigator research projects, doctoral dissertation improvement awards, conferences, workshops, symposia, experimental research, data collection and dissemination, computer equipment and other instrumentation, and research experience for undergraduates. The program places a high priority on interdisciplinary research as well as international collaboration."

The program explicitly fosters a multi-level science (in addition to more obviously being an interdisciplinary science) that spans from the study of cognitive phenomena in individual scientists (e.g., the study of fixation, insight, reasoning, and decision making) to the study of whole industries and policies at the industry level. What makes the overall effort a potentially transformative effort is the support of research at multiple levels: industry level policies are only successful if it has individual-level effects (i.e., that engineers and scientists change), and individual-level effects are only important if they scale to produce industry-level differences.

Another focus of the SciSIP program is the redesign of the surveys undertaken by NSF's Science Resources Statistics, the federal statistical agency responsible for collecting and disseminating data on the U.S. science and engineering enterprise. The most visible activity has been the redesign of the Business R&D and Innovation Survey (BRDIS) which collects information from a nationally representative sample of about 40,000 companies, including companies in both manufacturing and non-manufacturing industries. This survey is the primary source of information on business, domestic and global R&D expenditures, and workforce. The new structure enables respondents to provide detailed data on the following:

- How much is a company investing in its domestic and worldwide R&D relationships, including R&D agreements, R&D "outsourcing," and R&D paid for by others?
- What is the strategic purpose of a company's worldwide R&D activities and what are their technology applications?
- What are the details of a company's patenting, licensing, and technology transfer activities, and companies' innovative activities?

In addition, a limited number of questions are asked about activities related to new or improved products or processes. These are intended to serve as basis for collecting an expanded set of innovation metrics in the future. The results of this data collection are now being published as part of SRS's ongoing reporting activity:

Strategy

The focus of the program's strategy has been to convince the academic community that the study of science policy is a worthwhile academic endeavor. This has taken three main forms. The first has been to engage in a substantial amount of outreach through presenting at professional workshops and conferences (an average of five or six a year), through supporting specific workshops on various science policy topics (two or three a year), through establishing a very active listserv (which has grown to over 720 members in less than two years) and through supporting a Science of Science Policy website (*http://scienceofsciencepolicy.net*).

The second part of the strategy has been to invest in high quality research datasets. Good bricks need straw, and good research in an empirical field like science and innovation policy requires good data. Fields as disparate as biotechnology, geosciences, and astronomy have been transformed by both data and knowledge access. NSF hopes to similarly transform the study of science policy by improving science data. Such a transformation will occur in three ways. First, the scientific challenge is compelling: the way in which scientists create, disseminate and adopt knowledge in cyberspace is changing in new and exciting ways. Collaborations between computer scientists and social scientists, fostered by SciSIP, can capture these activities using new cybertools. Second, new and exciting data attract new researchers to the field. This in turn attracts new graduate students, who see new ground being broken and exciting opportunities for research. Finally, we aim to actively engage the federal science policy community through a variety of workshops, as well as direct engagement through the Science of Science Policy Interagency Group.

The program has made a total of 99 awards: 19 in 2007, 23 in 2008, 31 in 2009, and 26 in 2010. The program began to accept doctoral dissertation proposals in 2010; five of those were funded. The success rate for standard proposals is currently about 25%; higher for doctoral dissertation proposals. A total of 182 principal investigators have been supported—of those 147 are scientists from Social, Behavioral and Economic Science domains and the balance are from areas as diverse as Computer and Information Sciences, Education, Physics, Biology and Law.

Results

The program is beginning to achieve some of its ambitious goals. A SciSIP Principal Investigator (PI), who is a Business School Dean at a university with a strong focus on publicly-funded research, has noted "I know full well that this new program provides unique grant opportunities for faculty members in management, information systems, and other fields of business administration. He cites the following from his personal experience " . . . in the field of business research, and business management, the Science of Science & Innovation Policy papers are featured in some of the best sessions at the Academy of Management Meetings. This innovative program has sparked considerable interest in public policy among management scholars, and particularly in business schools. The impact of the research you are funding struck home when I read the latest issue of BizEd, the magazine of The Association to Advance Collegiate Schools of Business (AACSB, an association of educational institutions, businesses, and other organizations devoted to the advancement of higher education in management education. It is also the premier accrediting agency of collegiate business schools and accounting programs worldwide. The research you have funded was prominently featured in their magazine, which is circulated to thousands of business schools worldwide."

Additionally, the impact of the SciSIP program has influenced several National Research Council studies, and thus impacted public policy with respect to technology commercialization and academic and public sector entrepreneurship. One is the Congressionally-mandated evaluation of the Small Business Innovation Research Program. Another is a committee entitled "Best Practices in National Innovation Programs for Flexible Electronics" and a third is "Management of University Intellectual Property: Lessons from a Generation of Experience, Research, and Dialogue"

In another example, a major part of the science and innovation policy debate has been the role of R&D and research tax credits whose budgetary cost is about $15 billion each year [1]. The obvious policy question is how effective are these tax credits in stimulating innovation? SciSIP funded PIs have examined changes in R&D tax credit generosity across countries and US states over time to evaluate business firms' response. They estimate that for every $1 of tax credits firms spend about $1 more on R&D. However, the research also extends to the impact of firms' re-

[1] *http://www.ncseonline.org/NLE/CRSreports/08Aug/RL31181.pdf*, CRS–3

sponse to the uncertainty about the duration of the federal Research and Experimentation (R&E) tax credit, which is not currently permanent and in fact expired at the end of 2009. The uncertainty about renewal has offsetting effects—one is to increase short-term expenditures because firms think they need to do R&D now to get the credit. The reverse is to reduce overall R&D expenditures since uncertainty is detrimental to the expected payoffs from long-term investments such as fundamental R&D. The sign of the net effect is an empirical question, and again something the SciSIP PI has been working on—he finds a strong negative effect of uncertainty on general investment and employment, and is currently extending this work to R&D. The same PI presented in September 2009 to the Federal Reserve Bank Board of Governors, including Governor Bernanke; the Fed was trying to understand why the IT "productivity miracle", which was a major driver of US economic growth in the late 1990s, has slowed down by the late 2000s. One possible reason is that better use of IT is associated with organizational change, and the rate of organizational change has potentially slowed down; a major SciSIP-funded grant supports collecting a large national survey to try to examine why and how that change has occurred.

We can also learn from history. Another SciSIP PI has looked at two case studies in depth: the invention of the airplane and Edison's invention of the electric light. In both cases, the invention took a long period of time—110 years and 80 years, respectively. In both cases even the earliest attempts were based on many years [of work on mathematics and technology and hundreds of years of work of science. To illustrate, Sir Humphry Davy first demonstrated incandescence of materials in 1808. His work drew on the Voltaic pile (battery) invented in 1800, the Leyden jar developed in 1744, and carbon produced as charcoal during the Roman Empire no later than 25 A.D. Leyden jars depended on work by the ancient Greeks in 600 B.C. Thus, the foundation of the science behind electric light dates back 2400 years before incandescence, after which it took 80 more years of R&D to develop an effective electric light. The airplane also has a similarly long foundational period and duration of invention. In looking at various inventions, research has shown that there are several different weak methods but also some powerful strategies that vastly speed things along. Edison succeeded simply because he had enormous resources (the Edison Electric Light Company was capitalized at $300,000—about $30 million today. The Wright Brothers were far more efficient at developing the airplane than Edison was in developing the electric light.

How is the NSF fostering collaboration between social and behavioral scientists and researchers from other disciplines, including computer scientists, engineers and physical scientists in science and technology policy research?

This is being done in a number of ways: through the program call, through workshops, and through successful and visible interdisciplinary projects.

Program Description

The SciSIP program explicitly encourages interdisciplinary cooperation in the program description. In particular, the program states

> "The SciSIP program invites the participation of researchers from all of the social, behavioral and economic sciences as well as those working in domain-specific applications such as chemistry, biology, physics, or nanotechnology. The program welcomes proposals for individual or multi-investigator research projects, doctoral dissertation improvement awards, conferences, workshops, symposia, experimental research, data collection and dissemination, computer equipment and other instrumentation, and research experience for undergraduates. The program places a high priority on interdisciplinary research as well as international collaboration."

Workshops

Most of the workshops that have been hosted have been explicitly interdisciplinary in nature, bringing together domain scientists and social, behavioral and economic scientists, and have resulted in calls for proposals (called Dear Colleague Letters) supported by multiple NSF programs.

Examples include:

- A two-day workshop to advance the scientific study of federally funded centers and institutes as key elements in the innovation ecosystem. The workshop brought together engineers and natural, physical, and social scientists to address central questions relating to the role of NSF-funded centers and institutes in science and innovation policy.

- Two separate workshops studying innovation in organizations. One of these, hosted by the Conference Board and supported by four Social, Behavioral and Economic (SBE) Sciences and three Computer and Information Science and Engineering (CISE) programs, was attended by computer scientists, SBE scientists and representatives from the business community to examine the potential for cyber data to better inform our understanding of innovation. A second conference brought together 20 leading computer scientists (from the fields of data management, data mining, security/privacy, social networks) and social/organizational scientists (that included economists, sociologists, psychologists, anthropologists) to identify emerging major challenges in the collection and use of confidential data collection for the study of innovation in organizations. SciSIP led the reusulting development of a Dear Colleague Letter whose purposes was to gather and create new Cyber-enabled data on innovation in organizations, supported by six SBE and four CISE programs as well as the Office of Cyber Infrastructure.
- A workshop in conjunction with the NSF's Chemistry Division that examined the impact of science R&D in the United States, focusing on chemical sciences and related industries. This led to a Dear Colleague Letter from SciSIP and the Chemistry Division reaching out to the chemistry and the social science communities advising them of funding opportunities related to assessing and enhancing the impact of R&D in the chemical sciences in the United States.
- An interdisciplinary workshop which examined the potential for new visualization tools to track the impact of investments in science. These possibilities include tracing the impact of basic research on innovation, examining the changing structure of scientific disciplines, studying the role of social networks in the dispersion of scientific innovations as well as making comparisons of how the U.S. compares internationally in science. That workshop brought together researchers from a broad range of disciplines to examine such key questions, and to engage the federal science community in a discussion about whether and how the tools could be used in the federal context.
- Three workshops have directly engaged CISE and SBE researchers in enhancing NSF's ability to describe its research portfolio. The SciSIP program worked with the CISE directorate to form an Advisory subcommittee to provide advice on approaches to improving the way NSF interacts with its proposal and award portfolio. Although NSF staff still rely on traditional methods to do their jobs, such methods are becoming less practical given the rapidly changing nature of science, the increased recognition of the importance of funding interdisciplinary and potentially transformative research, and the significant increase in the number of proposals submitted. Individuals with research expertise in machine learning, data mining, information visualization, human-centered computing, science policy, and visual analytics were recruited for this effort. Nine teams were put together and charged with providing advice to NSF on identifying and demonstrating techniques and tools that characterize a specific set of proposal and award portfolios. Their report, in turn, will advise NSF on how to better structure existing data, improve use of existing machine learning, analysis, and visualization techniques to complement human expertise and better characterize its programmatic data. The results should help NSF identify tools that will help fulfill its mission including identifying broader impacts, as well as funding transformative and interdisciplinary research. NSF has also engaged program managers across the federal government so that our collective approaches can inform not only us, but other science agencies.
- A workshop responding to Congressman Holt's request for better ways to measure the economic impact of federal research investments. SciSIP, together with NIH and other agencies, is supporting the National Academy of Sciences' Board on Science, Technology, and Economic Policy (STEP) and Committee on Science, Engineering, and Public Policy (COSEPUP) 2011 workshop on science measurement. This workshop is aimed at discussing new methodologies and metrics that can be developed and utilized for assessing returns on research across a wide range of fields (biomedical, information technology, energy, and other biological and physical sciences, etc.), while using background papers that review the methodologies used to date as a starting point.

As one SciSIP PI has noted, "SciSIP.. creates a domain around which researchers from a variety of disciplines—biology and physics and economics as well as information science and public policy—can coalesce to pursue research topics in this domain for their own sake, rather than in the interstices of other projects in their home disciplines. As such, it acts as an attractor for top researchers across the natural and social sciences, allowing them to pursue their interests in SciSP topics"

Successful Examples

There are a number of examples of the fruits of these activities. For example, SciSIP funded research supports a University of Michigan research team consisting of a sociologist, a bioethicist specializing in informed consent and stem cell regulation, a bioethicist trained as a molecular biologist who is working on cell banking, and a post-doc in stem cell biology. The combination is a powerful one as it matches expertise with social scientific data and analysis methods, with deep knowledge about both the policy and the science.

Similarly, the interdisciplinary work of two SciSIP Pis has helped developed new metrics of the transmission of knowledge. These metrics go beyond citation metrics to usage metrics and help us better understand the impact that federal investment in research is having on research results. By mapping the structure of science and looking at how this structure changes over time, we can see the shifting landscape of scientific collaboration and understand the new emerging disciplines. That will enable us to to anticipate these changes and properly target research funding to new and vibrant areas. For instance, their work provides a striking example of the emergence of neuroscience over the past decade—changing from an interdisciplinary specialty to a large and influential stand alone discipline on a par with physics, chemistry, or molecular biology.

How is NSF fostering the development of science and technology policy degree programs and courses of study at colleges and universities? What is the current scope and level of support for such programs?

As with many NSF programs, the SciSIP program explicitly encourages submissions that support graduate student development. While there is no direct targeting of funds to policy programs, SciSIP supported 28 researchers from science and technology policy programs. In an example of the type of support that has been provided to expand the course of study, over 250 undergraduate students from Economics (behavioral economics), Cognitive Science, Electrical and Computer Engineering, and Industrial Engineering have participated in a project at Purdue University, which is an interdisciplinary collaboration linking social scientists and computer scientists and engineers.

A further example is the work done by Marcus Ynalvez at Texas A&M International University, which has the explicit goal of mentoring TAMIU Graduate Students (Students from Historically Underrepresented Populations): The hands-on training and mentoring of TAMIU graduate students represents an attempt to engage Hispanic students in international scientific research activities with the intention of introducing them to the possibilities of developing professional careers in science and technology. These students are currently gathering, synthesizing and reviewing literature materials for the project's manuscripts, publications, and reports. With the data from the Japan, Singapore, and Taiwan surveys, these students will be analyzing data using a number of statistical software such as: Statistical Packages for the Social Sciences (SPSS), STATA, and Statistical Analysis System (SAS). They will learn how to interpret statistical results associated with the family of generalized linear regression models, namely: linear, logistic, and negative binomial regression models, analysis of variance, and path analysis. Not only have the TAMIU graduates gained actual research experience, they have also developed professional relationships with students and professors from the prestigious National University of Singapore

How is NSF encouraging a community of practice in science of science policy and the dissemination of policy to policy makers

A major avenue has been the linkage with the Science of Science Policy Interagency group, which is discussed in more detail below. In addition, the listserv and the website have been very important dissemination vehicles.

However, the most important vehicle has been two PI workshops with the explicit goal of fostering further collaboration among the PIs actively engaged in the study of Science of Science & Innovation Policy and the link to the federal community. The 2009 workshop had three overarching goals:

- to provide NSF with an early opportunity to organize a collegial discussion of work in progress under SciSIP's two rounds of awards well before this work will begin to appear in professional forums and publications;
- to begin to develop from among the purposefully diverse set of disciplinary perspectives reflected in SciSIP's two solicitations and subsequent awards, a "community of experts across academic institutions and disciplines focused on SciSIP;" and
- To identify new areas of emphasis for support in future SciSIP solicitations.

The 2010 workshop, scheduled for October 19, 2010 seeks to focus on two objectives that flow from the National Science and Technology Council's 2008 report: *The Science of Science Policy: A Federal Research Roadmap*. The first task, as called for in the Roadmap report, is "to advance the scientific basis of science policy so that limited Federal resources are invested wisely." The second is to build a "community of practice" between Federal science and technology policymakers and researchers engaged in the development of new theories, tools of analysis, and methods for collecting and analyzing data.

This October 2010 workshop will consist of brief presentations by a number of SciSIP grantees who have been invited to participate via a competitive peer review of abstracts previously submitted based on their ongoing research. These presentations will be followed by roundtable discussions led by federal policymakers who will comment on the relevance of the research, followed then by open discussions among all participants. A networking session will be scheduled at the close of the formal sessions to allow for continued discussion.

2) As a Co-chair of the Science of Science Policy Interagency Group under the NSTC please briefly describe the work of that group and how the various federal science agencies are collaborating on the development and implementation of science of science policy tools to improve the management and efficiency of their R&D portfolios and other science and technology related programs.

In 2006, the National Science and Technology Committee's Subcommittee on Social, Behavioral and Economic Sciences (SBE) established an Interagency Task Group on Science of Science Policy (ITG) to serve as part of the internal deliberative process of the Subcommittee. In 2008, this group developed and published *The Science of Science Policy: A Federal Research Roadmap* which outlined the Federal efforts necessary for the long-term development of a science of science policy, and presented this Roadmap to the SoSP Community in a workshop held in December 2008. The ITG's subsequent work has been guided by the questions outlined in the Roadmap and the action steps developed at the workshop.

The development of the STAR METRICS (Science and Technology for America's Reinvestment: Measuring the EffecT of Research on Innovation, Competitiveness and Science) program is the number one priority of the interagency group. The initiative is a multi-agency venture led by the National Institutes of Health, the National Science Foundation (NSF), and the White House Office of Science and Technology Policy (OSTP).

Another major activity is sponsoring a series of workshops to bring the science agencies together to share what is already established in the field, identify gap areas and outline steps forward for the creation of better tools, methods, and data infrastructure.

The first of these workshops was held in October, 2009 to delve into the issues surrounding performance management of federal research and development portfolios. The focus was on sharing current practices in federal R&D prioritization, management, and evaluation. Over 200 agency representatives attended. The conference featured 27 speakers and panelists, representing 20 federal agencies, offices, and institutions, and over 30 poster presenters, representing more than 25 agencies and institutions. Topics that were discussed included:

- Methods to set federal research priorities and strategic directions;
- The use of metrics to improve federal R&D efficiency; and
- Ways in which research evaluations can inform current and future R&D decisions.

It addressed the following key questions:

- How do federal science and technology agencies systematically identify and prioritize research and development alternatives? How can these processes be strengthened?

- How can research-performance metrics be used to improve research efficiency? How can these metrics be improved?
- How do research-performance evaluations inform and improve R&D investment decisions? How can these feedback loops be reinforced?

While the 2009 workshop developed a dialogue within the federal science policy community, the ITG has a workshop planned for December 2010 that engages the federal community with the academic community in advancing the "Science of Science Measurement". The first goal is to create a dialogue between the Federal S&T agencies and the research community about relevant models, tools, and data that advance scientific measurement in key areas of national S&T interest. The second objective is to identify a joint Science of Science Policy (SoSP) research agenda for the Federal S&T agencies and the research community. The workshop has four modules intended to advance measurement in: 1) Economic benefits; 2) Social, health and environmental benefits; 3) S&T workforce development; and 4) Technology development and deployment. Four academic researchers will be presenting in each module, with a rapporteur synthesizing the presentation at the end of each module.

The audience will be primarily science policy practitioners from the Federal agencies who are interested in very practical issues, such as: getting new ideas about how to manage their portfolios in a more scientific manner; developing performance and outcomes metrics; measuring the return on investment; and using science to identify emerging trends in the U.S. scientific enterprise.

Another activity has been the establishment of a website to provide information on best practices to Federal and non-Federal agencies. The website (*http://scienceofsciencepolicy.net*) was launched in January 2010, and has become a model for other interagency groups (including the Forensic Science interagency group). The web site serves as a repository for data, documents, research papers, and communication tools for the communities of users. , The site receives over 2,000 hits a month. The associated Listserv is the highest visibility listserv in science policy, and has over 720 members.

The interagency group meets monthly, and has active participation by over 15 agencies. It is actively providing input to the Center of Excellence on Science Policy being established by the State Department in the Middle East.

3) Please provide a brief description and update on the status of the OSTP led project on science metrics, known as STAR METRICS, including a description of international engagement and interest in this effort

The STAR METRICS project is a federal and university partnership to document the outcomes of science investments to the public. The benefits of STAR METRICS are that a common empirical infrastructure will be available to all recipients of federal funding and science agencies to quickly respond to State, Congressional and OMB requests. It is critical that this effort takes a bottom up approach that is domain specific, generalizable and replicable.

Currently, the project is structured in two phases:

- Phase I: The development of uniform, auditable and standardized measures of the initial impact of ARRA and base budget science spending on job creation.
- Phase II: The development of broader measures of the impact of federal science investment, grouped in four broad categories:
  - Scientific knowledge (such as publications and citations) and, later,
  - Social outcomes (such as health and environment),
  - Economic growth (through patents, firm start ups and other measures),
  - Workforce outcomes (through student mobility and employment),

Phase I of the STAR METRICS project began in earnest in March of 2010 with funds formally designated for the project. The participation agreement was signed in May 2010, and a press release was issued by the three lead agencies: NIH, NSF and OSTP[2]. As noted in that press release:

> "A new initiative promises to monitor the impact of federal science investments on employment, knowledge generation, and health outcomes. The initiative—Science and Technology for America's Reinvestment: Measuring the EffecT of

[2] *http://www.whitehouse.gov/sites/default/files/microsites/ostp/STAR%20METRICS%20FINAL.pdf*

> Research on Innovation, Competitiveness and Science, or STAR METRICS—is a multi-agency venture led by the National Institutes of Health, the National Science Foundation (NSF), and the White House Office of Science and Technology Policy (OSTP)."

In Phase I, through a highly automated process, with essentially no burden on scientists and minimal burden for administrators, STAR METRICS collects longitudinal employment data from the participating institutions to be able to assess the number of jobs created or retained (or lost) through federal funding support. The system is set up such that all jobs will be captured and not just principal investigators and co-principal investigator. In addition, in Phase I, STAR METRICS can provide estimates of jobs supported through facilities and administration (F&A) costs and through various procurement activities in the institutions.

STAR METRICS will also help the Federal government document the value of its investments in research and development, to a degree not previously possible. Together, NSF and NIH have agreed to provide $1 million in funding a year for the next five years.

More agencies are joining the STAR METRICS consortium. While meetings of the Consortium are convened by OSTP, the lead agency is NIH, which is hosting the data infrastructure. The official STAR METRICS website will be available September 30 2010. NSF is providing key leadership in engaging the scientific community, particularly through the SciSIP program.

Phase II of the project expands the data infrastructure to incorporate the broader impact of science investments on scientific, social, economic and workforce outcomes. In keeping with the bottom up approach of the program, STAR METRICS is beginning a formal set of consultations with the scientific community to understand what data elements and what metrics the community would find useful to find in STAR METRICS. The first of these will occur October 22, 2010, with a meeting with Vice Presidents for Research of interested institutions. Other meetings will follow with research agencies and other interested groups.

In a very short period of time since formalizing the project, over 100 research-intensive universities, mostly from the Federal Demonstration Partnership (FDP), have expressed interest in participating in STAR METRICS; about 20 are contributing data. Universities have expressed enthusiasm and support for the project.

Science is fundamentally an international endeavor. And so must be its evaluation. In fact, there has been substantial international interest. Members of the STAR METRICS team have provided information or directly briefed Brazilian and Japanese science and technology agencies. The State Department is actively interested in learning about the program to advance the science of science policy in the Middle East.

Our most active international counterpart, however, is the European Union. A major presentation was given to the European Parliament in April[3]. A joint EU/US conference has been proposed for March 2011 in the Rockefeller Foundation's Bellagio Center. The goal is to produce a roadmap that will outline a path for creating a US/European collaboration in developing a common theoretical and empirical infrastructure to describe and assess the outcomes of science investments. To achieve this, it will bring together key European and US science policy experts and makers, administrators and academic researchers. The group is carefully chosen to consist of the key players from the US side who have the experience in developing such an infrastructure in the US. The European attendees will consist of individuals who have both the deep understanding of the issues and the ability to effect change in Europe in a collaborative framework with the US.

The outcomes will include a roadmap that represents a combined effort to build on and extend existing efforts in both regions: notably the US investment in the STAR METRICS program and the European efforts to build better assessments for their investments. It is hoped that the roadmap will have the same success that the Science of Science Policy Interagency Roadmap had in the United States and that in the EU the road map will be the basis for including assessment measures in future legislation implementing science programs.

Conclusion

The NSF's Science of Science and Innovation Policy program, the NSTC's Interagency SOSP ITG, along with STAR METRICS, represent the first efforts to construct a scientific framework that is supported by multiple agencies and multiple institutions—all jointly engaged. It represents a true bottom up approach to pro-

[3] *http://www.euractiv.com/en/science/eu-looks-to-us-model-for-measuring-rd-impact-news-448950*

viding an evidence basis for U.S. science policy. Its success is important for decisionmakers: in a nutshell, you can't manage what you can't measure and what you measure is what you get.

NSF's innovative Science of Science and Innovation Policy program, and STAR METRICS, can help all of us do a better job in explaining this essential symbiosis.

This concludes my testimony, Mr. Chairman. I look forward to answering any questions you or Members may have.

BIOGRAPHY FOR JULIA I. LANE

Dr. Julia I. Lane is the Program Director of the Science of Science & Innovation Policy program at the National Science Foundation. Her previous jobs included Senior Vice President and Director, Economics Department at NORC/University of Chicago, Director of the Employment Dynamics Program at the Urban Institute, Senior Research Fellow at the U.S. Census Bureau and Assistant, Associate and Full Professor at American University.

Julia has published over 60 articles in leading economics journals, and authored or edited six books. She became an American Statistical Association Fellow in 2009. She has been the recipient of over $20 million in grants; from foundations such as the National Science Foundation, the Sloan Foundation, the MacArthur Foundation, the Russell Sage Foundation, the Spencer Foundation, the National Institute of Health; from government agencies such as the Departments of Commerce, Labor, and Health and Human Services in the U.S., the ESRC in the U.K., and the Department of Labour and Statistics New Zealand in New Zealand, as well as from international organizations such as the World Bank.

She has organized over 30 national and international conferences, received several national awards, given keynote speeches all over the world, and serves on a number of national and international advisory boards. She is one of the founders of the LEHD program at the Census Bureau, which is the first large scale linked employer-employee dataset in the United States. A native of England who grew up in New Zealand, Julia has worked in a variety of countries, including Australia, Germany, Malaysia, Madagascar, Mexico, Morocco, Namibia, Sweden, and Tunisia.

Her undergraduate degree was in Economics with a minor in Japanese from Massey University in New Zealand; her M.A. in Statistics and Ph.D. in Economics are from the University of Missouri in Columbia. She is fluent in Swedish and German and speaks conversational French.

Chairman LIPINSKI. Thank you, Dr. Lane. Dr. Sarewitz.

STATEMENT OF DANIEL SAREWITZ, CO-DIRECTOR OF THE CONSORTIUM FOR SCIENCE, POLICY & OUTCOMES AND PROFESSOR OF SCIENCE AND SOCIETY, ARIZONA STATE UNIVERSITY

Dr. SAREWITZ. Thank you, Chairman Lipinski and Ranking Member Ehlers. I very much appreciate the invitation and the opportunity to testify. So, my name is Daniel Sarewitz. I am a Professor of Science and Society at Arizona State University where I Co-Direct the Consortium for Science Policy and Outcomes, which works to understand and improve the linkages between science and technology and social outcomes. We are located on ASU's Tempe campus. We also have a location here in DC. We are a highly interdisciplinary and collaborative organization involving researchers at dozens of other institutions. We are also fortunate to receive generous grant funding from NSF, including from the Science of Science and Innovation Policy Program, so I declare my vested interest in the outcomes of this hearing.

I would like to make three brief points in support of my over-extensive written testimony. The first is about the importance of the SciSIP Program itself. With shrinking discretionary budgets, vibrant economic competitors, and daunting challenges to our wellbeing, the Nation needs effective tools for making better decisions about how to design, assess, and set priorities for our science and innovation enterprise. For the most part, we lack these tools, as we have already heard. As former Presidential Science Advisor Jack Marburger said in 2005, "the nascent field of social Science of Science Policy needs to grow up, and quickly."

With modest resources, SciSIP is mobilizing a community of researchers to focus on the complex problem of how to bring the most out of our public investment in R&D. SciSIP reacted quickly to support research assessing the impacts of stimulus funding for R&D, and is beginning with NIH to take on the incredibly complex problem of evaluating what the nation gets for its enormous investment in bio-medical R&D. These are really difficult challenges and it is hard to see how this committee and others at the helm of the R&D enterprise can guide it effectively in the absence of such efforts.

A second point is that outputs are not outcomes. And SciSIP needs to focus on outcomes. Outputs are immediate products of R&D like publications, and patents, and Ph.D's. Outcomes are what people care about, not just economic growth, but of course economic growth, but also secure and affordable food supplies and energy supplies, high quality public health, a clean environment, expanding job opportunities and strong national defense. The 40-year war on cancer has yielded the output of remarkable new scientific knowledge yet very modest gains in public health outcomes despite the tens of billions spent. Thirty years of energy R&D output have done little to advance the outcome of reducing our vulnerability to energy-based threats to security, economy, and environment. Research on science and innovation policy to date has given us a pretty good idea how to design and assess science policies to advance outputs. But we still have a lot to learn about how to implement and assess successful outcome-based science and innovation policies.

My final point is that research on outcome-based science and innovation policies and the use of such research by decision makers are not separate problems. While the SciSIP Program is commendably serious about disseminating its research and its results to policy makers, the dissemination problem is also structural. That is it is built into the way we organize much research including SciSIP, and its great strength in supporting bottom-up inquiry on fundamental problems is also a weakness when there is an urgent need for new knowledge, the need that Dr. Marburger pointed out. Such cases require close ties between those who do research and decision makers who might use research results. We already heard from Julia Lane about her efforts to create those ties. Now on the one hand, these ties allow researchers to understand the needs of decision makers and to recognize the types of information that will be both usable and used. But at the same time, close ties allow decision makers to understand what research can and cannot do for them. Such mutual understanding breeds trust and value, and usable science.

There are many examples of federal programs that link research performance and research use, including USDA's Agricultural Extension Service, the USGS Earthquake Hazards Program, and NOAA's Regional Integrated Sciences and Assessments Program. Similarly, DARPA is justifiably well regarded for its capacity to connect the technology needs of DOD to research groups in academia and the private sector. These and other examples are discussed in the handbook "Usable Science", which I just happened to have brought along with me, which summarizes the results of CSPO's [Consortium for Science, Policy & Outcomes] five year NSF Decision Making Under Uncertainty project, carried out jointly with researchers of the University of Colorado.

These lessons can be applied to SciSIP. Let me mention three possibilities. First, NSF could sponsor one or more large centers for SciSIP research, education, and outreach with a core requirement to build strong, ongoing collaborative links between researchers and science policy decision makers. Second, NSF could work with mission-oriented R&D agencies to integrate SciSIP activities into a range of existing outcome-oriented programs. Third, NSF could require all of its center-scale awardees, such as Science and Technology Centers and Engineering Research Centers, to be designed from the outset to include integrated SciSIP components.

Through these sorts of approaches, SciSIP could enhance its capacity to produce usable knowledge for the near to medium term and help accelerate a convergence between science and innovation policy research and policy decisions across a range of R&D outcome priorities. Thank you for your attention. I look forward to discussing these issues more.

[The prepared statement of Dr. Sarewitz follows:]

PREPARED STATEMENT OF DANIEL SAREWITZ

Mr. Chairman, Members of the Committee, thank you for inviting me to testify today. My name is Daniel Sarewitz, and I am co-founder and co-director of the Consortium for Science, Policy, and Outcomes at Arizona State University, as well as Professor of Science and Society at ASU. My formal training was in geosciences, but for more than 20 years I have worked in science and technology policy, first as a AAAS Congressional Science Fellow and then a staffer on this Committee, working for Chairman George E. Brown, Jr., and more recently as an academic, at Columbia University and now at ASU. So I'm very pleased to return to the place that launched me on a new and incredibly interesting and exciting career path and intellectual journey, and honored that you have asked for my input to the Committee's deliberations on the status of the science of science and innovation policy.

Introduction: Input-Output Science and Innovation Policy

Most people agree that government support of research and development is an essential foundation of today's complex, knowledge-based, high technology society. Yet the problem of how to make the most out of the nation's investment in R&D remains amazingly poorly understood. This problem has been actively debated in Congress since World War II. In the interim the annual public investment in R&D has grown from a few tens of millions of dollars to about 140 billion dollars. Yet, throughout this period of remarkable growth—and, I should say, remarkable bipartisan support for such growth, exemplified by this Committee—the basic principles, terms of debate, and policy tools for guiding investment and measuring its effects have changed remarkably little.

For more than sixty years, the core of science policy has been the belief that more money for R&D translates into more benefits for the nation. Science policy has, above all else, been science budget policy. The capacity of the nation to solve problems related to science and technology has been measured by the incremental growth of the R&D budget. The idea that the size of the R&D budget is a measure of the social value of science and technology remains the bedrock of science policy.

Three other powerful beliefs have dominated science policy decision making. The first is that research becomes valuable for society as part of a linear progression starting with basic discovery and leading to application, either in the form of technological innovation, or information to inform decision making. The second, related belief is that there is a clear distinction between research activities aimed at creating new knowledge, and research aimed at applying that knowledge to solving problems. The third belief is that scientific excellence, as defined and assessed by scientists themselves, typically through the peer review process, is the best measure of the potential value of science for society.

The result of these beliefs has been a national R&D enterprise that is largely understood and discussed in terms of simple inputs—how much money is being spent on which type of science?—and simple outputs—how much scientific knowledge is being produced? That this simple input-output way of understanding science and technology policy led to the world's largest and most productive R&D enterprise is, however, much more of a happy historical accident than an endorsement of this way of looking at R&D policy.

Coming out of World War II, the U.S. simply had no serious scientific or economic competitors, so we had a huge head start that only began to be seriously eroded in the 1980s. Moreover, the U.S. R&D enterprise as a whole was—and still is—so much bigger than that of any other nation that simply as a function of scale it could—and still does—outperform everyone else. An additional crucial point is that by far the dominant player in translating the public R&D investment into tangible societal outcomes was the Department of Defense. The core of DOD's approach was the cultivation of very powerful linkages between high-tech private sector firms, research universities, and the DoD itself, an arrangement that was responsible for creating most of the important technological systems that undergird our society and our economy today.

I present this thumbnail sketch to explain how we have arrived at the situation in which we find ourselves today. The limits of the post-War input-output approach, as I have said, became increasingly clear starting in the 1980s, with the rise of serious economic and technological competitors, especially in east Asia; with the end of the Cold War, and the decline of DoD's catalytic role in civilian technological innovation; and with the increasing awareness of an array of social challenges that seemed to demand scientific and technological solutions—from cancer and emerging infectious diseases to energy security and environmental quality. Yet if one looks at the endless series of reports over the past decades sounding the alarm bells about the nation's science and technology enterprise, one finds the problem still discussed predominantly in terms of the same old input-output measures: how much are we spending, how many scientists are we producing, how many publications or patents are issued, and how do these input-output numbers compare to our economic competitors?

The problem with the input-output model is that it can't tell us very much about what actually matters: how the size, organization, and productivity of the R&D enterprise itself relates to the achievement of the societal outcomes that we desire and expect. Because pretty much everyone assumed that these outcomes flowed automatically from the R&D enterprise, as long as it was big and scientifically productive, there seemed to be no reason to worry about how the enterprise worked. These assumptions put a damper on research, as well as debate, about the complex relations between scientific advance, technological innovation, and the well-being of society. Why try to understand these issues if the only thing that really mattered was the size of the budget?

But in an era of constrained resources and mounting challenges to our well-being, the limits of the input-output approach have become impossible to ignore. We cannot ignore them because we need to make difficult choices about how to allocate scarce resources. We also cannot ignore them because we are faced with strong prima fascia evidence that the input-output approach is leading to significant science and innovation policy failures. For example, the National Institutes of Health's forty year War on Cancer has yielded remarkable new scientific knowledge, yet remarkably modest public health benefits for the tens of billions spent. The devastation of New Orleans by Hurricane Katrina occurred despite the existence of comprehensive scientific knowledge about the inevitability and precise consequences of such an event. Thirty years of energy R&D has left the nation no less vulnerable to energy-based security, economic, and environmental threats than it was when the Department of Energy was created. These are not input-output problems, but they are science and innovation policy problems.

In 1992, this Committee issued a brief "Chairman's Report" entitled the "Report of the Task Force on the Health of Research," which pointed at the need to re-think basic assumptions about science and innovation policy. (As a Committee staffer at the time, I was privileged to be one of the members of that Task Force.) While there certainly were, at that time, small pockets of academic scholarship on the links between science policy and societal outcomes, and while some federal S&T programs had of course had great success in achieving the outcomes that the public expected from them, the fact is that there existed in the United States at the end of the 20th century an extraordinarily modest capacity to develop knowledge, tools, and human resources that would allow the nation to improve its capacity to turn progress in S&T into progress toward desired societal outcomes.

A turning point in achieving high level attention and action came in 2005, when President Bush's science advisor, John Marburger, speaking at the Science and Technology Policy Colloquium of the American Association for the Advancement of Science, declared that "The nascent field of the social science of science policy needs to grow up, and quickly." His point was that the nation could no longer afford to set policy for one of it's most important areas of public investment on the basis of simplistic ideas that had arisen in a very different world, half-a-century ago. The National Science Foundation responded to the urgency of Dr. Marburger's call by creating the Science of Science and Innovation Policy (SciSIP) program.

Committee Question 1. (A) Please provide an overview of the research activities of the Consortium for Science, Policy, and Outcomes. (B) How are you facilitating interdisciplinary collaborations within the Consortium? (C) What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? (D) What are the most promising research opportunities and what are the biggest research gaps?

Background to CSPO:

The Consortium for Science, Policy, and Outcomes (CSPO) was conceived in 1997 during discussions between myself and Michael M. Crow, who was then Executive Vice Provost at Columbia University, and formally launched in 1999. The decision to create CSPO was made for much the same reasons that SciSIP was created: despite the overwhelming importance of science and technology in our society, policy makers and scholars almost completely lacked the knowledge and tools necessary to make informed and effective decisions. CSPO was founded as one small effort to begin to reverse this lack of capacity.

When Michael Crow became President of Arizona State University he asked me to move to ASU as well, and gave me the opportunity to help transform CSPO from a small research and policy center to a broader consortium with expanded ambition and reach. Today this consortium operates at three organizational levels: First, there is a core group of fifty or so faculty, researchers, students, and staff who work directly in CSPO, mostly in Arizona but with several of us located here in Washington, DC. Second, there is a significantly expanded group of collaborators throughout ASU as a whole, ranging from many of the university's top scientists and engineers, to faculty and students in ASU's programs on public policy, law, business, architecture and design, communications, journalism and even the arts. Third, we have deep and persistent collaborations with researchers and students at other universities in the U.S. and around the world. Virtually all of our major research thrusts are carried out in collaboration with individuals or groups at other universities, and CSPO hosts an continual stream of visiting scholars and students, many from foreign universities and research institutions, for periods of up to two years.

In briefly describing CSPO's major research activities, I want to emphasize a point that should be obvious but is often lost in discussions of the Science of Science and Innovation Policy. Public support for science and innovation is justified for a wide range of reasons, many of which are non-economic. For example, we count on science to provide a safe, abundant, and tasty food supply for a growing population; ensure the protection of our natural environment and the provision of reliable and affordable energy; protect and improve our health; help ensure national security; and create new and challenging work opportunities. The reason I belabor this obvious point is that in fact we are particularly empty-handed when it comes to understanding how best to design and assess S&T policies aimed at advancing these non-economic outcomes. This is the arena where CSPO focuses most of its efforts.

CSPO is engaged in a wide range of research activities that seek to advance knowledge, real-world practice, and human resources in this broad domain of science and innovation policy for social outcomes. And I want to gratefully acknowledge the National Science Foundation's generosity in providing peer-reviewed grant support for many of our most important and I would say high-risk, high-pay-off ideas, through a variety of its programs, including SciSIP.

At the core of all of our research is a commitment to looking at S&T activities as part of larger social systems. Trying to understand and assess the outcomes of science and innovation by studying and measuring research and development activities alone is like analyzing a family's home life by studying lumber mills and brick kilns. What makes a given line of research valuable for society? Of course the science itself must be of high quality, just like a fine home needs to be constructed of quality materials. But for investments in science and innovation to support desired social outcomes, many other elements will come into play: the ways that scientists choose projects; the culture and organization of research institutions; public-private interactions; economic incentives and regulatory structures; public preferences and behavioral norms—all this and more make up the process by which knowledge, innovation, and social benefit are connected.

1. (A) Please provide an overview of the research activities of the Consortium for Science, Policy, and Outcomes.

With this background, let me outline some of our efforts, in four areas of direct relevance to the science of science and innovation policy.

(1) CSPO's flagship research program is our Center for Nanotechnology in Society (CNS), an NSF Nano-scale Science and Engineering Center which has just been renewed for a second and final five-year grant period, under the directorship of CSPO co-director Professor David Guston. CNS takes a systems view of technological innovation to ask: what are the factors that may influence whether an emerging domain of technology, in this case nanotechnology, is able to move toward areas of social need and desired outcomes? CNS involves multiple universities and researchers from multiple disciplines bringing numerous specialties to bear on what we call "real-time technology assessment," or a capacity to understand linkages between new knowledge, emerging innovations, and societal outcomes—as they are unfolding.

Among the many specific research activities encompassed by CNS are relatively traditional tools for assessing scientific productivity such as citation and patent analysis, as well as proven methods for tracking public opinions and preferences. But we also bring social scientists together with nanoscale scientists and engineers to reflect on the choices available to them for advancing nanotechnology, and to develop and discuss future scenarios of nanotechnology-enabled society. We cultivate ongoing discussions with the public about potential benefits, problems, and dilemmas of nanotechnology. We bring graduate students working on nanotechnology into discussions of science policy and social outcomes. We work with science and technology museums to create programs and exhibits that go beyond technical explanations to help people understand the ways that nanotechnology and society influence each other.

In total, what we are trying to create with CNS is a test-bed for developing a more holistic understanding of science, innovation, and social outcomes, where the choices made about science, innovation, and their application in society are brought out in the open and discussed even at the earliest stages of the innovation process, to bring into better alignment the directions of science and innovation, and the aspirations and needs of society. I also hope it is clear from this brief description that standard categories of "basic research," "applied research," "education," and "outreach" are not pursued separately, but are part of an integrated approach at CNS.

I want to emphasize three elements of U.S. science policy that made this research program possible. First was the explicit desire of this Committee and the Congress in general, as expressed in the 21st Century Nanotechnology Research and Development Act of 2003, to ensure that nanotechnology advanced along with a capacity to understand unfolding social implications. Second was the complementary recognition by the National Nanotechnology Initiative, under Mihail Roco's early leadership, and the National Science Foundation, that understanding the social aspects of nanotechnology should be an important aspect of the overall nanotech research agenda. And third was ASU itself, a university that has made huge strides in reducing the barriers to true interdisciplinary collaboration, and that is simultaneously committed to connecting the work of its faculty and students to the needs of society.

(2) A second project I want to mention is Science Policy Assessment and Research on Climate (SPARC), funded through NSF's Decision Making Under Uncertainty program. SPARC is a collaboration with the Center for Science and Technology Policy Research at the University of Colorado, and we are finishing the project up after a five-year funding period. SPARC explores a question that lies at the heart of science and innovation policy: what makes the results of a scientific research project useful, and usable? While the broad context for this project was the nation's considerable investment in research related to climate, our research looked at science policy decision making aimed at many different problems, including water management, weather and natural hazards, nanotechnology, technological standards, agriculture, and ecology.

SPARC results reinforce a major point: science policies tend to be more successful when they are carried out through institutional arrangements that allow scientists and decision makers to understand each other's needs and capabilities. Fostering close, ongoing, trusting relations between those who produce new knowledge and those who might benefit from it seems to be an essential attribute of science policies that lead to new knowledge quickly moving into society for public benefit. Drawing on the lessons of this major project, we produced a short handbook for science policy decision makers, called "Usable Science." We released this report last April at a meeting here in DC that attracted about 100 participants, many from federal agencies. The handbook is available at: *http://cstpr.colorado.edu/sparc/outreach/sparc_handbook/*.

(3) A third project, called Public Value Mapping, or PVM, has been supported by the SciSIP program, as well as the V. Kann Rasmussen Foundation and the Rockefeller Foundation. The idea behind PVM draws on my previous point that most publicly funded S&T activities aim to advance a variety of social outcomes, not just economic ones. PVM finds that these desired social outcomes—what we call "public values"—are clearly expressed at many levels across the science and innovation policy endeavor—in legislation and laws; in the strategic plans and budget documents of R&D agencies; in the websites and press releases of individual R&D programs and even projects.

Because public values are harder to characterize, measure, and assess than economic values, they are often given short shrift both in debates about science and innovation policies, and in research to evaluate the outcomes of such policies. Yet a key concept for PVM is that the public values associated with science and innovation policies may conflict with one another, and with economic values. For example, a new medical technology may create profit for a corporation and benefit from those who have access to the technology, even as it contributes to health care outcome disparities and over-diagnosis and unnecessary treatment. PVM seeks to unravel and clarify such complexities, in order to help view and assess the full range of social outcomes tied to science and innovation policies.

In brief, our research aims first to identify public values across a particular area of science and innovation policy. We then analyze how various value statements actually relate to each other (for example, are they complementary or contradictory?) and assess whether the research activities are in fact organized in ways that may allow them to achieve those values. Our work is still preliminary. During three years of NSF-supported research, we have completed a set of detailed case studies, looking at S&T policy issues such as technology transfer, nanotechnology for cancer treatment, and environmental chemistry. One intriguing, but still quite preliminary, result of our work is that we think we can say something about the potential for a major research program to achieve desired social outcomes based in part on how public values are articulated across the program's various levels and components. For example, our study of natural hazards research at the U.S. Geological Survey shows a strong coherence among public values expressed by scientists, the agency, legislative mandates, and various stakeholders, whereas our analysis of Federal climate change research shows considerable diversity and even conflict among values within and across these various levels of activity. We are now working to test the hypothesis that the relations among public values may in fact be predictive of a program's performance. If this turns out to hold up after further research, it could offer a powerful tool for assessing the capabilities of science and innovation policies.

(4) As one final example, I want to mention CSPO's growing work on energy technology innovation. This is a cross-cutting theme that works its way into a number of our research projects, but I think it helps to communicate our overall approach. Consider, for example, solar energy technologies, which may have particular potential to serve energy needs in a desert state like Arizona. Yet to understand the potential for solar energy R&D to contribute to Arizona energy needs, one also needs to understand issues of regulatory incentive, land use, water access and availability, public lands management, agricultural policies, transmission corridors, military bases, Indian reservations, even immigration. Each of these variables may play a crucial role in determining the outcomes of solar energy science and innovation policies—and policies that do not attend to these variables run the risk of failing to achieve their desired social outcomes, regardless of levels of funding or scientific productivity.

1. (B) How are you facilitating interdisciplinary collaborations within the Consortium?

CSPO facilitates interdisciplinary collaboration in three main ways. First, we organize our activities around problems, not around disciplines, and then we bring into our research teams the expertise that we need to help us understand what's going on and how to make progress.

Second, as an administrative matter, CSPO is located in ASU's College of Liberal Arts and Sciences, so it does not have a disciplinary affiliation. Our core faculty members have advanced degrees in fields ranging from earth sciences and electrical engineering to political science and philosophy. Core faculty are jointly appointed between CSPO and a variety of academic units, including the Schools of Life Sciences; Government, Politics, and Global Studies; Human Evolution and Social Change; Geographical Sciences and Urban Planning; Sustainability; Communications; and Social Transformation. If these don't sound like familiar names for traditional academic disciplines, that's because ASU itself has moved to reorganize standard departments into interdisciplinary units in order to bring appropriate intellectual force to bear on complex problems.

Third, we have worked hard to cultivate long-term collaborations with natural scientists and engineers across the university, many of whom are affiliate faculty members at CSPO. We work with these colleagues to design new educational and research projects and programs that return value both to CSPO and to our science and engineering partners. These activities create familiarity and trust that allow us to engage in higher-stakes collaborations. For example, many of the major science-and-engineering grant proposals submitted by ASU to funding agencies now include an integrated set of activities aimed at understanding and enhancing societal outcomes. We have even been funded by NSF, partly with the support of the SciSIP program, to study the impacts of natural science-social science collaborations in labs at ASU and around the world.

1. (C) What new and continuing areas of research in the science of science and innovation policy (SciSIP) could significantly improve our ability to design effective programs and better target federal research investments? (D) What are the most promising research opportunities and what are the biggest research gaps?

CSPO faculty members have been brainstorming over the past few weeks to develop a short list of "foundational/transformative" research challenges in response to a call for ideas issued by NSF's directorate for Social, Behavioral, and Economic Sciences. Given CSPO's orientation, our ideas, not surprisingly, are directly relevant to the SciSIP program.

1. Science and innovation policies often aim to help transform existing technological systems to achieve particular societal outcomes: for example, to move the nation's energy system toward a more economically, environmentally, and geopolitically secure technology base; or to move the nation's health care system to achieve better health outcomes at lower cost. New scientific and technological advance are obviously going to be key drivers of such transitions. Yet modern societies have very little understanding of how to catalyze and steer these sorts of complex system changes, and well-intentioned efforts can often lead to unanticipated consequences whose benefits are very difficult to assess, as we have seen, for example, in efforts to advance alternative biofuels. **A key SciSIP research priority should be to gain fundamental understanding about the drivers and dynamics of transitions in complex socio-technical systems.**

2. Science and innovation policies are, in one sense, a bet on the future: that a certain type of knowledge or technology will prove useful or valuable. Yet the future of social and technological change is impossible to predict in detail. To try to deal with this unpredictability, a relatively small number of forward-thinking companies, academic units, and non-profit organizations employ a variety of techniques and tools that can allow them to better visualize, understand, and discuss a range of alternative possible futures. Such activities can inform decision making by helping to make clear the broad array and potential implications of scientific, technical, and social options and pathways available for addressing social challenges. **SciSIP should support the study and assessment of existing tools, and the development and testing of a range of new tools, to bring future-visioning techniques to bear on science and innovation policy making processes.**

3. **In general, SciSIP should emphasize support for research and education programs that foster integration between natural sciences and engineering, and social sciences.** Such integration can help to ensure that science and engineering activities are conceived and carried out with a realistic understanding of the social context in which knowledge and innovation are pursued and applied. In turn, social scientists will gain a deeper, and earlier, understanding of the potential futures that cutting edge R&D programs are making possible. The result should be a growing capacity to design and conduct science and innovation activities that are better able to contribute to desired social outcomes.

4. **SciSIP should consider supporting the development of a set of case studies to identify and characterize the key attributes of S&T institutions and programs that strongly link science and innovation activities to desired social outcomes.** Case studies should range across the S&T enterprise, sam-

pling a variety of sectors, scales, structures, and desired outcomes. Such a program would need to be coordinated to ensure comparability between the methods and organization of the cases. Its institutional and programmatic focus would make it distinct from, and complementary with, the STAR METRICS approach that NSF and sister agencies are already taking. This case-based effort should focus on the development of a set of key organizational principles that science and innovation policy makers can use to guide investment strategies and priorities.

Committee Question 2: Is the Federal Government, specifically the National Science Foundation, playing an effective role in fostering SciSIP research and the development of a community of practice in SciSIP? What recommendations, if any, do you have for the National Science Foundation's SciSIP program?

Overall, I believe that NSF is doing a good job in building the SciSIP program and community. But this is a very difficult task. The community of researchers working in the SciSIP domain is rather small and very diffuse. In fact, it does not really identify itself as a single community, but rather as several independent communities, for example, innovation economics, science and public policy, and science and technology studies. So there's simply not a lot of capacity yet in this domain, and what capacity there is needs to be better integrated. Moreover, most of the quantitative data available for analysis of science and innovation policy is input-output data—budget levels, numbers of scientists and graduate students, publication numbers, patents, and citations, and so on. Such data can be subjected to highly sophisticated data mining and analysis techniques using ever-improved software packages designed for this purpose, so it is very attractive to researchers. But this kind of input-output data can offer only an incomplete and in many ways distorted view of the societal value of the S&T enterprise, a view that does not allow us to escape the simplistic beliefs of the past.

Now it's clear that those running the SciSIP program understand these problems. They brought together a good cross section of the community to help plan the program in the spring and summer of 2005; they have sought to attract grant applications from a wide array of researchers; they have organized or otherwise supported events to bring together SciSIP researchers to build a sense of integrated community; they have provided grant support to a diverse set of research approaches and problems; and they are working through the STAR METRICS program to try to build better quantitative data sets that can assist certain types of analytical work. All this is very positive.

To some extent, however, NSF's institutional strength is also a weakness here. The agency prides itself on its bottom-up approach to setting its research agendas. While the SciSIP program does reflect a top-down decision to create a new program area, in part as a response to concerns repeatedly expressed by then-Presidential science advisor Marburger, the shape and direction of SciSIP has significantly been dictated by the existing research community. Much of that community continues to work within the input-output model of science and innovation policy, due, as I've said, to existing data sources and tools. For similar reasons of measurement ease, the community also tends to focus on economic outcomes to the significant exclusion of the much broader range of societal outcomes that the nation seeks to derive from its S&T investment. Because researchers and peer reviewers are drawn from the same general communities, such tendencies can be difficult to escape.

A range of tools are potentially available for building the community and its coherence, and driving the intellectual agenda away from an input-output framework, and toward a systems-oriented, outcomes-focused approach. Not all of these tools require new money. SciSIP should use program guidelines and requirements to transform and build the research community; indeed, this year's program announcement is notable for its openness to a wide range of approaches to SciSIP research. **SciSIP could also consider using some of its budget to support training grants, similar in spirit, if not in scale, to NSF's successful IGERT (Integrated Graduate Research and Traineeship) program, as a way to more quickly build up capacity.** However, if the Committee, and NSF, believe that the science and innovation policy research community needs to be significantly larger and more coherent, this will probably require more resources. To reinforce my position throughout this testimony (also see my comments on "dissemination," below), any claim to a bigger budget must be matched by programmatic design elements to help ensure that knowledge created by SciSIP is both usable and used. **This would likely require a commitment to fund integrated Science and Technology Center-type science and innovation policy research organizations that can create and support ongoing interaction between SciSIP researchers and policy**

makers, perhaps analogous to NOAA's Regional Integrated Science and Assessment program.

Committee Question 3. Please describe the education and outreach activities of the Consortium for Science, Policy, and Outcomes.

CSPO sponsors a wide variety of education and outreach activities, ranging from formal degree programs and intensive, short-term training activities, to public outreach events and products targeted at science and innovation policy makers.

1. Graduate Degree Programs

The ASU Professional Science Masters in Science and Technology Policy was initiated in 2009. It provides professional education for students seeking advanced public, non-profit, or private sector careers in science and technology policy and related fields in the United States or abroad. Students learn essential skills, knowledge, and methods for analyzing innovation, expertise, and large-scale technological systems. Particular emphasis is placed on the political and societal contexts and impacts of science and technology policy. The program is a one-year, 30-credit cohort-based program designed to attract students of the highest caliber in their early to mid-careers. Key learning outcomes of the program include:

- Understanding of the theoretical foundations of the interactions among science, technology, and society.
- Understanding of US and, where appropriate to a student's career interests, international science and technology policies and the policy processes that generate them.
- Analysis of knowledge systems supporting policy decisions.
- Analysis of the social and policy dimensions and implications of large-scale technological systems.
- Analysis of scientific and technological innovation systems.
- Skills in collaborative, team-based analysis of science and technology policy problems.
- Skills in effective professional communication.

Ph.D. Program in the Human and Social Dimensions (HSD) of Science and Technology. Here CSPO collaborates with ASU's Center for Biology and Society and Center for Law, Science, and Technology to offer a highly interdisciplinary and integrative program of advanced study. We aim at training scholars and practitioners to understand and inform the conceptual and philosophical foundations of scientific research; to analyze and assess the increasingly powerful roles of science and technology as agents of change in society and the economy; and to challenge universities to become leaders in fostering the new science and technology policies necessary to meet the problems and opportunities of the 21st century.

The HSD curriculum is flexible, combining a strong, integrated, first-year experience, with substantial freedom for students, in conjunction with their advisors, to design carefully crafted programs of study relevant to their own areas of interest and expertise. The curriculum trains researchers with the necessary skills and preparation to analyze three key aspects of the study of the human and social dimensions of science and technology: 1) the historical, philosophical, and conceptual foundations of science and technology; 2) the social and institutional foundations of scientific research and technological systems; and 3) the political, ethical, and policy foundations of science and technology.

Research projects of current HSD students supported by CSPO include:

- Social and ethical challenges of smart grid development
- Leadership training in graduate science and engineering education
- Comparative analysis of interdisciplinary research fields in the US and China
- The emergence and stabilization of legal regimes in online communities
- The role of non-governmental organizations in energy siting decisions in the United States
- Public values and public engagement in energy policy in the United States
- The organization and management of international scientific assessment processes
- Connecting knowledge to decision making in water policy
- information technology in learning & inequality

2. Non-Degree Programs and Training

Ph.D. plus. This integrative, non-degree program offers advanced graduate students in science and engineering the chance to consider how their research relates to the world of science policy and the relationship between science, technology and societal outcomes. Science and engineering students work with a CSPO faculty member to write an additional chapter of their dissertation that explores the social implications, political context, or ethical concerns of their work. The Ph.D. plus process is informal, and is arranged by discussions between the student, her or his dissertation advisor, and the CSPO advisor. Most Ph.D. plus students take one or more classes offered by CSPO faculty; attend seminars and other activities sponsored by CSPO; and in general interact closely with the CSPO community for an academic year or more.

In the annual *DC Summer Disorientation*, cohorts of about 15 science and engineering graduate students spend two weeks in Washington, DC interacting with the government officials, lobbyists, staffers, regulators, journalists, academics, museum curators, and others who fund, regulate, shape, critique, and study science and technology. Students participate in interactive role-playing experiences where they may testify at mock Congressional hearings; work under tight deadlines to write briefing papers for senior officials; or write op-ed pieces for a demanding editor. The goal is to help future scientists develop an understanding of the political and social context of their research. CSPO has recently expanded this program and now accepts graduate students from outside of ASU.

The Next Generation of Science and Technology Policy Leaders. Here we are seeking to catalyze a community of early-career science policy scholars who can span the terrains of intellectual inquiry and real-world practice, communicate effectively to general audiences, and contribute to effective decision making on key issues of science, technology, and society. We organized a national competition to select a dozen early-career science policy researchers and practitioners (5 years or less since Ph.D). This "Next Gen" group prepared draft papers, and each scholar was then paired with an early career "communicator" (typically a writer working through new media). The scholar and the communicator collaborated to craft a compelling, non-scholarly description of the scholar's work—something that would appeal to a general audience. Next Gen scholars also led a roundtable discussion where each presented her/his research to a group of about 40 people at a major CSPO-sponsored conference, to allow the scholars to hone the more technical aspects and presentation of their work, and to interact intensively with an engaged audience. Next Gen scholars are now working on two versions of their research papers, one for a policymaking audience, and one for an academic audience. This project was supported by grants from NSF's programs on Science, Technology, and Society, and Informal Science Education.

3. Outreach

CSPO views outreach as an integral part of its operations at all levels—not as a separate, add-on, or late-stage activity. As described above, our research and education programs often involve policy makers, members of the public, and scientists and engineers, and so also serve an outreach function by creating and strengthening links and communication between CSPO scholars and these other groups. Indeed, in many cases it is difficult to know where research ends and outreach begins. For example, much of our work on energy innovation policy is presented to policy makers and the media in briefings and policy reports at the same time as it is written up for academic audiences (see: *http://www.cspo.org/projects/eisbu/*). Similarly, SPARC involved numerous workshops that brought scientists and science policy makers together in a way that enhanced both communication and learning.

The integration of outreach and education is apparent in CSPO's growing collaboration with science museums and science centers. We view these collaborations as ways of reaching wider audiences and increasing the ability of our graduate students—social scientists as well as natural scientists and engineers—to communicate to broader audiences. Our Center for Nanotechnology in Society has fostered a national strategic partnership with the NSF-funded Nano-Scale Informal Science Education Network to develop programs and exhibition materials and plans that incorporate societal interests and outcomes in communicating about emerging technologies. CSPO opens science communication opportunities for scientists and engineers through its monthly Science Café series with the Arizona Science Center and incorporates museum-floor experience into its integrated training of doctoral scientists and engineers. CSPO is also working with the Museum of Science, Boston and the National Academy of Engineering to plan a national educational campaign to focus on climate change and engineered systems, to prepare the next generation of engineers, citizens, and leaders to meet the challenge of adapting the nation's technological infrastructure to climate change.

Overall, we are continually engaged in a wide variety of efforts to make our ideas accessible to the public and policy makers, through informal and formal meetings and briefings in the Phoenix area and in Washington, DC; through "handbooks" for decision makers; through ongoing contact with the media; as well as by writing op-eds and articles for non-technical magazines, websites, and blogs. We have just received a small supplement to our SciSIP grant on Public Value Mapping to produce engaging, instructional web-based videos for science policy practitioners. New outreach products and activities are promoted via CSPO's monthly electronic newsletter, which goes to over 3000 people in academia, government, and industry. In all, I think it is fair to say that CSPO views outreach, education, and research as equally necessary foundations for pursuing its mission.

Committee Question 4. How can the dissemination of SciSIP research findings be improved so that policymakers are better informed of the current state of research? Are there best practices that can be implemented by the Federal government and/or the research community to improve the incorporation of science and technology policy research into the decision making process?

SciSIP program officers, in collaboration with their grantees, with organizations like the American Association for the Advancement of Science, and with other federal agencies, has made an impressive effort to ensure that research results are made available to science and innovation policy makers, through the SciSIP website and listserve, and through a variety of workshops, including one to be held this coming December.

SciSIP and NSF more broadly face something of a dilemma here, however. As I'm sure the Committee well appreciates, academic researchers are generally not rewarded for communicating their work to policy makers, or even for making the results of their work comprehensible to non-experts. I'm extraordinarily fortunate to work at a university where this is not the case. Moreover, given the fundamental nature of much of the research supported by SciSIP, the extent to which project results can translate into results immediately useful to decision makers may be highly variable. At the same time, it's fair to say that science and innovation policy decision makers may not always be either receptive to, or able to act on, the results of research conducted under SciSIP.

In line with many of the comments I've already made, and consistent with research done by CSPO and many other groups, the best way to further improve the value of SciSIP research for decision makers would be to increase the level of interaction between the researchers and decision makers. This point should not be interpreted as a criticism of the current SciSIP program, which as far as I can tell is effectively pushing the boundaries of typical NSF practice, and working at the limits of its human and fiscal resources, to try to maximize dissemination.

Yet ensuring that researchers are providing knowledge that decision makers can actually use is not only a matter of "dissemination," it is also structural. For SciSIP results to be both usable and used, researchers and decision makers must each come to understand the needs, capabilities, and languages of the other—a process that we have termed, in our SPARC project, "reconciling the supply and demand of research." Such a reconciliation takes time and ongoing interaction. It can certainly be pursued along multiple paths—through joint committees, workshops, personnel exchanges, interviews and surveys, and so on—but the key is ongoing and meaningful interaction leading to mutual understanding. An NSF research program, even one advanced with the creativity and vigor that characterizes SciSIP, is unlikely to be able, by itself, to provide the sort of institutional infrastructure that leads to the production of consistently usable knowledge. The idea of integrated SciSIP centers, previously mentioned, could be one way to create a greater capacity to move ideas into use. Federal agencies and programs that sponsor mission-oriented research, and that have a proven record of producing usable knowledge, might also be able to play a role here to help achieve the necessary integration.

Committee Question 5: What are the fundamental skills and content knowledge needed by SciSIP researchers and practitioners? What are the backgrounds of students pursuing graduate degrees in science and technology policy, and what career paths are sought by these graduates? Is the National Science Foundation playing an effective role in fostering the development of science and technology policy degree programs at U.S. universities? If not, what recommendations, if any, do you have for NSF and/or the universities with such programs?

As I've suggested, the domain of SciSIP research and practice cannot and should not be defined by any particular set of skills or area of knowledge. In fact, given the complexity and diversity of the challenges facing SciSIP policy makers, it will be important to keep the field as open and flexible as possible, where the necessary skills and knowledge are determined based on the problem at hand, and on the evolution of the field itself, rather than some arbitrary boundary. I've already mentioned the varied backgrounds of CSPO's core faculty group, and our graduate students are if anything even more diverse, coming to us with degrees in business, information systems, science and technology studies, astrophysics, political science, law, English, public policy, library and information science, philosophy, physics, biology, environmental science, geology, anthropology, sociology, and industrial management.

Graduate training in science and technology policy is also diverse, occurring in many different types of programs, with many institutional and administrative arrangements, in many U.S. universities. There is no standard-model science and technology policy graduate degree, and given the complexity of the field perhaps that is just as well, but it does create challenges in terms of attracting resources, creating an identity, and setting priorities. Similarly, while many career paths are open to those who have advanced training and degrees in science and technology policy, there is no formula for how to build or advance a career in this field, as there is in, say, law, medicine, or engineering. In CSPO's brief experience with graduate education, we do see our students and post-docs progressing on traditional academic paths, but they are also going into the private sector, working at nongovernmental organizations, and taking up positions in government agencies and think tanks. I also want to emphasize the importance that we place on "continuing education" via our professional Masters program, which we hope will reach mid-career professionals already working in areas related to science and technology policy, and equip them with tools to do their jobs more effectively, or to move into more complex jobs, in the public, private, and nongovernmental sectors.

As I discussed in my response to Question 2, NSF's SciSIP program, as well as its Science, Technology, and Society Program, are working hard to build a sense of community and identity among science and technology policy researchers, and to provide support for research across a broad domain of problems and applications. However, as discussed at length by about 75 members of the community at this summer's Gordon Conference on Science and Technology Policy, the traditional academic structure of universities remains a considerable obstacle to building long-term capacity in the field, and most science and technology policy programs exist in the margins and spaces of standard disciplinary schools and departments. I am fortunate enough to work at a university whose leadership has a strong commitment to cultivating interdisciplinary, problem-based research that can link knowledge creation to solutions for complex societal problems. Yet even at ASU the long-term future of science and technology policy research probably depends on finding a way to more closely knit CSPO into the fabric of the formal academic units on campus.

One conclusion here is that NSF's ability to foster the development of the field of science and technology policy is partly dependent on incentivizing universities to recognize SciSIP as a field worth cultivating. While the SciSIP program is certainly of a scale sufficient to mobilize and motivate individual researchers working on science and innovation policy, it is probably not big enough to get the attention of university administrators. I have already emphasized the potential value of applying an integrated Science and Technology Center model to building the SciSIP community and moving its research results into use. An NSF commitment to supporting one or more such centers would also send a strong signal to university leaders that the science of science and innovation policy is a national priority, deserving of strong focused effort and investment from our universities.

BIOGRAPHY FOR DANIEL SAREWITZ

Daniel Sarewitz is Professor of Science and Society, and co-director and co-founder of the Consortium for Science, Policy, and Outcomes (CSPO), at Arizona State University (*http://www.cspo.org*). His work focuses on revealing the connections between science policy decisions, scientific research and social outcomes. How does the distribution of the social benefits of science relate to the way that we organize scientific inquiry? What accounts for the highly uneven advance of know-how related to solving human problems? How do the interactions between scientific uncertainty and human values influence decision making? How does technological innovation influence politics? And how can improved insight into such questions contribute to real-world practice? He is the author of *Frontiers of Illusion: Science, Technology, and the Politics of Progress* (Temple, 1996), an exploration of the public myths that underlie decisions about science and technology; the co-editor of three other books; and the author of many articles about the interactions of science, technology, and society. In addition to scholarly journals his work has appeared in *The Atlantic Monthly, The New Republic*, and many newspapers; from December 2009 until September 2010 he wrote a monthly column on science policy for the journal *Nature*. His work has also received featured coverage on NPR's Morning Edition, in the *New York Times* and the *Chronicle of Higher Education*. From 1989–1993 he worked on R&D policy issues for the U.S. House of Representatives, first as a AAAS Fellow in the office of Congressman George E. Brown, Jr., and then as a staffer on the Committee on Science, Space, and Technology. He received a Ph.D. in Geological Sciences from Cornell University in 1986. He now directs the Washington, DC, office of CSPO, and focuses his efforts on a range of activities to increase CSPO's impact on federal science and technology policy processes. His new book, *The Techno-Human Condition* (co-authored with Braden Allenby; MIT Press) will be published in March 2011.

Chairman LIPINSKI. Thank you, Dr. Sarewitz. And it is the beginning of votes, but we should be able to get to the testimony in here. Dr. Murray.

STATEMENT OF FIONA MURRAY, ASSOCIATE PROFESSOR OF MANAGEMENT, TECHNOLOGICAL INNOVATION & ENTREPRENEUR GROUP, MIT SLOAN SCHOOL OF MANAGEMENT

Dr. MURRAY. Okay. Thank you very much. Thank you, Chairman Lipinski and other Members of the Subcommittee, for the opportunity for being here. My name is Fiona Murray as you heard before I am a Professor of Innovation and Entrepreneurship at the MIT Sloan School and I am also Associate Director of the MIT Entrepreneurship Center.

Now to start my remarks I thought I would just describe the perspective I bring. Briefly, I am the grateful recipient of two SciSIP Grants. I worked on what I would think of as a SciSIP oriented research agenda for more than a decade, although I really only discovered the SciSIP research community in about 2006. As a faculty member of a business school I also engage on these issues with managers, scientists themselves who are also interested, sometimes at the lower levels, in how to organize effectively to ensure the productivity and impact of their research.

I should also just say something about my own training. I have a background, a Bachelor's, Master's, and Ph.D. in Chemistry. That is a very unusual training for somebody who does SciSIP. I think it enables me to bring a unique understanding of the bench science to this research, although as I do note in my written remarks I am not sure that this is an ideal past to learn the rigorous social science methods that one really needs. I have had to rely on again self-education and some very patient co-workers to get me over what I think is a quite high bar to make a serious contribution to this endeavor, and in particular to do it in a way that contributes to the policy and the scholarly debate.

I want to just take my time to see if I can make three points. I will make two if time—if only time permits. Something about the vision of SciSIP that—from what I think that means about the kinds of gaps there are in the research. And then also how I think the scientific community might more effectively be organized to really have an impact in terms of research links to the community and in particular education.

So I think that SciSIP is not completely about doing science and technology analysis. I think there's already an excellent scholarship describing policy initiatives, the government attitude toward science, and the politics of science and innovation policy. But I think that what SciSIP brings, which is unique, is this sort of scientific lens to the problem. And what I mean by that is that it is a serious and I think important attempt to undertake causal analysis and evidence-based analysis asking whether and how particular policy interventions actually have an impact, whether it is in the short run or the long run. And so I think that good scientific research defines impact richly: it is about the level of the rate and the direction of scientific progress and innovation, but it is also about long run impact on economic growth.

But I also want to emphasize this causal piece of what kinds of policies we think make a difference. I think that at its best, SciSIP defines policy broadly but precisely in particular research instances. And so it can mean everything from high level national policies, the laws, but also agency implementation processes, agency selection processes, but below that, community behaviors, things like the Bermuda Laws and so on. And even at some microlevel, lab level choices around how we choose to organize the scientific research at the ground level.

I think a key approach to SciSIP has been grounded in two recent developments. One is the data development which has already been discussed. But I would also say it has been enabled, actually, by a massive scientific data infrastructure investment, so some of my own work has really been enabled by investments in things like GEN Bank and that ability to interrogate genetic data to then do science policy analysis.

But also I think a second piece of social science methods is in program evaluation. Actually, you are familiar with this from the work that you do on evaluating education policy. But I think that the ability to use experiments and causal analysis and so on from that policy evaluation tool kit is extremely important to pushing SciSIP forward.

So I think that SciSIP has really been critical and attracted serious cause, but in my view there are still some gaps. To pick up the "straw and bricks" analogy, it strikes me that while we need bricks, if we want to cross the bridge from data to understanding we actually have to build a bridge with those bricks. And what does that mean? I think that does mean more analysis as well as just measurement. I think at the moment a lot of the scientific work, including my own, is intrinsically focused on biologists and on funding at the National Institutes of Health. That is critical, but not the only arena, and I think that there is—we do need to understand how other disciplines and other agencies are working.

I think that there has been a focus on national-level rules and specific agencies and less on these community-level choices about how to organize structure, collaborations, and more informal efforts. I think we also need to focus on distributional issues. So not just how many more papers are produced, but what kind of a breakthrough or everyday science, what kinds of research, are they American or foreign, and so on. I don't think we have focused enough on that.

And let me in the last few seconds just say something about the SciSIP community. I think that the community actually needs to do more of its own bottom-up organizing. The NSF has done a tremendous job in kind of structuring it in a top-down way, but that is a huge amount of work for one agency to do. And I think as a community we need to do a more bottom-up in order to both engage in more knowledge exchange among ourselves and to focus on education. And I think the educational imperative at the Ph.D. level does need to be organized across a number of campuses. And then, as I think at the policy level of our links, the policy makers again have to be organized in a more community-based way. So I would suggest that that needs to be done through a consortium of universities but with this tripartite mission of research, education, and then links to policy. And I will leave my remarks there. Thank you very much.

[The prepared statement of Dr. Murray follows:]

PREPARED STATEMENT OF FIONA MURRAY

According to the National Science Foundation (NSF), the Science of Science & Innovation Policy (SciSIP) program "supports research designed to advance the scientific basis of science and innovation policy[1]. The program is an important and bold attempt to build a strong intellectual foundation for science and technology policy making regarding the laws and rules that shape the institutional environment in which scientific research and innovation takes place. It does so by adopting recently developed, leading-edge methodological approaches based on both large scale empirical data analyses and complementary qualitative analyses. The explicit goals of the program are to fund research that "develops, improves and expands models, analytical tools, data and metrics that can be applied in the science policy decision making process". From *my* perspective as a SciSIP scholar, I conceptualize the SciSIP agenda as the systematic, evidence-based and causal analysis of the impact of policy interventions on the rate, direction and impact of scientific knowledge production and innovation. If successful in research and in coupling to policy decisions then this agenda will enable Federal and state policymakers, as well as others engaged in shaping the production and translation of scientific knowledge (including scientists themselves, universities, Foundations and scientific communities), to design more effective policies and practices that ensure that investments in science and innovation have rapid and extensive scientific, social, and economic impact.

In this testimony I lay out my personal views of the SciSIP program from the perspective of an NSF–SciSIP scholar (and grant recipient), and as a Faculty member in a leading School of Management who engages routinely with scientists concerned with the impact of their research, policy students as well as MBA students and executives hoping to work effectively at the academic-commercial interface.

In what follows I examine some recent breakthroughs that have enabled SciSIP research, outline some of the key research emerging from SciSIP to date and critical gaps. I then turn my attention to what I observe as the need for greater community building and finally, the potential for a significant educational initiative.

[1] Accessed from *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=501084&org=sbe* 9/16/2010.

The notion that there can be a "science" of science and innovation policy is relatively recent (Marburger 2005). There is a long and distinguished traditional of science policy research nonetheless, the current focus on measuring the causal influence of science and innovation policy levers at different levels (national policy, agency interventions as well as community and lab-level actions) can be linked to advances in economics and related fields in the early 1990s. During this period, leading economic historians including Paul David, Joel Mokyr and Nathan Rosenberg developed critical conceptual breakthroughs in understanding the economics of science and innovation as grounded both in institutions (policy levers) but also in the micro-level behaviors and incentives of scientists and engineers themselves. Building on economics as well as the sociology of science, they came to view Science as a distinctive institution in several ways: as a knowledge production system, as an input into technological innovation, and as a reward system.

The empirical promise of this conceptual agenda was taken forward by a group of economists and sociologists who aimed to evaluate the impact of public policies on research behavior, research outputs, and associated economic outcomes (Marburger, 2005; Jaffe, 2006). In following this agenda, scholars confront a number of key challenges. In particular is it possible to separate the influence of a particular policy or institution from the underlying nature of the scientific knowledge that is being developed? To put it more simply, in the policy "whodunit" it is often hard to say whether it is the policy that had the effect of speeding up scientific progress in a particular area or a chance in our understanding of a scientific problem. Without a parallel universe for policy experiments, when one observes the production or diffusion of a piece of knowledge within a *given* policy environment, one cannot directly observe the counterfactual production and diffusion of that knowledge had it been produced and diffused under alternative policy conditions. To resolve these challenges, SciSIP scholars have combined methodological advances in program evaluation- particularly a "natural experiments" approach—with novel data techniques. The experiments-based approach (with which the committee is likely familiar from its work on education) relies upon methods pioneered in public finance and program evaluation (Meyer, 1995; Bertrand, Duflo, and Mullainathan, 2004; Angrist and Pischke, 2008). To complement these methods, SciSIP scholars have made extensive use of novel datasets including data on publications, patents and most recently citations. This approach uses these "documents" as the core objects of analysis, assuming that they represent "pieces of scientific knowledge," and citation analysis to investigate the impact of institutions on the cumulativeness of discovery and innovation (Garfield, 1955, De Solla Price, 1970; Jaffe, et al, 1993; Griliches, 1990, 1998). When placed within a framework to evaluate science and innovation policy, these elements constitute a robust approach to analyzing and tracking the causal impact of public policies on science and innovation inputs and outputs.

The power of the emerging SciSIP agenda is to incorporate these novel approaches and therefore move beyond description and observation of science at work or particular policies towards the more systematic analysis of particular institutional interventions. Thus pioneering SciSIP research typically combines three elements:

i) Providing clear theoretical foundations for understanding the ways in which institutional change (at any level) might influence the behavior of scientists and therefore the rate and direction of their knowledge production.

ii) Building careful empirical designs that enable causal analysis, and undertaking these empirical studies using systematic data gathering methods at different levels (including quantitative data but also including qualitative studies).

iii) Grounding the analysis in a deep understanding of the phenomenon—the details of the particular policy changes or organizational choices as well as the ways in which these shape scientists daily life.

As a contributor to the broader SciSIP agenda and approach, my research in the past few years has focused on the conflicts and compromises shaping the boundary between academic science and the commercial world—especially the impact of intellectual property (IP) rights and IP licensing strategies over basic scientific research in areas as diverse at human genetics, stem cells and cancer biology. More recently I have expanded my research to examine the community and organizational-level interventions that scientists can make including understanding how research quality is governed (through retractions) and how projects are selected and evaluated). In my own work, I have found that my training as a scientist provides aids in the third element of the SciSIP approach but my work is strongly based on the theories and methods of economics and sociology of science and therefore links the three aspects outlined above.

A research project of mine recently completed with a series of co-authors illustrates the SciSIP approach to the analysis of science policy. It was designed to adjudicate one policy element of the institutional complex—the impact of intellectual property rights on research tools (and the licenses that shape access to such tools) on scientific productivity and diversity. Rather than theorizing broadly, it focuses specifically on one controversial episode in the genetics community initiated by the discovery, patenting and then exclusive licensing of mouse genetics technology (the Oncomouse approach and the related Cre-lox approach) and the subsequent licensing agreement made among DuPont, the Jackson Laboratories and the National Institutes of Health to enable greater access to these key research tools.

In *The Oncomouse that Roared* (Murray 2010), I take a qualitative approach to the question of whether and how the Oncomouse patent influenced the scientific community. Rather than compare the mouse genetics community to another scientific field (which may have any number of inherent differences), I compare the periods before and after the Oncomouse patent was granted and licensed. For 3–4 years, with no intellectual property rights yet granted the mice were subject only to the informal norms that characterize a competitive, but collegial, scientific community. After the grant of the patent, DuPont (exclusive licensee) strongly enforced its property rights on scientists. Through detailed interviews and documentary analysis comparing the pre- and post- patent period, I follow the SciSIP approach and closely analyzed the impact of the Oncomouse patent on mouse geneticists. I find that some scientists reluctantly acquiesced, dealing with complex contracts. Others defied DuPont, sharing mice informally in the face of opposition from their universities. Behind the scenes other more complex changes were also taking place as scientists sought to reshape the role patents in their scientific life. This is reflective of broader changes in the scientific community in the face of higher levels of commercial interest and engagement and the resistance to the encroachment of high-powered commercial interests. Such a grounded perspective highlights the importance of understanding how scientists respond to policy interventions and has a number of policy implications. However it also raises a more SciSIP-oriented question about the causal impact of the compromise (when the NIH persuaded DuPont to sign a Memorandum of Understanding making Oncomice open for experimentation) on the level and type of research using these genetically modified mice i.e. do such policy interventions shape the rate and direction of science.

I examine the causal impact of these shifts to greater openness in "*Of Mice and Academics*" (Murray et al. 2010). The "dependent variable" in this paper is the level and type of scientific research publications that use genetically engineered mice in each year from 1990 until 2006—based on a dataset of over 20,000 publications that are coded by their level of basicness, the rating of the journal in which they are published, the rank of the school affiliations of the authors etc. The "independent variable" is the timing of the policy shift in the openness of particular types of transgenic mice (Onco mice and Cre-lox mice). To aid in the interpretation of the data we also include a control group of papers that build on mice never influenced by intellectual property rules. A central idea of this research design is that while research discoveries (such as engineered mice) are developed at a given point in time, their use by subsequent researchers takes place over time. This insight motivates a differences-in-differences approach to the analysis of follow-on scientific research: If the policy environment governing the incentives and/or ability to build on published discoveries changes over time (and affects only some discoveries but not others), it is possible to identify the impact of the policy change by examining how the pattern of follow-on research (captured in published articles) changes after the policy intervention. In other words, policy changes that impact one group of articles and not another can constitute a natural experiment. This paper exemplifies the SciSIP approach by linking (microeconomic) theory about the way researchers respond to openness, with data/empirics that allow for causal analysis, and a sufficiently detailed understanding of the policies and practices of scientists to enable appropriate research design. We find that the NIH MoU did indeed increase not only the level of research using these mice but also spurred a greater diversity of researchers to move into the field, follow novel paths and take new approaches.

Taken together these two papers address questions of how institutional and organizational changes shape the rate and direction of scientific knowledge. They follow the three key elements of the SciSIP approach by carefully and precisely focusing on the phenomenon at hand, using that detailed understanding to link theories of scientists' behavior to careful data, and building empirical strategies in a way that enables causal analysis, normative conclusions and theoretical contributions.

ASSESSING THE GAPS IN SciSIP KNOWLEDGE

As outlined above, the SciSIP agenda presents far reaching research opportunities for scholars whose goal is to contribute to the social sciences, to our understanding of science and innovation in the economy and to have policy impact. A number of significant gaps in the current state of knowledge remain and can be usefully considered around the organizing framework laid out below. This describes SciSIP research according to the level of analysis at which the policy interventions are taking place: national rules and regulations, agency-level interventions, community norms and practices and organizational actions. I then propose three cross-cutting questions that apply to each level (see below). To illustrate this perspective and the gaps it reveals, I first describe research on high level rules and regulations then move to more micro-level analysis of organizational interventions.

- **National rules and regulations**: This includes research on the effectiveness of national rules and regulations on the rate and direction of scientific progress. A major area of focus includes research on the influence of the Bayh-Dole Act on university researchers (Owen-Smith and Powell 2003). In my own recent research, we have examined the impact of US regulations with regards to the funding of research in the area of human embryonic stem cells (Furman, Murray and Stern 2010). *Gaps at this level of analysis remain with regards to the role of international rules and regulations on science in the United States, and the ability of U.S. researchers to remain highly competitive and at the knowledge frontier in the light of growing global spending on scientific research. In addition it would be valuable to understand how the particular funding levels, structure and incentives of university systems in different countries impact downstream outcomes, such as scientific production, firm founding, and health & welfare, and how they contour the impact of government policies such as those related to intellectual property rights*.
- **Agency or University-level rules and norms**: Funding agencies, especially the Federal government, have a variety of opportunities to shape the rate and direction of scientific progress. Both areas have up to now been poorly understood. Recent work funded by SciSIP has made significant progress along these two dimensions but gaps remain. *In particular the influence of non-Federal funding sources particularly corporate funding and the growing foundation funding is poorly documented and understood*.
    - **Shaping the Direction of Research**: Funding agencies, as they select among research projects and shape the expectations and controls they place on researchers have a variety of opportunities to influence knowledge production. This has often been thought of as a black-box with the scientific community utilizing the peer review system as the best mechanism to self-regulate and shape direction. Pioneering analysis by my MIT colleagues shows that exceptional scientists are much more likely to produce innovative breakthrough science when using long-term grants that allow them exceptional freedom in the lab (Azoulay et al, 2010)[2]. This study raises the question of how researchers are encouraged to move into new and emerging research areas, and how to encourage ideas at the high-quality high-risk tail of the distribution.

      We must encourage more research to understand the impact of funding choices and funding incentives on the type of research outcomes. This agenda could also benefit from the analysis of scientists outside the U.S. in settings where different types of incentive systems exist. In line with recent interest in Challenges (prizes) as an alternative incentive mechanism, we should also extend this analysis to include other funding mechanisms or reward systems.
    - **Shaping the Disclosure and Sharing of Knowledge and Materials**: Funding agencies have an opportunity to shape the rate and effectiveness with which knowledge that is generated as a result of grant-making is shared among scientists and is diffused into the economy along productive routes. Among the most important and controversial rules shaping such impact of scientific research are the rules around intellectual property rights. This has been the topic of vigorous debate particularly with regards to the increasing levels of patenting within the scientific community. This is the research arena in which SciSIP researchers have made

[2] They do this by comparing the research profiles of similar biologists some of whom receive more open ended long-term funding from Howard Hughes while others receive more traditional R01-style grants from the NIH.

one of the greatest contributions, with their research informing policy discussions at the National Academies of Science, within the National Institutes of Health (NIH) and elsewhere. In particular, research has explored the impact of patenting on the rate at which that research is diffused within the scientific community and on the rate at which commercial or socially-beneficial products are developed (Murray and Stern 2007; Huang and Murray 2009; Walsh et al. 2003, 2005). *Extensive research documents the impact of IP, licensing and material sharing practices on scientists, but gaps in our knowledge exist with regards to the impact of these policies on both scientific knowledge production and economic impact (few studies examine both with Williams (2010) a notable exception). We also have a less systematic understanding of how to design the "intellectual commons" in an efficient and effective manner so as to promote and rapid follow-on research and commercialization. There is also a significant opportunity to extend these studies beyond the study of life scientists to explore differences across research communities in a range of disciplines such as chemistry, computer science, materials science etc*.

- **Community level activities**: The policies and practices that emerge from the scientific community also play a critical role in scientific progress and impact. Thanks to more systematic analysis of resource-sharing arrangements both informally (see Hauessler et al. 2009; Waltsh et al., 2005) and through formal mechanisms such as Biological Resource Centers, there is definitive evidence that investments in community-based infrastructure such as materials repositories and data repositories have a significant positive impact on the rate of scientific progress by enabling access, certification and sharing (Furman and Stern 2010). More recent analysis of the self-governance of scientific communities through the system of retractions has also pointed out the role of the community as a crucial analytic lens (Furman and Murray 2009). In another stream of research grounded in organizational theory and sociology, scholars have examined whether and how different community structures emerge in order to undertake the complex task of horizontal collaboration (e.g. Powell et al. 2004, O'Mahony and Bechky 2008) and collective work (Ferraro and O'Mahony forthcoming).

  At this level of analysis, critical questions remain unanswered: how are scientific communities formed? How do they coalesce around new research areas and what role might policy-makers play in such community formation? For example do mechanisms such as those used in DARPA enable community building and how does this shape the long run effectiveness of scientific communities?

- **Organizational Interventions**: Scientific research is an activity increasingly undertaken by collections of scientists organized into teams, networks, collaborations and networks. Recent scholarship highlighted the potential for significant productivity benefits of specific organizational choices (Cummings and Keisler 2005, 2007, Wutchy et al. 2007, Jones et al. 2008)[3]. Recent work on open source computer science communities highlights the complex and sophisticated nature of the organizational and governance choices that these groups of scientists can make (Dahlander and O'Mahony forthcoming) and their implications for the nature of the knowledge production (MacCormack et al. 2006, 2008). *However, there remained only limited research that examines the organizational choices of scientists for specific research projects—they choice of collaborations, organization of tasks in the lab, governance of the laboratory. In part this gap arises because of the historic perspective of the scientist as "loan genius." Moreover, the strong sense of autonomy among the scientific community has limited the research on choices that scientists themselves make*.

Opportunities for further research also cut across these levels of analysis with three of key importance:

i) **On what field has the SciSIP research been focused?** In other words, is the analysis focused on a particular scientific discipline or sub-field e.g. biology, high-energy physics, nanotechnology? In my opinion, too large a share of current SciSIP research (including my own) highlights the biologists to the exclusion of other arenas. For example we have little knowledge of the influence of policies on material scientists who, like biologists,

[3] Ben Jones, a leading scholars in the SciSIP field and author of several key papers in this area is currently a senior economist at the Council on Economic Advisors.

rely on complex materials, data, images etc. Our knowledge of chemistry, computer science & engineering remains fragmented.

ii) **On what outcomes has the SciSIP research been focused?** Is the analysis focused on academic publications, patents or marketed products? As noted above, these outcomes are now well documented in the SciSIP literature. More emphasis however should be placed on linking up different measures i.e. publications and patents and finding metrics that capture commercializable or commercialized products (see Williams 2010) or measures that capture the broader knowledge landscape such as recent analysis of the patenting of the entire human genome (Jensen and Murray 2005). In this regard, data on licensing would be more valuable than patenting data alone and yet such information (for ideas developed using Federal funding) is not available. I would strongly recommend that this be changed to facilitate greater and more systematic analysis using measures closer to the outcomes and impacts of economic interest.

iii) **On what part of the outcome distribution are SciSIP analyses focused?** It is important that SciSIP researcher evaluate *which* researchers and *which* institutions were most affected by particular policy interventions rather than simply highlighting the average impact of particular policies. How do policy interventions impact the distribution of knowledge outcomes? While there may be no impact on the mean perhaps interventions influence the distribution of outcomes—with more high and low quality research. How might policy-levers all levels influence different researchers? What is their marginal impact on different groups of scientists: those at elite highly funded schools versus elsewhere, or those with international co-authorship ties [4]. Studies that emphasize these distributional outcomes should be encouraged by SciSIP because it is from the richness and diversity of the scientific community that novel breakthrough outcomes arise. Studies could also fruitfully include analysis of the differential impact of policies on male versus female scientists [5].

SciSIP COMMUNITY

The SciSIP, led by the National Science Foundation with critical input from Program Officer Julia Lane has made tremendous progress in spurring a group of scholars to pioneer studies in the science of science and innovation policy. For some of these scholars, this represented an increase in their commitment to a field in which they already had an interest. For others, SciSIP was a new departure and an opportunity to move into a new and burgeoning field of great policy relevance and with significant intellectual challenges. The time is now ripe to move from funding of individual researchers to extending and emphasizing the SciSIP community. A stronger scholarly community—once established—will provide a number of critical benefits. It will be in a position to design and implement its own **common pool resources** and data sharing infrastructure to ensure that research methods, data and analytic tools are widely and effectively shared among scholars. At the moment there only a limited data-sharing infrastructure: the STARS program represents a key effort to gather new data, however many studies rely on complex historical datasets that incorporate rich and varied data sources but which are not shared across the community. While issues of confidentiality do arise, it is imperative that we follow the lead of the scientific communities we study and build a more effective infrastructure, norms and rules for data exchange and reuse [6].

Community building will also enable a richer interchange across scholars whose disciplinary training and identify lies in different areas. At the present time, my perspective on SciSIP is that there exist various sub-communities largely within dis-

[4] A distributional approach would enable SciSIP scholars to assess the impact of policies on numerous dimensions: researcher and institution status, nature of the researchers' institution (university, private firm, government lab, etc.); researcher cohort; collaboration type (e.g., within vs. across institution, state, country, and/or field); basic vs. applied research; journal status; article breadth (multiple subjects vs. single subject); journal reputation ("impact factor"); and network characteristics.

[5] Some of my own work has examined the theme of gender in scientific research. In "*An Empirical Study of Gender Differences in Patenting among Academic Life Scientists*" (Ding, Murray & Stuart 2006) we show that for over 4,000 life science faculty, after accounting for the effects of productivity, networks, field, and employer attributes, the net effect of gender remains: women patent at 40% the rate of comparable men. Other research in this spirit includes Ding et al. (2009).

[6] See Murray and O'Mahony (2007) for a detailed examination of the need for incentives for disclosure, reuse and accumulation in different knowledge communities and how these incentives are provided.

ciplinary silos who communicate but with little exchange across these traditional boundaries. For example, those who take an economics oriented approach gather as a community under the rubric of the Innovation Policy Working Group of the Bureau of Economic Research Productivity Program (including the Summer Institute Innovation Policy and the Economy activities). Not surprisingly however, this is not a forum in which sociologists, historians of science and technology or science and technology studies (STS) scholars share their research. In sociology there are few if any systematic gatherings of scholars with science policy interests and SciSIP researchers from STS and organizational behavior share similar concerns. One strong recommendation I have is for the NSF SciSIP program to fund the establishment of a "knowledge hub" that can orchestrate annual or biannual research meetings for interested SciSIP scholars. As I outline below in my comments on structuring SciSIP education, an effective cross disciplinary hub (that could be modeled on the Consortium on Cooperation and Competitiveness (CCC)) with governance from faculty from a number of key universities and rotating responsibility for cross-university research meetings and some (limited) cross-university doctoral training. Such a forum should also enjoy strong input from the NSF but overall would be most effective if it was organized with "bottom-up" support from faculty rather than managed directly by the NSF or other agency.

Building stronger linkages between the SciSIP research community and the community of science policymakers is another key pillar of the broader SciSIP community that remains to be constructed. At the present time, there is limited awareness of the key findings of SciSIP research among policymakers, and SciSIP scholars have only been engaged in a limited way in recent debates over key changes in science policy. For example, in the recent discussions over the role of innovation grand Challenges there was very little scholarly input from the SciSIP community; many prize and challenge designers and implementers were involved but there was little or no discussion of the tradeoffs associated with the use of challenges and the characteristics of the most effective problems that might be solved using challenges (and whose which are less likely to be tractable with this incentive system). Building stronger links to the policy community is a long-term task that starts with the education of a new generation of policy makers to become critical consumers and co-producers of SciSIP research. However in the short run, links could be established with different government research funding agencies through a series of targeted workshops that bring policymakers, agency employees and SciSIP researchers to focus either on the issues, problems and successes of a particular agency or to focus on cross-cutting issues of mutual interest. This is likely to require sustained engagement through a series of regular meetings and dialogues in order to build up trust, mutual respect and an appreciation of the problems and opportunities that our nation's research agencies, researchers and policymakers confront and the tools and insights that might guide them going forward.

SciSIP EDUCATION

Education is a critical element of the SciSIP agenda and should be a central pillar of SciSIP going forward. To date the program has focused largely on research and establishing a community of scholars among established academics. There is a pressing need to determine the best mechanisms through which to build up the educational aspects of SciSIP and to fund this education. The challenge of SciSIP education can be considered along two dimensions—education of producers of SciSIP research and education of consumers/practitioners of SciSIP research.

PRODUCERS

The educational requirements of SciSIP *researchers* are intensive; the approach requires strong disciplinary foundations in the social science. These must then be complemented by three other elements: theory, phenomenon, data/empirics:

- Theory: A perspective of the theoretical foundations that ground our understanding of the behavior of scientists, the scientific community, and scientific progress (these can include a microeconomic approach based on understanding incentives, the role of control rights etc. as well as a sociological focus on norms and practices or a psychological view)
- Data/Empirics: Strong data and empirical skills specific to science and science policy. SciSIP is grounded in a belief that while every scientific research project is different, systematic data gathering, the use of both large-scale analysis (with publication, patent, citation, collaboration data) and granular field-data, and careful empirical design will enable scholars to draw causal inferences regarding the impact of specific policy levers (at the national, regional, agency, university and lab level) on scientific productivity and impact.

Therefore education must give researchers the ability to identify, gather and analyze such data

- Phenomenon: A deep appreciation for the nature of scientific work and for the ways in which particular interventions in scientific progress have shaped productivity, impact or direction. This is challenging for scholars without a scientific training but is essential if scholars are to find the most effective research settings for their studies and if they are to make their work relevant to scientists and to science policy practitioners.

The education of the "producers" of SciSIP research is a critical challenge that should be a high priority for the SciSIP community. Specifically, we must strengthen the education of PhD students who will become the leading scholars in the field developing the research agenda, pushing forward and filling research gaps and pioneering new methods for the scientific and rigorous analysis of science and innovation policy. The skills needed to push this agenda forward are two-fold—first a strong disciplinary grounding in the "home' discipline—economics, sociology, social psychology etc. and second, an in-depth understanding of the theories, data/empirics, and the phenomenon (as outlined above).

Establishing PhD "SciSIP field concentrations" within traditional disciplinary PhDs: In my opinion, it is not fruitful to try and establish a new discipline within universities termed the "science of science and innovation policy". Instead I believe that it would be extremely valuable establish a "SciSIP field focus" within a variety of PhD programs within traditional disciplines including economics, sociology, public policy etc. At the present time, Public Policy schools are offering PhD degrees with a S&T policy focus. However, the promise of building a "science" of S&T policy is to extend the intellectual community well beyond the usual confines of policy analysis and ground the empirical and theoretical study of scientific productivity and impact in economics and sociology, as well as psychology and other adjacent disciplines. Therefore, as a complement to S&T Policy PhD education in Public Policy Schools it is critical to establish the field of "SciSIP" within the traditional education of PhD social scientists within their traditional departments. [It is worth noting that this is not an effective educational path for those from a scientific background to move into SciSIP. To do so requires a switch into a social science program to learn the foundations of the particular social science discipline followed by a SciSIP field focus].

Let me illustrate the proposal of a "SciSIP field focus" with the case of economics: Building a "SciSIP field focus" within economics would involve establishing a suite of courses and educational materials at a small number of leading departments (who could share materials, exercises, data etc.). This could then be complemented by educational 'bootcamps' which would bring these PhD students together (from across schools) in a common forum to build their skills, build community and hear from leading SciSIP scholars. Such an approach would mirror the development of entrepreneurship as a field of study within economics—an area that was pioneered by the "Entrepreneurship Bootcamp" funded by the Kauffman Foundation and taught at the National Bureau of Economics. The National Bureau of Economic Research has played an important role in coalescing much of the activity around education in the economic foundations of entrepreneurship through the Entrepreneurship Working Group now part of the Productivity Program. This has enabled vibrant cross-school collaboration not only on research but also teaching. At the PhD level this has helped to build up and educate a community of young scholars within economics departments and management schools who now have additional training allowing them to pursue this field within their discipline.

Hub and Spoke Approach: To build a strong and effective SciSIP-oriented PhD educational program will require using Federal education funding to actively seed a "SciSIP" field focus within at least 4 to 5 schools per disciplinary area (with at least two disciplines represented)—the Spokes. This should be supplemented by funding to develop an effective SciSIP 'Hub' for PhD education. The SciSIP Hub would coordinate activities that encourage coordination across these educational efforts, community building activities for the students involved, and the community "Bootcamp". One model to develop and effective SciSIP 'Hub' for PhD education is the Consortium on Cooperation and Competitiveness (CCC) which "links together scholars interested in long-run performance of U.S.-based companies and institutions" but with a recent focus on PhD-level education, training and community building among PhD students from a number of programs (based mainly within leading Business Schools) with the involvement of academic faculty. As they described, "No single U.S. university or graduate school contains a "critical mass" of scholars from diverse disciplinary backgrounds concerned with issues that are primary to CCC. Accordingly, the network structure of the Consortium is a significant source of strength."[7] A similar argument can be made with regards to the SciSIP agenda, suggesting that a similar consortium could be invaluable in advancing the PhD education and the scholarly community.[8]

CONSUMERS

The consumers of SciSIP research include Science and Technology policy makers as well as scientists and engineers at different stages in their education. Each of these groups could benefit from a deeper understanding of the results of SciSIP research. In particular, it should be a high priority of the SciSIP community to ensure that the SciSIP agenda is well understood within S&T Policy education; S&T Policy graduates are key stakeholders in the SciSIP research community will be leading consumers of our research, and partners in future research design and implementation.

Science & Technology Policy Masters Education: As students with Masters-level education in science and technology policy move out into the policy community, into research-based public policy organizations, and into the funding agencies that are the subject of much SciSIP analysis, they should be educated to be critical consumers of SciSIP research and to be co-producers of that research in partnership with academics. Much SciSIP research is relatively new and involves novel methods that are highly technical in nature and are not always taught to public policy researchers. Therefore, SciSIP has not yet been incorporated as a central pillar into the S&T Policy curriculum. For example, I supervise a number of MIT Technology and Public Policy students each year and find that they do not have an extensive and thorough grounding in the SciSIP approach, methods and results. Nonetheless, the students are quick to learn and start to use this approach in the course of their thesis work. However, it would be more effective to do this in a more programmatic fashion.

NSF therefore has an important opportunity to work with a number of leading S&T policy programs around the country to develop a curriculum for education in the imperative, methods and results of the SciSIP agenda. This will require a distinctive training from that provided to PhD social scientists for a number of reasons. First, these students can be expected to have less grounding in the data-oriented empirical methods that are common in SciSIP research. The focus should be on understanding the empirical approach and critiquing its validity and the robustness of findings rather than on replicating studies. Second, it is critical to share an understanding of the research design of SciSIP projects particularly those that are based on careful analysis of policy changes, policy experiments and other studies with a thoughtful counterfactual basis. This is a methodological approach that has been pioneered within SciSIP (as noted above) and is a critical element in the education of S&T Policy students. A greater understanding of the SciSIP approach will enable higher levels of collaboration between researchers and policy makers in the future. In particular, it has the potential to seed a higher willingness to work collaboratively with scholars to design and analyze policy experiments with the goal of increasing our understanding of the impact of specific policy interventions on scientific progress

Education of Scientists & Engineers: As has long been recognized in our analysis of scientific productivity, faculty and students engaged in leading-edge research in science and engineering play an important and distinctive role in shaping the productivity and direction of their laboratories. Indeed the organization and direction of large and increasingly complex research laboratories with collaborators that cross disciplines, cross universities, and often cross national boundaries is a daunting task. Nonetheless, we provide limited education to our science and engineering colleagues to guide them in this challenging activity. Offerings for scientists and engineers during undergraduate and graduate education are limited. As we develop new knowledge regarding the factors shaping research group productivity and the role of lab leaders in this productivity, it provides another opportunity for the National Science Foundation together with other leading funding agencies to work to provide such education. Effective education for scientists and engineers would involve three elements:

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[7] *http://businessinnovation.berkeley.edu/ccc.html*

[8] The CCC was funded by an initial endowment of $500,000 in May 1988 by the Walter and Elise Haas Fund. It has also been supported by grants from the Alfred P. Sloan Foundation in New York, the Smith Richardson Foundation, the Pew Foundations, the Ford Foundations, and the Herrick Foundation. From 1990–1995, the Sloan Foundations was the primary funding source for the Consortium. At the current time, the funding for doctoral activities is largely provided by individual schools supporting their students and hosting the event and by the Kauffman Foundation.

- **Teach science and engineering undergraduates** about the role of science and technology in society and the economy and given them a broader perspective on their technical education by highlighting the role of S&T policy. Focusing on the results of SciSIP oriented research will emphasize the importance of systematic, rigorous and data-driven approaches to policy, institutions and organizations. This will also provide them with tools to guide them in their subsequent careers, since they will run into the problems of the science and technology at every stage of their careers.
- **Provide PhD students** with short courses regarding the ways in which their research can be more productive and have a more rapid impact on society and the economy based on SciSIP findings. Focus on the key interventions in the process of knowledge production (according to the SciSIP framework)—government policies, regulations etc., university policies and practices, organizational choices. Make this relevant through a focus on the career choices they will have to stay within academia, move into business or focus on policy. For those staying at the bench (in academia or industry) examine how to maximize productivity and impact using the results of SciSIP research—organizational choices they have available, the role of incentives in research teams, the most effective collaborative processes they can use, etc. Highlight the key processes involved in shaping commercial impact including entrepreneurship and technology transfer and the SciSIP results on how these are most effectively deployed. Finally highlight the key role of policy in shaping some of their choices. A program of this type has not, to my knowledge been developed systematically for PhD students. This could be done in conjunction with other career-oriented activities provided by the NSF and other funding agencies to recipients of PhD grants and Fellowships.
- **Educate science and engineering faculty** to have a deeper understanding of how they can achieve greater productivity and impact, based on the systematic, evidence-based results of SciSIP research by running short courses at the university level (perhaps for new faculty), examining the organizational and institutional activities that they could undertake to increase the productivity and impact of their laboratory. This could be incorporated into existing efforts on grantsmanship, communications etc. Possible topics could include two dimensions: factors shaping productivity including lab organizational choices, lab size choices, and collaborative models and factors shaping impact including patenting, technology transfer, materials sharing, networking communication etc. Such an approach would provide a platform for sharing the findings of SciSIP research with academic researchers while at the same time having an on the ground impact on the productivity of investments in research. Finding a possible funder of such an initiative would allow for key educational materials to be developed. The participation of key scientific societies in this activity would also expand the set of stakeholders in the SciSIP agenda.

REFERENCES

Azoulay, P. G. Manso, J. Graff Zivin (2010) Incentives and Creativity: Evidence from the Academic Life Sciences. MIT Sloan Working Paper.

Angrist J. and J.S. Pischke (2008) *Mostly Harmless Econometrics*, Princeton, NJ: Princeton University Press.

Arrow, K. and R. Nelson (1962). *Rate and Direction of inventive Activity: Economic and Social Factors*. UMI Press.

Bertrand M., Duflo E. and Mullainathan S. (2004) "How Much Should We Trust Differences-in-Differences Estimates?" *Quarterly Journal of Economics*, 119(1) 249–275.

Cummings, J. N., & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. Social Studies of Science, 35(5), 703–722.

Cummings, J. N., & Kiesler, S. (2007). Coordination costs and project outcomes in multi-university collaborations. Research Policy, 36(10), 1620–1634.

Dahlander, Linus and Siobhan O'Mahony. Forthcoming. "Progressing to the Center: Coordinating Knowledge Work" *Organization Science*.

De Solla Price, D. (1970), "Citation Measures of Hard Science, Soft Science, Technology, and Nonscience", in C. Nelson and D. Pollock, eds. *Communication among Scientists and Engineers*, (Cambridge: Heath Lexington Books).

Ding, W. F. Murray & T. Stuart (2006). "An Empirical Study of Gender Differences in Patenting among Academic Life Scientists." *Science*, Vol. 313, pp. 665–667.

Ding, W., S. Levine, P. Stephan & A. Winkler (2009). The Impact of Information Technology on Scientists' Productivity, Quality and Collaboration Patterns. Berkeley Institute for Research on Labor and Employment Working Papre.

Fabrizio Ferraro and O'Mahony, Siobhán. Forthcoming. "Managing the Boundary of an Open Project," in *Market Emergence and Transformation*, W. Powell and J. Padgett, Eds.

Furman, J. and S. Stern. (2010) "Climbing Atop the Shoulders of Giants: The Impact of Institutions on Cumulative Knowledge Production," *American Economic Review*, forthcoming.

Furman, J. F. Murray (2009). "Governing knowledge production in the scientific community: Quantifying the impact of retractions". MIT Sloan Working Paper (under review).

Furman, J., F. Murray, and S. Stern. (2010) "Growing Stem Cells: The Impact of U.S. Policy on the Organization of Scientific Research," working paper.

Garfield E. (1955) "Citation Indexes for Science," *Science* 122: 108–11.

Griliches, Z. (1990) "Patent Statistics as Economic Indicators: A Survey," *Journal of Economic Literature*, 92: 630–653.

Griliches, Z. (1998) *R&D and Productivity: The Econometric Evidence*, Chicago, IL: University of Chicago Press.

Haeussler, C., L. Jiang, J. Thursby & M. Thursby, 2009. "Specific and General Information Sharing Among Academic Scientists," NBER Working Papers 15315.

Huang, K., F. Murray (2009). "Does Patent Strategy Shape the Long-Run Supply of Public Knowledge: Evidence from Human Genetics." *Academy of Management Journal*, 52(6).

Jaffe, A. (2006) "The 'Science of Science Policy': Reflections on the Important Questions and the Challenges They Present," Keynote Address at the NSF Workshop on Advancing Measures of Innovation: Knowledge Flows, Business Metrics, and Measurement Strategies.

Jaffe, A., M. Trajtenberg, and R. Henderson (1993) "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations," *The Quarterly Journal of Economics*, 577–598.

Jensen, K., F. Murray (2005). "The Intellectual Property Landscape of the Human Genome". *Science*, Vol. 310, 14 October 2005, pp. 239–240.

Jones, B.F., Wuchty, S., Uzzi, B., 2008. Multi-university research teams: shifting impact, geography, and stratification in science. Science 322 (5905), 1259—1262

MacCormack, A., M. J. LaMantia, Y. Cai and J. Rusnak (2008). Analyzing the Evolution of Large-Scale Software Systems using Design Structure Matrices and Design Rule Theory: Two Exploratory Cases, *Proceedings of the 7th Working IEEE/1FIP Conference on Software Architecture (WICSA)*, Feb 2008.

MacCormack, A., J. Rusnak and C. Baldwin (2006). Exploring the Structure of Complex Software Designs: An Empirical Study of Open Source and Proprietary Code, *Management Science*, Jul 2006.

Marburger, J. (2005). "Wanted: Better benchmarks," *Science*, 308(5725): 1087.

Meyer, B. (1995). "Natural and Quasi-Natural Experiments in Economics," *Journal of Business and Economic Statistics*, 13, 151–162.

Murray (2010). "The Oncomouse that Roared: Hybrid Exchange Strategies as a Source of Productive Tension At The Boundary Of Overlapping Institutions". *American Journal of Sociology*, forthcoming.

Murray, F. and S. Stern (2007) "Do Formal Intellectual Property Rights Hinder the Free Flow of Scientific Knowledge? An Empirical Test of the anti-Commons Hypothesis," *Journal of Economic Behavior and Organization*.

Murray, F., P. Aghion, M. Dewatrapont, J. Kolev and S. Stern (2010). "Of Mice and Academics: The Role of Openness in Science". NBER Working Paper.

Murray, F and S. O'Mahony (2007). "Exploring the Foundations of Cumulative Innovation: Implications for Organization Science," *Organization Science 18 (6): 1006–1021*.

O'Mahony, Siobhán and Beth Bechky. 2008. "Boundary Organizations: Enabling Collaboration Among Unexpected Allies," *Administrative Science Quarterly* 53: (422–459).

Owen-Smith, Jason, and Walter W. Powell. 2003. "The Expanding Role of University Patenting in the Life Sciences: Assessing the Importance of Experience and Connectivity." *Research Policy* 32(9): 1695–1711.

Powell, Walter W., Douglas R. White, Kenneth W. Koput, and Jason Owen-Smith. 2004. "Network Dynamics and Field Evolution: The Growth of Inter-organizational Collaboration in the Life Sciences." *American Journal of Sociology*. 110(4): 1132–1205.

Walsh, J., C. Cho and W.M. Cohen, "View from the Bench: Patents, Research and Material Transfers," *Science*. September 23, 2005, pp. 2002–2003.

Walsh, J, A. Arora and W. M. Cohen, "Effects of Research Tool Patents and Licensing on Biomedical Innovation," in W.M. Cohen and S. Merrill, eds., *Patents in the Knowledge-Based Economy*, National Academy Press, 2003.

Williams, H. (2010). "Intellectual Property Rights and Innovation: Evidence from the Human Genome", MIT Working Paper.

Wuchty, S., Jones, B.F. & Uzzi, B., 2007. The Increasing Dominance of Teams in Production of Knowledge. *Science*, 316(5827), 1036.

BIOGRAPHY FOR FIONA MURRAY

Fiona Murray is an Associate Professor of Management in the Technological Innovation and Entrepreneurship Group at the MIT Sloan School of Management and Faculty Director of the MIT Entrepreneurship Center. She received BA and MA degrees in Chemistry from the University of Oxford before coming to the United States where she received her doctoral degree from Harvard University's School of Engineering and Applied Sciences. Her research interests moved away from the bench to the study of science-based entrepreneurship, the organization of scientific research and the role of science in national competitiveness. After a lectureship at Oxford's Said Business School, Fiona joined the MIT Sloan School of Management where she studies and teaches innovation and entrepreneurship with an emphasis on the life sciences, chemicals and materials sectors. Fiona is well-known for her work on how growing economic incentives, particularly intellectual property (IP), influence the rate and direction of scientific progress. Fiona works with a range of firms designing global organizations working with a wide range of internal and external innovators (through traditional contracts and "Open Innovation" mechanisms) that are both commercially successful and at the forefront of science. She is also actively involved in policy debates over the appropriate use of IP and licensing in universities and more recently debates on when and when not to use patents to promoted discovery research in neglected diseases. She is also interested in the most effective organizational arrangements for the rapid commercialization of science including start-ups, public-private partnerships, the role of venture philanthropy, and university-initiated seed funding. Her research has been widely published in a diverse range of scientific and social science journals including Science, New England Journal of Medicine, Nature Biotechnology, Research Policy, Organization Science and the Journal of Economic Behavior & Organization.

Chairman LIPINSKI. Thank you, Dr. Murray. Dr. Teich.

STATEMENT OF ALBERT H. TEICH, DIRECTOR OF SCIENCE & POLICY PROGRAMS, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Dr. TEICH. Thank you, Chairman Lipinski, Ranking Member Ehlers, other Members of the Subcommittee. Thank you for the opportunity to testify at this hearing today. I am Al Teich, and I am the Director of Science and Policy Programs at the American Association for the Advancement of Science.

As you know, AAAS and I myself have been deeply involved in science and innovation policy for many years. Although this has been an active field of research at least since the 1960s, and it has produced a large body of literature and a substantial number of researchers, there is a feeling that the results of this work are not widely known or used among those who actually make science and innovation policy.

This was behind the frustration of Dr. Marburger in his speech, which led to the establishment of the NSF SciSIP Program. The SciSIP Program has a unique mandate to couple advances in fundamental knowledge about processes of scientific discovery and technological innovation with issues of relevance to policy makers. Among the features that differentiate the SciSIP Program from its predecessors is the fact that it is not just supporting individual research grants, but it is attempting to build a community of practice among researchers and to connect that community with potential users of the research, practitioners in the Federal Government.

AAAS has played an active role in building this community of practice through a workshop in 2009 that brought researchers together to learn from one another. In that workshop, we saw how SciSIP researchers reflect distinct disciplinary traditions that can inhibit productive interdisciplinary dialogue. Even in this not-very-large field, they can't always talk to one another. They may ask different questions, use different theoretical frameworks that employ different methodologies even when they may address seemingly similar topics.

At the same time, because of the academic reward system, SciSIP researchers, like many other researchers, seldom speak in terms that policy makers find directly useful. And as one speaker said at the 2009 AAAS workshop, policymakers are confronted with a Babel of tongues which leads them to ignore the experts and turn to other sources of information and advice. Next month AAAS will convene another workshop with NSF support. In that one we will try to connect researchers with customers in the government. We hope that that workshop will serve to allow the two communities to better understand each other's needs and expectations.

While projects like the AAAS-NSF-SciSIP workshops are an important step in building a community of practice, there is more that can be done. Here are a couple of ideas just as food for thought. Regarding research, researchers tend to communicate directly with their peers by journals and conference presentations in order to gain recognition in their fields. But few policy makers read those journals or attend those conferences. We need to find ways to encourage SciSIP researchers to communicate with policy makers, either directly or through the media, and to be rewarded and not penalized by less policy-oriented peers in their fields for doing so.

On the teaching side, although many of the university programs that provide graduate training in science and innovation policy are interdisciplinary, the training they provide is not always responsive to the needs and priorities of policy makers. It might be useful to strengthen ties between researchers and policy makers by engaging policy makers in helping to develop and review curricula as well as engaging them in teaching as adjuncts or guest lecturers. Some schools already do this. Others would do well to follow their lead.

Beyond education, there is another mechanism for promoting greater mutual understanding between researchers and policy makers. It is people transfer. One approach might be to create a program to give SciSIP researchers the opportunity to work in government for perhaps a year. Providing SciSIP researchers an opportunity to work in a policy making setting for a while, as we do for scientists and engineers in our Congressional Fellows Program, would allow them to gain firsthand knowledge regarding the needs, priorities, and modes of operation of the potential users of their work. Like our workshops, this hearing is an opportunity for the science policy community to hear from you, as policy makers, what research questions you believe SciSIP researchers should be addressing. I look forward to the Q&A as an opportunity to exchange ideas on that subject.

[The prepared statement of Dr. Teich follows:]

PREPARED STATEMENT OF ALBERT H. TEICH

Chairman Lipinski, Ranking Member Ehlers and members of the Subcommittee, thank you for the opportunity to testify today on the evolving subject of the Science of Science and Innovation Policy.

The American Association for the Advancement of Science (AAAS) is the world's largest multidisciplinary scientific society and publisher of the journal *Science*. The association, which celebrated its 162nd birthday earlier this week, encompasses all fields of science, engineering, mathematics, biomedicine and their applications. For more than thirty-five years, AAAS has demonstrated its commitment to and involvement in science policy issues with projects and activities such as the annual AAAS Science and Technology Policy Forum, the Science and Technology Policy Fellows Program, more recently with our Leadership Seminar in S&T Policy, and—most directly relevant to this hearing—our joint project with the National Science Foundation on the Science of Science and Innovation Policy (SciSIP). We have served the academic science policy community by publishing the first *Guide to Graduate Education in Science, Engineering and Public Policy* (known as the SEPP Guide) in 1985 and maintaining it as an online resource to the present day.

Background

From one perspective the Science of Science and Innovation Policy is not entirely a new field. Since the 1950s—and probably earlier—economists, sociologists, political scientists and others interested in public policies for science and technology have sought ways of measuring the value of research investments. Research articles on topics such as measuring Return on Investment (ROT) from research and development (R&D), national innovation systems, and comparisons of state and international standings have been published for many years. Government tools such as the 1993 Government Performance and Results Act (GPRA) and the more recent Program Assessment Rating Tool (PART) as well as their programmatic forebears, have attempted to quantify the value of government investment in various programs, although they have found R&D programs more difficult to assess than others.

In the 1960s, the National Science Foundation (NSF) supported the development of research and graduate education programs in science and technology policy in a number of universities. During the 1970s, it created the R&D Assessment and R&D Incentives programs, which funded research on some aspects of S&T policy in universities and non-profit institutions. In addition to the SciSIP program, the Foundation currently funds research in science policy and related areas through a number of programs, including the Science, Technology, and Society Program in the Directorate for Social, Behavioral, and Economic Sciences, and the Division of Science Resources Statistics, which has long provided data and analysis of importance to science policymaking.

The current Science of Science and Innovation Policy endeavor is unique, however, in its focus on drawing this research together into a systematic, coherent body of knowledge that can be brought to bear directly on national policy decisions. The National Science Foundation's SciSIP program is engaging the science policy community in research in theory, methods, models, and data development along four broad themes—workforce issues, innovation ecosystems, outcome measures, and data infrastructure. The program has an explicit mandate to couple advances in fundamental knowledge about processes of scientific discovery and technological innovation with issues of relevance to policymakers. As a field of research, the Science of Science and Innovation Policy has essentially been raised in relevance from a largely academic discourse to a field with a potential national impact.

Science and technology policy research can have and has had a positive effect on national policy decisions. R&D data analyzed and reported by NSF, as well as by AAAS, for example, has provided a roadmap for decades for policymakers such as the Members of this Committee as a guide for crafting the federal R&D portfolio.

As the NSF SciSIP program is still quite young and has been awarding grants for only a few years, we believe that it is premature to expect the results of that program's research to be incorporated into national policy decisions. Furthermore, the results of any science and technology policy research—whether within or outside SciSIP—must still run the gauntlet of the policy process.

In other words, simply because the research has been done, does not mean that it will be used. As helpful as the AAAS R&D budget analysis may be to its users, policymakers still make decisions based not only on research and analysis, but also on constituent needs, economic and political considerations, public opinion, and their own perspectives on national priorities. The same goes for studies that measure the effectiveness of federal programs. Politics is not a contaminant in the policymaking process. It is, after all, the essence of a democracy.

One way that policymakers can increase the likelihood that SciSIP research be used to inform the design of effective federal programs and the management of federal research investments is to conceptualize and design research that both advances knowledge in a discipline and answers specific questions relevant to policy. Some examples of such research topics are given in the NSF SciSIP program solicitation:

- examinations of the ways in which the contexts, structures and processes of science and engineering research are affected by policy decisions,
- the evaluation of the tangible and intangible returns from investments in science and from investments in research and development,

It should be pointed out that science and technology policy research is just as unpredictable as basic research in physics, chemistry, or life sciences, and decision makers must take into consideration the fact that some studies may yield unanticipated results and that some may serve long-term rather than short-term needs. It is important to ensure that an effective SciSIP portfolio balances research that reflects short-term and long-term policy interests.

Among the features that differentiate the SciSIP program from similar, past efforts, is its focus on building a *community of practice* among researchers in the many disciplines engaged in the study of science and innovation policy and its conscious effort to build bridges between this community and the practitioners in the federal government. Previous programs to support science and technology policy research have always focused primarily on providing grants to individual principal-investigators.

AAAS has played an active role in building this community of practice. We organized a workshop of the grantees from SciSIP's first and second rounds (FY 2007 and 2008) of awards to further construct this community. The outcome of that workshop was a report, titled, *Toward a Community of Practice*.[1] Next month we will convene a second workshop to continue building a community of practice by connecting the researchers with potential users of their results in the federal policy community.

[1] Albert H. Teich and Irwin Feller, *Toward a Community of Practice: Report on the AAAS–NSF Grantees Workshop*, March 24–25, 2009 (Washington, DC: American Association for the Advancement of Science, August 2009). Available online at *http://www.aaas.org/spp/scisip/scisip_report.pdf*.

There are challenges to building this SciSIP community of practice. A sizable group of researchers working on current projects as well as a large body of literature already exists. To an important degree, these individuals and this literature reflect distinct disciplinary traditions that can inhibit a productive interdisciplinary dialogue. These disciplinary clusters may ask different questions, draw upon different theoretical frameworks, and employ different methodologies and analytical models even when they may address seemingly similar topics (e.g., diffusion of innovation). Sometimes it seems they even speak different languages.

At the same time, as these researchers speak to an audience of their peers—albeit within their disciplines—they often do not speak a language that policymakers understand or find useful. A concern expressed at the first AAAS SciSIP workshop was that policymakers would be confronted with a "Babel of tongues" which would lead them to ignore the experts and turn to other sources of information and advice.

Another challenge is the fact that not all SciSIP researchers have experience working at the interface between academic research and federal policymaking. Some lack an understanding of the user community and who the policymakers are, what information or datasets they might require, or what other information they might need to know in order to effectively address national policy priorities. This is not to imply that these researchers are not familiar with the organization of government or the legislative process. Rather, it has more to do with the subtleties and nuances of the "game" and having an insider's perspective on the complex policy questions that decision-makers face and the interplay of interests that often shapes the debate over science and innovation policy.

The AAAS project is an effort to build these necessary relationships and to help SciSIP researchers and policymakers speak each other's language and better understand each other's needs and expectations. The goal is not to build a grand overarching theory of science and innovation policy, but to seek convergences among findings and a higher degree of understanding within the community about new perspectives and paradigms regarding science and innovation policy. It is to build a more interdisciplinary approach with an eye towards practical application by practitioners.

This community of practice is intended to assist individual researchers or teams of researchers by enlarging the set of variables and/or relationships that they consider in their work. It provides an opportunity to expose research findings to a wider set of critical perspectives and allows researchers to consider how their findings may relate to other disciplines and research findings in other areas.

As you know, the NSF initiative in the science of science and innovation policy stemmed from a sense that the body of science and innovation policy research does not seem to be very widely known or used among those who actually make policy in these areas. The AAAS SciSIP project is intended to facilitate interaction between relevant federal agency representatives and the growing community of SciSIP researchers, to help the agency representatives learn about emerging theories and models, and to connect research results with policy issues. At the same time, SciSIP researchers should be able to learn from the user community about their policy priorities and needs, which can help shape the direction of future projects.

While the SciSIP program and projects like the AAAS–NSF SciSIP workshop are an important step in building a community of knowledge and a strong foundation between research practitioners and policymakers, there is more that can be done.

Communication: As noted earlier, researchers addressing questions of science and innovation policy have tended to direct their work to colleagues, peers and others within their core discipline. This includes presentations at professional associations and conferences, and publishing in specialized journals (e.g., *Research Policy, Social Studies of Science*). This is quite understandable in view of the reward structure of academia and desire on the part of scholars in this field and others to gain recognition from their peers. Relatively few policymakers read such journals or attend academic conferences with any regularity. One could approach this problem in two ways: One approach would be to encourage policymakers to read these journals and/or attend more academic conferences. Given the constraints of time and energy they face, this seems unlikely to work. Alternatively, SciSIP researchers might seek, in addition to their regular publication outlets, opportunities to reach out to policymaking community either through themselves writing for those publications that policymakers do read or by cultivating opportunities to have their work reported in popular media.

Education and Training: This "clustering" of a narrow core discipline has not only worked its way into the presentation of information, but in the education and training of students studying science and innovation policy that only encourages self-organization of a research area. Although the AAAS SciSIP program may help in encouraging the development of a more interdisciplinary curriculum, it isn't the central goal of the project.

As the committee has noted, there are about 25 U.S. universities that offer graduate education in science, engineering and public policy. There is no central organization for these programs and do not share a common curriculum or even a common nomenclature. The AAAS *Guide to Graduate Education in Science, Engineering, and Public Policy* mentioned earlier lists programs such as Science Policy; Technology Policy; Science and Technology Policy; Science, Technology, and Public Policy; and Engineering and Public Policy. In addition, many programs in Science and Technology Studies (STS) include a policy component, and some programs in public administration and public policy provide for a science and technology concentration. Furthermore, these graduate programs can be administered within different academic departments: Schools of Engineering, Public Administration, International Affairs, etc. Some programs allow for students to take coursework outside the traditional curriculum in other tangential fields (e.g., law), while other schools do not.

Many of the graduates of these programs have gone on to very successful careers. Nevertheless, it might be useful to have people from the policy community—the potential users—involved in reviewing the curricula of these programs as well as engaging in teaching as adjuncts or guest lecturers. This is obviously easier for universities in the Washington, DC, area to do than for those in other regions and some institutions in this area do it regularly to good effect. But it is worth the effort and expense for all.

Fellowships: Another potential mechanism for promoting cross-fertilization of ideas and greater understanding of the policymaking community's needs, is to create a Fellowship program for SciSIP researchers to work in government for one year, similar to the AAAS Science and Engineering Policy Fellowship that allows scientists an opportunity to work at a federal agency or in a congressional office or committee. Intergovernmental Personnel Act appointments could also be used for this purpose. Providing science and policy researchers and/or graduate students an opportunity to work in a policy office of the federal government would allow them an opportunity to learn first-hand the language, needs, and priorities of an agency, department, or congressional committee.

Conclusion.

I would like to thank the Members of the Subcommittee for holding this hearing and for their interest in the SciSIP program and the area of science and innovation policy research. I look forward to working with your staff as we prepare for the next AAAS workshop. Like our workshops, this hearing is an opportunity for the science policy community to hear from you, as policymakers, what research questions you believe SciSIP researchers should be addressing. I look forward to the Q&A as an opportunity to exchange ideas on that subject.

BIOGRAPHY FOR ALBERT H. TEICH

Al Teich is Director of Science & Policy Programs at AAAS, a position he has held since 1990. He is responsible for the Association's activities in science and technology policy and serves as a key spokesperson on science policy issues. Science and Policy Programs, which includes activities in ethics, law, science and religion, and human rights, as well as science policy, has a staff of 40 and a annual budget exceeding $13 million. He also serves as director of the AAAS Archives.

Teich received his bachelor's degree in physics and his PhD in political science, both from M.I.T. Prior to joining the AAAS staff in 1980, he held positions at George Washington University, the State University of New York, and Syracuse University. Al is the author of numerous articles and editor of several books, including *Technology and the Future*, the most widely used college textbook on technology and society, the twelfth edition of which will be published in 2011 by Cengage Learning.

He is a Fellow of AAAS and the recipient of the 2004 Award for Scientific Achievement in Science Policy from the Washington Academy of Sciences. He is a member of the editorial advisory boards to the journals, *Science Communication; Science, Technology, and Human Values*; *Review of Policy Research*; and *Renewable Resources* and has been a consultant to government agencies, national laboratories, industrial firms, and international organizations. He is past president of the Washington Academy of Sciences; former chair of the Board of Governors of the U.S.-Israel Binational Science Foundation, where he remains a member of the executive committee; a member of the Technical Advisory Committee of the Maine Space Grant Consortium; the Norwegian Research and Technology Forum in the United States; the Advisory Board of the University of Virginia's Department of Science, Technology and Society; the Program Committee for the 5th EuroScience Open Forum (to be held in Dublin, Ireland, in 2012) and the Council of Advisors for Research and Innovation Strategy of the National University of Singapore.

Teich speaks frequently before audiences in the U.S., as well as Europe and Asia. He has appeared on National Public Radio, CNN, C–SPAN, as well as various other electronic media and has been quoted in numerous print media, including *The New York Times*, *The Washington Post*, *National Journal*, *The Chronicle of Higher Education*, and *CQ Weekly Report*.

Chairman LIPINSKI. Thank you Dr. Teich. I am going to start questions. If you want to leave to get over to vote I think we have about four minutes left, probably, in the first vote. But I think this vote is going to last a long time. But we will—if the witnesses can come back afterwards—it is probably going to be about an hour though. I am not sure if any of you have—we will have to leave at that point, but—yes, Dr. Ehlers, yes. You have a suggestion?

Mr. EHLERS. No, just a quick comment which shows the importance of this topic and why we should come back if we can depending on the votes. But I would simply observe that the current process in the Congress is that science policy is set by the Appropriations Subcommittees. Money controls everything and when they decide to give a certain amount of money to a certain project, that basically ends up being the decision. That totally ignores the input of other scientists and SciSIP's folks who have a much greater interest. So something you can think about in the meantime is how that could be addressed without throwing out the Appropriations Committee entirely which is probably impossible. So I just wanted to mention that, and I hope you will have some brilliant ideas on how we could practically address that particular problem. My staff just informed me that 300 people have not yet voted, so we could probably walk over instead of running over. But I hope the votes don't run too long. And I would be delighted if any of you would take on the challenge too and follow this.

Let me add one quick last comment. When Newt Gingrich was here he wanted to double the funding in NIH, which did happen in the Appropriations Committee. I argued that we should have equal funding increases for NSF, treat all the sciences equally. He said we will do that one next. Well, unfortunately we lost the majority and so the next—they were happy. But today I have heard Newt say in numerous speeches that one big mistake he regrets is not having increased NSF and the other hard sciences at the same time when he increased NIH. So let that be a moral note for all of you who hope someday to be the Speaker of the House of Representatives. Thank you very much.

Chairman LIPINSKI. I am hoping that you can make sure you spread that work amongst your colleagues before you leave.

Mr. EHLERS. Yeah.

Chairman LIPINSKI. So you can help us—who really wants to make sure we get that done, get that done in the future. Well, you now have your homework assignment. You will have probably about an hour and we will be back. Hopefully sooner than that, but it is going to be at least 45 minutes I would say and I look forward to hearing your answers. I am most interested in how we really make these connections. Dr. Teich, I appreciate some of your comments. I would like to delve maybe some more into how we can, having been a—now as a political scientist, and talk about not—

policymakers don't read the journals. Political scientists weren't reading the journals because it didn't really speak to them, much less the policymakers. But I would like to delve into that also some more, how we can improve that. But the Subcommittee will be in recess.

[Recess.]

Chairman LIPINSKI. I call this hearing back in. I will now start the questioning. I understand Dr. Sarewitz has to leave at four o'clock so we will—each of us will get the chance to ask some question before you have to leave. So I will now recognize myself of five minutes and will begin with Dr. Sarewitz.

You mentioned in your testimony that most of the data available for SciSIP analysis are input/output data, level of funding, number of graduate students, patents, et cetera, publications. And if you—data offer an incomplete view of societal value of S&T investments. So what would you suggest that we do to better characterize and measure the social outcomes of R&D?

Dr. SAREWITZ. Okay. Thanks for asking that. It actually—see, how should I put this—it—my answer will reflect a diversity of perspectives here. I think we can all agree that the process—and Julia actually wrote about this wonderfully in *Science Magazine*—that the process that leads from R&D to a particular desired social outcome, for example more employment or better health, is extremely complex, with many different inputs into the process. But I think that measuring is one way to understand things but also very close case-based and textual analysis is another way to understand things. And my view is that the system is so complex that we are probably not going to come up with a big theory of how you can predict social outcomes from science and technology inputs. But we are going to be able to develop a number of principles that reflect our understanding of particular examples.

So I think the kind of data that—and I wrote about this a little bit in my testimony—that we really need a kind of—data that we are lacking that would be very important is very granular case studies of both successes and failures in this full range of linkages from laboratories to social outcomes for a particular range of scientific priorities. And I think by doing that we will be able to elicit a set of general guiding principles that can help you guys distinguish between policy decisions that make sense and policy decisions that don't make sense. I guess I am a little skeptical of the idea that we will ever be able to actually predict with precision. But I think we can be a lot smarter about the basic set of assumptions if we can develop some really close case studies from end to end, case studies that show great detail.

Let me just quickly say, one, we are looking, for example, at Arizona State we are looking at the development of the solar power industry in Arizona, because obviously we have a lot of sun there. And so it is not—one of the important inputs of course is R&D into the solar power industry, but there are all sorts of local dynamics, from water availability, land use, obviously regulatory frameworks, all of those things are important and they are not generalizable.

So while I think we can develop a very rich case study around solar in Arizona, I don't think we should necessarily worry about a grand theory. So we should develop best practice case studies looking very closely at the full process of leading from the R&D activities themselves to the societal outcomes.

Chairman LIPINSKI. Did anyone else want to—any of the witnesses want to comment on that? Have anything to add to that? If not I am—now I think about this in your answer, Dr. Sarewitz and I—do we have the data available right now? Would we need to do a better job of collecting data so that we can do this kind of research? The whole generalized ability of this is when you look at almost anything that is really a social process. I always go back to my days as a political scientist in trying to put together these theories that will predict outcomes and the struggle with doing that and trying to make political science into physics. How much can we do here when we are talking about doing the SciSIP research, and what we can really glean from the data that we have?

Dr. SAREWITZ. So let me just say this. A diversity of perspectives is here and that is good. I mean, I think it is a rich field and it needs to bring lots of perspectives together, from the highly quantitative model to the more case-based qualitative work. We need all of that. I think we know a lot. I think Dr. Teich's point about the problems of communicating what we know is really important, and that thinking about how to communicate more effectively the things that we already know, for your benefit, is an essential part of it. And so two things need to go on simultaneously. They are—this field is really only just beginning to kind of get its legs.

Dr. Murray talked about how she's been doing it for a long time, didn't know there was a field out there. I have been doing it for a long time as well, but more or less in small groups. So Dr. Lane's, you know, efforts to create a community does two things. One is, it creates—it has created the intellectual momentum that we are going to need to move the field forward, but it also allows us to really collect what we know already, which I think is considerable, and present that, if we can figure out how to communicate effectively. I would be glad to talk about that a little bit, too, if you would like.

Chairman LIPINSKI. Well, let us come back. Right now I am going to yield back my time. I assume my time is up and I want to yield now to recognize Dr. Ehlers for five minutes.

Mr. EHLERS. Thank you very much and I don't have any questions for you Dr. Sarewitz, other than to note that we produce weather today that is very close to what you have back home. We did put a little moisture in the air as well, so that is a little different.

Dr. SAREWITZ. I wouldn't be dressed like this either.

Mr. EHLERS. That is true. But I appreciate you coming. I don't have any questions for you that have not been either answered or explained already. But I would like to ask on the two ends of the panel, Dr. Lane, Dr. Teich, you both are quite familiar with the Congress and how it operates. Do you have any suggestions on what someone in the Congress could do to help educate our Members about the importance of science policy and what it should be, what it can do, what it cannot do, and any wisdom you could give us I think would be very helpful as we go forward in the Science Committee and try to—I hate to use the word modernize, but you know what I am talking about. Just try to get the workings of the

House of Representatives and the Senate to reflect reality, and what should be done about the Science of Science Policy and in particular, what role science policy should have in guiding the Congress on the very difficult issues we have, particularly those relating to funding. So we will start with you, Dr. Lane, and go to Dr. Teich, and also Dr. Murray if you have any comments on that.

Dr. LANE. Well, thank you very much for that thoughtful question. I am not as wise in the ways of Congress as you, obviously, so this is very much in the spirit of the suggestion rather than an expert approach. One of the things that I think is most important, that will get Congress to understand the value of science investments, is evidence. If there is clear evidence of the impact of science investments, on the four sets of dimensions—social, scientific, economic, and work force—that both has a qualitative aspect, that is, that there are real people affected, and there are real advances that are made in the quality of life, but also quantitative. That is, when you can unambiguously say there were—this amount of investment led to a whole variety of different sets of outcomes, and that tracer is clear. I think that is what gets people in Congress's attention, because obviously they are serving the American taxpayer, and that is what the American taxpayer is interested in finding out.

Mr. EHLERS. Okay. Dr. Teich.

Dr. TEICH. Yeah, I think I would turn that around a bit and point out that it is really very much up to us in the SciSIP and science policy communities to communicate effectively with you in the Congress. You have so many messages coming at you from so many different directions that somehow, what we need to do is differentiate the kinds of information that we have, hopefully evidence-based. And we have to recognize that it is not the only influence, the only thing that you have to take into account in making decisions.

That decision—I was struck by something Chairman Lipinski said about making political science into physics. I started out, I got an undergraduate degree in physics and my Ph.D. in political science, and you know physics; in some respects physics is lot easier, you know. You start, you can—my freshman physics, you know, assume a frictionless plane. Okay, well you can assume a frictionless plane and it works in some respects. Assume a frictionless Congress and you know you have got nothing. It doesn't make any sense. So there is a—politics isn't neat. It is not, and data doesn't always trump a lot of other factors that go into decisions. We have to understand that we have to communicate within that framework, and then I think it is up to you in the policy community to make use of that. Best I could do on short notice.

Mr. EHLERS. If we had a frictionless Congress, things might go better. Dr. Murray, do you have any wisdom to add to this?

Dr. MURRAY. I am not sure it is wisdom. It is certainly a thought I have, is that—I think it is important for us to provide data that is meaningful. I think it is also important for us to think about studies that really show, again, sort of causal impact. So I think that there is some new work that has been funded by SciSIP and in other places where we can say, look, you know we did have a quite big shock to the system in terms of additional funding going in quite rapidly through the Recovery Act, and some of the spending in other countries that means very big shifts in research funding allocation that have happened relatively quickly. And so I think we have a lot of opportunities to both study those things and also to marshal that evidence—because I think you could always go in and just say, we want more for science and technology, and everybody has heard that and of course we are going to say that. And so I think that coming in with evidence that says—when you get these shifts, both in level and distribution, real things happen, real differences, and outcomes happen. I think if we can marshal that evidence in a persuasive way, then I think we can be much more informed and are much more likely to be listened to.

Mr. EHLERS. Okay. Well, those are very good comments. I worry a little bit about the Congress requiring a lot of evidence because you know many experiments don't come out that well and the Congress would say, now—next time you come around, say, well, you know, you sold me on this project and nothing really good came out of it. And that is pretty hard to overcome.

I really appreciate the ideas you have presented and the comments you have made today. And it has given me some new insight. And I really do think that we need more concentration on this not only in the Congress, but among the science policy community. And what I said several times earlier on about this was—I deliberately said "Unlocking the Future" because I wanted someone in the future to write better, something better about science policy and something along the line of Vannevar Bush's book which was probably—it could have been what we want today, but nevertheless he addressed a lot of issues that had to be taken into account. He himself was very different but very concerned about the fact that Congress did not pick up on a lot of his suggestions, and particularly one creating a different version of the National Science Foundation, but yet out of his work and his arguments, eventually, I think some ten years after he wrote the book, they did start establishing the National Science Foundation. So even though he regarded his work as a failure because the Congress didn't pick up on it, eventually it did happen.

So I encourage the science policy community to become very active, and frankly, also very aggressive in your addressing Members of Congress. It would not hurt at all if a few people from the science policy committee ran for Congress and got elected. I just had an experience on the Floor not 10, 15 minutes ago. Someone came up to me and had been present this morning at the Science Committee meeting and said Vern, what in the world are we going to do without you, because I had used my scientific knowledge in a number of statements. And I say well, I think, you know I don't think I do that much. They will get along. But the matter of fact is there won't be any scientists left on the Science Committee. And it is just helpful to be inside all the side discussions that are held. It is good to have someone there.

So I repeat, as I have done with every speech I have given to every engineering or scientific group: run for Congress. We need more scientists in the Congress, and incidentally not just for the benefit of science, but most scientists are fairly clear thinkers on issues and frictionless or not, and they have a lot to contribute to the operation of the governing bodies of this country.

I would actually say I probably got—had much more impact at the state level because I was truly a rarity there. And most state governments don't have the resources to have scientists on staff. And I had endless amounts of work to do trying to resolve things, such as resolving difficulties between optometrists and ophthalmologists, or dealing with questions such as the foam installation that was the rage for awhile pumping into homes and now people are sick from formaldehyde fumes from that. These are issues no one in the state legislature was equipped to deal with, and I resented all the time I had to spend on it, but at the same time it was very useful to society. So spread the word, please, and thank you again for being here. I appreciate it very much.

Chairman LIPINSKI. Thank you, Dr. Ehlers.

Mr. EHLERS. Chairman, I beg your pardon but I have a bill on the floor that has just been called up and I have to rush down there to speak on it, so my apologies.

Dr. TEICH. Mr. Ehlers, before you go I just want to say on behalf of AAAS, the science community and the SciSIP Community, we are going to miss you. Thank you for everything that you have done.

Mr. EHLERS. Thank you very much. I appreciate that.

Mr. LIPINSKI. Dr. Ehlers, we will assume I have your permission to continue here and wrap up. See as there was no objection from Dr. Ehlers I will—I was asking for your permission to continue on and to wrap up here. Thank you. Okay. You are still here, and frictionless. I will now recognize myself for five minutes. I—it is funny, the—talking about the assumptions and comparing physics to—or trying to make political science into physics. I had a colleague of mine in grad school in political science who was also, like myself, had a background in engineering before going to get a Ph.D. in political science, and he always would say that political science had physics envy and we were trying to be physics. Now it did not stop. Political scientists, and even focusing specifically on Congress, Congressional scholars did not—some were not afraid to make assumptions that wind up where they were talking about something that was supposed to be Congress but pretty much—very much not Congress anymore after all the assumptions that were made, and make all these assumptions that said, with this, we were dealing with a imaginary legislature, but then we are going to pretend like it is Congress. Hopefully that is not the type of work that is going on here in SciSIP.

I want to make sure—one thing I wanted to ask—Dr. Murray talked about this, and I want to ask everyone about, if they have any more comments on this. Because I know Dr. Murray, in your testimony you talked extensively about it as training, you know, more people to be able to do this research in having programs that produce the type of, you know you, go into what she is talking about, Ph.D. programs, but we need to, in general, produce people who can do this, to do this work. And I know that people who are doing this, researchers in this field, are located—as I mentioned in my opening statement—in all kinds of different places.

Dr. Murray, I know you are in the business school. Are there any suggestions—I don't know if there is anything else you wanted to add, Dr. Murray, or Dr. Teich, or if Dr. Lane would want to say anything about where we are right now in terms of programs that are producing researchers that can do SciSIP—where that is going. Are there programs such as this that are out there? If not, where are they coming from? Is this something that we need to, you really think we need to do more of and concentrate on, to found such a specific field like this, or can we get by with people coming from different fields. Is that the way to do it? So I just want to throw that question out there. As a, former political science academic I am interested, in you know, questions like this in terms of what we are doing out there in higher education.

Dr. LANE. So I think that is a very interesting question. It is an important question. The main area—if you are going to train people in doing this kind of research, they are going to go into the field and do the kind—develop the kind of skill sets that we need. You want them to be able to get tenure. You want there to be able to be a career ladder. And the program, besides SciSIP, isn't sufficient to support an interdisciplinary field in its own right. Nor is it, I think, possible to develop career paths for such a narrow set of skills.

So I think what is important is to convince very smart people in economics, and sociology, and psychology and many of the other areas, that feel that science policy is a really important and interesting field, that they can bring their skill sets to bear on, to answer important science policy questions and that they can publish and get—advance within their own disciplines. So I think that is what is critical rather than trying to establish a separate field in its own right. I don't think that is feasible given budget constraints and so on. So that is what we have been explicitly been trying to foster, to make it an intellectually challenging, exciting, and publishable type of field.

Chairman LIPINSKI. You going to comment Dr. Murray?

Dr. MURRAY. Yes, I think it is—I think that there are three different constituencies for education. One is the Ph.D.'s, who are probably the producers of research. The other—and then there are the science and technology policy, typically Master's students, who tend to go into policy roles who I think we need to educate to be better consumers [of this research] and also people who really understand what we do and can help do it with us. And then finally there are, probably, the scientists and engineers themselves who could benefit from understanding some of this. We then become a sort of bottom-up constituency who can shape agencies and so on. I think on the Ph.D. side, I think Julia is exactly right. I don't think you can have a new discipline of SciSIP. I think it is both too small, and, in fact, one of the great values of SciSIP is indeed the fact that people come from these other strong disciplinary foundations. I think what we do need to emphasize, though, is a serious, a sort of a field focus.

If you think of a Ph.D. in political science or economics, mostly there is a field. At the moment I don't think many places already have a field focus in something that we would recognize as SciSIP. And I think that we could go a long way towards funding things that would help establish that. You know, Ph.D. education requires, especially in something like this, you know, significant evidence, and teaching materials, and data sets, and things so that students can work on this, and so that we can effectively collaborate across a set of schools to really begin to develop material, share expertise. And then potentially bring the Ph.D. students together as a community so that they recognize one another even though they are always going home and we know we are educating them to be hired by business schools' economics departments and so on.

So I think that there is an opportunity there as long as we make sure we know what we're trying to accomplish, which is not a new discipline. I think on the science and technology Master's side, I am less familiar with that because even though I do SciSIP research I don't teach in the technology and policy program at MIT. But that in and of itself tells you something, which is that there is, I think, a little bit still of a disconnect—that the traditional science and technology policy programs have not necessarily sort of incorporated SciSIP research into their teaching material.

And so again I think that there is an opportunity to do something about that. Not to insist that people do it, but to provide opportunities to develop a really effective curriculum so that as people go into different—into their careers as policy makers, they understand what we are trying to do, some of the methods, they know good SciSIP research from less good SciSIP research and they themselves can say oh, you know, we are doing something in our agency. We could actually run that as an experiment that could be studied. We could try two different ways of allocating funding and we could really do the analysis with real data. And I think if we could educate people to that level, we would have a much better interchange in the long run, and it would be a really—it would be a very vibrant community.

Chairman LIPINSKI. And Dr. Teich.

Dr. TEICH. Yes, well, a couple of things worth noting in response. First of all, there are and have existed for some time about 25 programs in universities around the United States, and some outside the U.S. in addition to those 25. They have provided graduate education in science—in what we have called science, engineering and public policy, and which overlaps quite substantially with what we now call SciSIP. We had many years ago we published a guide, an old-fashioned paper type guide. We now have a website on the AAAS website that links to all of these programs which could help people find them.

I don't see this as a discipline either. As was said a moment ago, it is a—my analogy is that it is more like a field of, let us say, area studies in which, like Latin American studies, for example, or African studies, it is a field in which many different disciplines contribute to an understanding of what is going on in this business. So that is one thing that I wanted to mention.

Another thing is that there is—there are a lot of young people who are very interested in this, and we need to encourage them. There is an organization—an international non-profit—it is incorporated as a 501(c)3 called Triple Helix, Inc., which has about 500 students from many universities, prestigious universities around the world, which provides an opportunity for students to educate themselves about the relationships between science and society, in ethics, business, and law. They actually publish an undergraduate journal, which—a couple of people from AAAS's staff serve on their Board of Advisors. They also have a poster session at the AAAS Annual Meeting.

And then there is a group called the Science and Technology, or STGlobal Consortium, which is an association of graduate students and these programs that I mentioned, which also brings together people. They have a conference usually here in Washington in collaboration between the AAAS and the National Academies to provide an opportunity for younger people to explore this field, get into it if they're interested, and some of them do. We at AAAS have hired on our staff several people who have been graduates of these programs—master's degree graduates from these programs and some have been highly successful and are really leaders, young leaders in the field.

So I am an advocate for this kind of education and I think we are doing it. I think it will be useful for Congress, and for Members of Congress if they were aware of this, to provide, I would say, moral support by speaking at their meetings and having staff attend and so on. So I am—I will leave it at that.

Chairman LIPINSKI. Well, thank you, Dr. Teich, and I had a—when we were going out for votes, I was getting in the elevator and someone who had been sitting in the audience, he went up and thanked me for having this, the hearing on SciSIP, and said, how do Members really become educated? How do you have the time? And I said, it is very, very difficult and what it really takes is a dedication to, you know, being educated, because the incentives, other than really wanting to do a good job and being interested in this topic, aren't there. It is unfortunate.

But the good thing is that we do have staff who are well educated in these things and it leaves me to thank the staff for all their work that you do, and all the staff on the Science Committee do an excellent job so that we—help us to do a better job here, hopefully, on the Science and Technology Committee, help the Members do a better job. So I thank the staff for all the work that they do.

With that I want to thank the witnesses for their testimony. The record will remain open for two weeks for additional statements from the Members and for answers to any follow up questions the Committee may ask of the witnesses. With that the witnesses are excused and the hearing is now adjourned.

[Whereupon, at 4:23 p.m. the Subcommittee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Julia Lane, Program Director of the Science of Science and Innovation Policy Program, National Science Foundation

Questions submitted by Chairman Daniel Lipinski

Q1. You describe in your testimony an effort by NSF to improve upon the way in which NSF interacts with its proposal and award portfolio. Can you please elaborate on this effort? How might the new tools you are developing to be utilized in the development of future NSF budget proposals, new programs or other aspects of policy development at NSF? Also, can you please elaborate on the relevance of this effort to the broader impact criterion?

A1. The SBE and CISE directorates have established a joint subcommittee of their directorate advisory committees that is exploring new ways to analyze and oversee NSF's portfolio of proposals and awards. The subcommittee is developing a report that will be available to NSF leadership and the broader community in November 2010. A particular focus of the report will be identifying tools to help NSF program staff better identify and support transformative and interdisciplinary research and gauge the broader impacts of NSF's investments. The report will also advise NSF on how to better structure existing data, improve use of existing technologies to complement human expertise, and characterize its programmatic data.

These new tools and resources have many potential uses in establishing, justifying, and implementing budgetary priorities for NSF. A principal aim is to assess the alignment of NSF's priorities with emerging trends and opportunities in science and engineering research and education and to assess NSF's impact on areas of national priority. Other potential benefits include improving the efficiency of NSF's core business processes by providing program officers with new resources for managing the merit review process.

Appendix 2:

Additional Material for the Record

STATEMENT OF THE CALIFORNIA HEALTHCARE INSTITUTE (CHI) SUBMITTED BY REPRESENTATIVE BRIAN P. BILBRAY

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CALIFORNIA HEALTHCARE INSTITUTE

STATEMENT OF THE
CALIFORNIA HEALTHCARE INSTITUTE (CHI)
SUBMITTED TO THE
SUBCOMMITTEE ON RESEARCH & SCIENCE EDUCATION
HOUSE COMMITTEE ON SCIENCE & TECHNOLOGY
SEPTEMBER 23, 2010

INTRODUCTION

The California Healthcare Institute (CHI) is the public policy association which unites over 275 of our state's leading biotechnology, pharmaceutical, medical device, and diagnostics companies, premier universities and private research institutions, and venture capital firms to advocate policies that advance biomedical research, investment and innovation. We are grateful for the opportunity to provide comment on science and innovation policy. Additionally, we applaud the Research and Science Education Subcommittee for its continued attention to issues surrounding research and development programs, investment in science innovation, and workforce development.

BACKGROUND

California's biomedical industry, employing 275,000 across the state, has been a powerful engine of economic growth for the Golden State for nearly 30 years. California has built a workforce and industry that is vital to the state's economy — and to the country's continued leadership in scientific, engineering and medical innovation. Moreover, the partnerships and technology transfer agreements among California's biomedical companies and academic centers continue to nurture excellence in education here and innovations that are improving health, healthcare and quality of life the world over.

Many of the jobs within the biomedical industry require high levels of specialized training, and the industry employs a substantial number of scientists, researchers and clinicians with doctorate degrees, both Ph.D.s and M.D.s. At the same time, opportunities exist within academia and companies for individuals with high school diplomas and undergraduate degrees. The industry also employs professionals with business, information technology, human resources and other areas of expertise.

To continue to drive innovation in medicinal compounds and medical devices, researchers must be well-versed in math and science and insatiably curious about human conditions and diseases. Recruiting, managing and retaining today's brightest is a challenge that companies and universities spend significant resources addressing.

Yet the biomedical industry must and does take the long view on workforce development. Through a number of programs, California companies are working to develop elementary and high school students' interest in math, science and engineering. Some programs are directed at the students themselves, while others are designed to give their teachers the tools and insights they need to make the sciences more compelling and relevant to young people.

California's commercial and academic organizations also have collaborated in a number of ways to draw college students and working adults to life sciences careers. From biotechnology curricula at community colleges to business-focused skills training in post graduate programs, universities and industry are working together to ensure that prospective employees are equipped to succeed.

An example is the Professional Science Master's (PSM) program at the California State University system. These programs concentrate in areas such as biotechnology, bioinformatics and biostatistics. The impetus to create the programs was in response to industry's resounding cry that academia does not provide enough graduates who can hit the ground running and bring immediate value. An online Master's of Science program in regulatory affairs is taught by regulatory professionals and teaches students to take a product from concept to FDA approval, including foreign regulatory approval. Industry professionals also teach our quality control program, which focuses on the processes involved in developing a company's standard operating procedures, such as bringing a product from early-stage clinical trials to product approval, and all of the extensive training and statistical analysis that must take place for successful results.

Furthermore, researchers at universities and institutes (and within many companies throughout California) also work together to promote education and innovation through many avenues. Through support from the National Science Foundation (NSF), the National Institutes of Health (NIH) and other federal agencies, researchers are able to move discoveries from their labs toward the marketplace. These discoveries form the basis for technology transfer agreements that fuel the commercialization of medical breakthroughs, expand the world's scientific knowledge, improve public health and spearheads tomorrow's disease treatments.

CONCLUSION

In summary, CHI supports the Subcommittee's continued work relating to science and technology policy, particularly as it pertains to biomedical innovation. Additionally, we encourage the Subcommittee to continue to explore ways in which successful public-private partnerships have been formed and have fostered great success and enthusiasm in these fields. Again, we thank you for the opportunity to have our remarks be a part of the record. We look forward to working with you on this endeavor.

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