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# Science and Innovation Policy Studies in the United States: Past and Present

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# Science and Innovation Policy Studies in the United States: Past and Present

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# Science and Innovation Policy Studies in the United States: Past and Present

Over the last four years, a new generation of research on science and innovation policy has begun in the United States. The development is very welcome after a hiatus in funding for the field of a decade or more. Although research in the new generation builds on a solid base of earlier scholarship, the new wave is quite different from its predecessors in a variety of ways. This paper reviews the past development of the field and describes the emergence of the present generation, pointing to its distinctive structural features.

In brief, the first generation of science and innovation policy studies (SIPS) was commissioned through policy analysis offices whose primary mission was short-term analysis of current issues directly for decision makers. Research done in this mode had a high probability of being useful in the policy process, both because its subjects were pre-screened and because there was an intermediate organization that absorbed the results and applied them in short-term policy analysis requested by decision makers. In this paper, I call this the <u>mediated model</u> for policy-relevant research.

The second generation of SIPS, in contrast, is steered more generally by a roadmap developed collectively across government agencies, and the research program that supports it is working on building a broader "community of practice" that includes agency and Congressional staff, short-term analysts, and researchers. In this paper, I call this the <u>distributed model</u> for policy-relevant research.

It is impossible to compare the results of the two models -- too late to collect data for the first generation and too early to see the results of the second. They are by no means mutually exclusive. Both belong on any menu of options for new program structures in other countries.

## 1. The foundations of science policy research in the United States

When the President's Science Advisor, John Marburger, kicked off the second-generation SIPS effort in 2005 by calling for the development of a "new interdisciplinary field of quantitative science policy studies" (Marburger 2005b), he said that the field of "social science of science policy" was "nascent." He was wrong. For decades, U.S. social scientists, working with scientists and engineers, had been producing policy-relevant methods, models, and results to help characterize the science and engineering enterprise. Their work had been supported for policy purposes by major U.S. funding agencies and used in policy discussions. Let me briefly mention some of these bodies of knowledge by discipline.

Economist Robert Solow published his Nobel-winning work on the role of technology in growth theory in 1957, proposing that the residual left after taking labor and capital into account in economic growth was the influence of technology (Solow 1957). This claim may be the most commonly used observation in science and innovation policy documents, although it has become so commonplace that Solow is seldom cited. Likewise, Paul Romer (1990), who made technological change endogenous to growth models, thus introducing an era of New Growth Theories and concepts of the Knowledge Economy, is not cited nearly as often as his ideas are used.

Microeconomic studies began much earlier to treat technology endogenously. In the same year as Solow's classic article, Zvi Griliches was completing his dissertation at the University of Chicago on the diffusion of hybrid corn, which founded the subfield of the economics of technological change (Griliches 1957). Griliches was soon joined in this kind of analysis by Edwin Mansfield (1961), with an article on technical change and the rate of imitation. Richard R. Nelson and Sidney Winter (1976) first published their evolutionary theory of technical change a decade late. All these U.S. luminaries have brought students and followers into this subfield. Mansfield's later work on academic knowledge and industrial innovation (Mansfield 1991) produced an estimate of returns on the investment in academic knowledge that is very widely cited in policy circles. All these economists have had policy audiences in the United States and elsewhere over the past five decades.

A policy-relevant branch of sociology was being started at a similar time. In 1957, Robert Merton gave his presidential address to the American Sociological Association on reward systems in science, "Priorities in Scientific Discovery" (Merton 1957), introducing a conceptual model that has pervaded the understanding of incentives in the research community ever since, in sociology, economics, and policy. Two of Merton's students, Jonathon and Stephen Cole, carried out a classic study of the peer review system that still stands as one of the few empirical studies of the system's effectiveness (Cole, Rubin, and Cole 1978). It is still an obligatory citation in any analysis of peer review. Another Merton student, Harriet Zuckerman, provided early inspiration for studies of scientific careers with her work on Nobel Prize winners (Zuckerman 1977). Pelz and Andrews (1976) provided early insights into the organizational contexts of research with their classic comparative study.

Historians of science were also making their contributions. Perhaps the most influential thinker in this category was Derek deSolla Price, whose quantitative inclinations combined with the emerging citation databases to produce seminal work on networks in science. In 1965, he invented the idea of the specialty group, a small network of people who follow each other's work intensively (Price 1965). The idea had more impact in sociology than in history. Diana Crane (1972) took it up in her book Invisible Colleges, and it moved into the domain of other network analysts in the work of Woody Powell and his students (for example, Powell 1996). The network concept was particularly influential among information scientists, who used co-citation clustering and later techniques to begin to produce the maps of science that are currently moving to center stage again with the second generation of SIPS. Networks themselves are still a central concept in policy-relevant studies of science.

The turbulent public and political environment of science has also been an object of attention from U.S. scholars for decades. The Cornell tradition of science policy studies, formed around the inspiration of Dorothy Nelkin, shows the powerful combination of STS (studies of science, technology, and society – a largely humanistic, critical endeavor) with a focus on policy topics. Along with her other 25 books, Nelkin's edited volume Controversy (1979) went through multiple editions and exposed countless U.S. undergraduate students to the complex relationship between science and society. Nelkin's junior colleague Sheila Jasanoff, trained as an attorney but working in the interdisciplinary STS milieu, produced a series of books that spoke directly to policy audiences (for example, Jasanoff 1990), making her perhaps the best-known STS scholar in policy circles today.

Several distinguished university programs housed these scholars in the early days of the field, including Harvard, MIT, Columbia, Cornell, Yale, and the University of Pennsylvania. Today there are thriving programs that mix elements of these approaches on a variety of campuses, including Arizona State, Carnegie Mellon, George Mason, George Washington, Georgia Tech, and the University of Colorado. In terms of professional meetings, this research community has found a home at both the annual meeting and the spring policy forum of the American Association for the Advancement of Science and more recently at the Atlanta Conference on Science and Innovation Policy, the Gordon Research Conference on Science and Technology Policy, and the meetings of the Technology Transfer Society. The community now sees itself as very much part of an international field.

## 2. Policy Research and Analysis at the National Science Foundation

As these elements of the U.S. SIPS research community were forming and producing insights into policy issues, the knowledge base for science policymaking was also being built within federal agencies. Within the National Science Foundation, two particularly important developments took shape in the early 1970s: the Science Indicators volume and the Office of Research and Development Assessment.

***SRS and Science Indicators.*** NSF had been collecting data on the U.S. science enterprise since the early post-war period, when today's datasets on science and engineering personnel had their origins in registries of experts who could be called on in case of further emergencies (Cozzens 1997). Surveys asking universities and government laboratories about their expenditures also began in the 1950s and 1960s. This work was housed in its Division of Science Resources Studies (SRS), later renamed Science Resources Statistics. By the early 1970s, the National Science Board (NSF's governing body, which had general responsibility for information on the S&T enterprise) decided to compile the various kinds of data SRS was collecting in one volume, called at that time Science Indicators (later renamed Science and Engineering Indicators). The goal of the volume was to detect and monitor development and trends; evaluate their implications; provide continuing appraisal of U.S. science; establish a new mechanism for guiding the nation's science policy; encourage quantification of common dimensions of science policy; stimulate interest among social scientists in this important area of public policy; and provide a regular focus for the Board's annual reports (Cozzens 1990, based on Congressional hearings held in 1974). Two hopes were evident: improving the ability to measure and evaluate results, and eventually to provide a basis for comparing the payoff of planned programs.

The inaugural (1972) volume was produced entirely from existing data, but by the time of the 1974 edition, the Indicators staff had begun to commission new data to fill the analytic holes in SRS data. The first bibliometric indicators, for example, were commissioned in that way in the early 1970s. The Science Indicators volume, however, never fulfilled on the hopes of its founders to be an analytic, evaluative report, for good political reasons. The report has to go through extensive review each time it is produced, by every federal agency represented in its pages. In order to survive this review, it has become a very a-political document, more an encyclopedia than an assessment (Cozzens 1990).

***RDA*** A second important development during this period was the establishment of the Office of Research and Development Assessment (RDA) in 1973. A former staff member, J. David Roessner, points to the economic environment of the time as the stimulus for RDA.[1] An economic downturn led to the desire to analyze what science, technology, and research could do for the economy. The staff, led by Len Lederman, eventually included about thirty people, with mixed backgrounds in policy studies, economics, law, and technology.

RDA's primary clients were in the White House Office of Management and Budget (OMB), although the unit also did work for top level administration at a number of agencies, including Transportation, Oceans and Atmosphere, Space, and Defense. At that time, the head of the OMB branch with responsibility for science was Hugh Loweth, a sharp thinker who did not hesitate to ask difficult questions about what science could produce for the country. Lederman and other staff members met regularly with Loweth himself and with various groups that worked under him, absorbing the key questions arising in the political context of science first hand. They took assignments for short term analysis from these groups and reported their results to them directly.

The most important element of RDA for the purposes of this paper is that it had a budget from NSF to support research. For example, it supported some of Mansfield's work on return on investments in R&D in the 1970s, and in a later incarnation provided start-up money for analytic patent citation data and early literature-based visualization techniques. This funding was done highly strategically. The staff spent a lot of time thinking through the central issues in science policy practice, trying to keep their own knowledge ahead of the curve so that they could respond effectively to short-term requests from clients. This strategic thinking generated demand for certain kinds of research knowledge, which they reflected in carefully worded solicitations focused on particular issues. They developed a relationship with relevant research communities and encouraged researchers to apply. For example, Roessner worked on diffusion of innovations; the distinguished diffusion theorist Everett Rogers was one of his grantees. The research projects themselves were applied, but the questions they addressed were fundamental, and grantees were always encouraged to publish their results.

Because of this special strategic relationship with decision makers on the one hand and the policy research community on the other, there was never a question about whether the results of RDA-supported research would be used. The research focus derived from client needs, and there were professionals available to read the results and package them in ways that fed directly into policy practice. In the view of at least one former RDA analyst, the presence of staff inside the agency was the key to making this relationship work. Agencies need to have their own internal capability to absorb research results, understand their implications, and synthesize them for policy audiences, if research findings are going to be utilized, in his view.

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[1] The account and analysis of RDA is based on an interview with J. David Roessner, December 7, 2009.

In addition, according to Roessner, to no small degree whatever success RDA achieved was due to a significant degree by the enlightened leadership and management of Len Lederman. He knew how to interact effectively with policy clients, he knew that it was important to keep RDA staff from getting embroiled in administrative issues, and he knew how to inform policy clients constructively that they were asking the wrong question.

***PRA and the Peter House scandal.*** In 1979, RDA became the Division of Policy Research and Analysis (PRA) at NSF, located in the Directorate for Scientific, Technological, and International Affairs. PRA housed three groups of analysts: a technology assessment group, a socioeconomic analysis group, and an engineering analysis group. They continued to work for OMB, but also for the Office of Science and Technology Policy at the White House (OSTP), the Congressional Office of Technology Assessment (OTA), and other clients. The first Director of PRA was Al Bean, an RDA veteran. After an interim period, Peter House became the second director.

House pushed the staff towards more short-term analysis and saw little need for the extramural research. PRA's staff numbers dropped during the early 1980s, and its extramural funds shrank as well. The latter was true across NSF, which in 1981 was spending about $10 million on policy-relevant research, out of several offices including SRS and the planning office of the NSF Director. By the early 1990s, virtually nothing of the $10 million remained. Research support for science policy studies was concentrated in a small program (several hundred thousand dollars per year) in the social science directorate, under the leadership of RDA's original director, Len Lederman. This last program was maintained for a few years after Lederman's death as a separate focus in the STS program, but was eventually fully absorbed there.

Peter House was dismissed in the early 1990s after a scandal involving a projection of looming shortfalls in science and engineering personnel, which proved to be based on faulty assumptions (see Mervis 1992). Many of those who are familiar with the success of RDA and the early PRA in maintaining the interface between policy-relevant research and science policy blame the House scandal for NSF's subsequent turn away from supporting policy research in the 1990s. The scandal apparently led to a desire by management to avoid policy analysis, and eventually to the scattering of the policy analysis staff and elimination of the office. From the perspective of the RDA model, these moves robbed NSF of the crucial internal capability to stimulate policy-relevant research and draw informed policy implications from research findings.

***Other agencies.*** NSF plays a special role in support for science policy as part of its Congressional mandate. It is part of NSF's mission to building the information base for S&T policy decision making, and it is part of the role of the National Science Board to make broad statements about S&T policy in the United States (although for reasons of politics across agencies it has not taken up that role very actively). It is therefore not surprising that the other major federal funding agencies did not develop the kind of system-level research and analysis capabilities that NSF at one point held. The National Institutes of Health, however, made a major contribution to the development of bibliometric data through its support in the 1970s and 1980s of the literature-based data also used in <u>Science Indicators</u>; the two contracts together allowed the series to get on its feet. The NIH contract came from the evaluation unit, which also paid the contractor to collect early funding acknowledgments data (by hand, at libraries). Under NIH funding, the contractor used the dataset to develop journal influence measures, along with the sorting of journals into four categories from basic to clinical. NIH ended the contract in the late 1980s, thinking they were not getting enough insight from it. The same contractor was building the early patent citation databases (with support from NSF's PRA) and soon began to put the two together into powerful demonstrations of the close links between research and innovation using citations from patents to the literature (see, for example, Narin et al. 1997). There was thus a research contribution from the work, although the contractor's main job was not building social science theory.

## 3. The Marburger Call

Given these circumstances, it is also not surprising that Jack Marburger was not exposed to findings from the field of science policy research in his role as Director of the Office of Science and Technology Policy. The drying up of NSF research funding had slowed the growth of the field; it is hard to support graduate students without research grants. The interface staff at NSF had been dismissed or scattered. So Marburger's main exposure to any research knowledge base to inform the decisions he had to make and justify came from Science Indicators, which as we have seen had evolved away from its original analytic and evaluative mission.

Indeed, his call for a "new interdisciplinary field of quantitative science policy studies" at the AAAS Science and Technology Policy Forum in April 2005 was influenced by a recent report from the National Research Council on the indicators database, according to Lynda Carlson, Director of SRS.[2] SRS had commissioned an NRC committee to look at its R&D surveys and make recommendations for updates (Brown et al. 2004). OSTP staff were interested in the results, and NRC staff briefed Marburger on them a few weeks before Marburger's AAAS speech in April, 2005; he cited the report in the speech itself. The OSTP staff gave SRS advance notice that the speech was coming and would reference SRS and "science metrics" extensively.

The speech (Marburger 2005b) was well placed to get the attention of the science policy research community. Most of the speech was devoted to the usual budget discussions that take place at this meeting, but it turns in the last section to a vision of "an econometric model of the R&D enterprise." After praising the Science and Engineering Indicators volume, Marburger noted that "the indicators are not linked to an overall interpretive framework that has been designed to inform policy." Addressing the needs of policy required much more, he noted, than improving the data in the ways the NRC report recommends. He called in particular for models, like the ones available to economic policy makers, to give insight into issues such as likely futures of the technical workforce, the impact of globalization on technical work, the impact of federal funding on the proliferation of research centers, and the effects of huge fluctuations in state support for public universities. These were the tasks he recommended to the "new" field.

The science policy researchers in the audience were amazed that Marburger was not aware of the decades of work that had been done.[3] Another widespread reaction was that no econometric model could provide what he was seeking. A third reaction was

[2] Interview with Lynda Carlson, December 17, 2009.
[3] I can report this from my own experience, and several of those I interviewed reported the same.

delight that perhaps this high-level call would produce some new resources for the funding-starved area. The last turned out to be the case, as discussions began in the fall of 2005 around starting a program of research funding for this field at the National Science Foundation.

Before describing the crafting of that initiative, however, let me report on other statements from Marburger that supported his initial one. In May of 2005, he followed up his speech with an editorial in Science magazine calling for "better benchmarks" (Marburger 2005c). In the editorial, he lamented that "benchmarks" on technical personnel gave little policy guidance, and again called for "econometric models" on a cross-national basis, to allow estimation of the effects of different policy actions. In October of 2005, addressing the Consortium of Social Science Associations (Marburger 2005a), he called attention to an OMB document (Bolten and Marburger 2005) that called for a new interagency effort to develop an analytic framework for science policy decisions, and affirmed that the social sciences would be the major contributors to the effort. In May, 2006, he addressed the Atlanta Conference on Science and Technology Policy on his desire to see the field unfold, and in October, 2006, the Blue Sky II Conference sponsored by the OECD conference in Ottawa on new indicators. In that speech (Marburger 2005d), he again emphasized the role of models in making sense of data and pointed out that new computational capabilities made that goal more accessible to social scientists than at any time in the past.

Over the intervening summer, an OECD Global Science Forum had been held, with Dr. Marburger as keynote speaker, on "developing our understanding of public investments in science." A main conclusion of that discussion was that there should be stronger contacts and interactions

> between the community of experts in analytical modeling and indicator development with the government officials who need tools for optimizing national and regional research policies. The latter would appreciate having a concise description of the indicators and models that are available and their potential utility in the policy domain. … The policymaker community could provide guidance to technical experts about its major preoccupations and the high-level strategic categories for which it would be most desirable to measure or project the impact of science. (OECD 2006, p. 4)

In short, researcher-policy dialogue would be helpful to both parties. Marburger had already announced, in June 2006, an initiative within the U.S. federal agencies that would create such a dialogue (Marburger and Portman 2006, p, 3). I will return to that initiative in the section below on the Science of Science Policy Interagency Task Group, after picking up the trail again of the formation of the NSF funding program.

### 3. The NSF Response

In September 2005, the National Science Foundation had been instructed by the Office of Management and Budget to include a new initiative in the "science of science policy" in its budget request for FY2007. The Directorate for Social, Behavioral, and Economic Sciences (SBE) was given the lead on the initiative, consonant with Marburger's regular references to social scientists in his vision for the field. From the beginning, it was clear that some of the new funds would be spent in SRS on survey updating and redesign; this was quite consistent with the origins of the effort. In addition, SBE leadership was clear from the start that the research portion would be distributed through an open call for investigator-initiated proposals judged through peer review. “Building a new interdisciplinary research area” fell within NSF’s core skill sets. To do that, program staff would listen widely to the research community and craft a program to follow their advice, as they had done in other areas.

There are three divisions within this directorate: Behavioral and Cognitive Sciences (BCS), Social and Economic Sciences (SES), and Science Resources Statistics (SRS). Each one held a workshop to consult with the research community on how to shape the new program (the following summary is taken directly from Fealing 2006).

- The BCS workshop, May 2006, was on the “Scientific Basis of Individual and Team Innovation and Discovery.” It brought together cognitive scientists, social psychologists and engineers to discuss the psychological study of science and engineering.” It identified frontiers for collaborative research in
    - Memory and analogy mechanisms in creative design processes
    - Computational models of creativity
    - Models of synergy between individuals and teams to improve performance
    - Ways to build more innovative teams
    - Management and leadership issues in innovation and creativity
    - Impact of disciplinary cultures on transformative work
- The SRS workshop, in June 2006, on “Advancing Measures of Innovation” was attended largely by scholars in the economics of technological change, and focused on two areas
    - Better research ingredients and investments and returns to these investments, including
        - Improving the analytical framework to identify gaps
        - Enriching the taxonomy of fields of science and engineering to understand emerging and interdisciplinary fields
        - Mapping knowledge and investment flows in the “national innovation system”
        - Including local and imported human capital inputs, i.e., university professors and graduate students, foreign postdoctoral researchers, and foreign collaborators
    - Improve comparability, scope, relevance, and availability of international data
        - Redesign surveys
        - Improve data sample frames, links, and aggregability
        - Map the globalization and capitalization of R&D

        - Collaborate with other Federal agencies on R&D and innovation metrics
        - Collaborate with OECD, UNESCO, Statistics Canada and others to improve the international comparability of workforce and mobility data
        - Utilize new cyberinfrastructure-based data extraction, matching and manipulation techniques

- The SES workshop, in July 2006, included sociologists, economists, historians, political scientists, and philosophers of science, who identified a research agenda spanning these fields, Major agenda items were
    - Understanding interrelationships in the national innovation system, including
        - How intellectual, social and physical organization influence creativity and innovation
        - How scientific knowledge and expertise influence policy and decisions
        - How global changes in economic, political, and social relationships influence the production and uses of science and technology
        - How changes in science and technology influence patterns of globalization and well being
    - Understanding knowledge creation and innovation at a variety of scales – from small groups through organizations to global networks, from historical to contemporary
    - Understanding how ethics and social values shape science and technology
    - Developing and employing new computational tools and strategies for mining large-scale textual data sets and for visualizing the patterns and dynamics in them
    - Developing new strategies and vehicles for the education, training, mobility, and diversity of the STEM workforce

An exchange at this last workshop was particularly revealing of NSF's approach to the program and the contrast with RDA.[4] The organizers deliberately included junior researchers, many of whom had not thought of themselves before as doing policy-relevant work. There was considerable debate at the workshop over what questions Dr. Marburger wanted answered and whether the ones he had expressed were the right ones. One young researcher commented, "If he [Marburger] would tell me his top three questions, I could design research to shed light on them." He was corrected by an NSF

[4] I was the organizer of the workshop and witnessed the exchange personally.

program officer present: "It doesn't matter what Marburger wants. We want to hear from you what should be in this program."

While these workshops were being planned, a position was created for a Science of Science Policy Advisor to the SBE Directorate, to be the program officer for the initiative. Kay Husbands Fealing, a program officer in the Economics program, was appointed to the position in early summer 2006, and crafted the program prospectus using the workshop reports and her other interactions with the research community. The prospectus for the first time called the program "Science of Science and Innovation Policy" (SciSIP), adding innovation to the phrase Marburger had used repeatedly. This addition not only reflected NSF priorities at the time, but surely responded to feedback from the research community that the program needed to think about the whole innovation system, not just its science component.

The prospectus (NSF 2006) made the practical context of the program clear, with reference throughout to building the foundation for providing predictive information to policymakers about impacts and outcomes. It identified three types of activities the program would undertake: building understanding, improving metrics, and developing a research community. Reflecting the range of fields encompassed by the Directorate, the problems described ranged from cognitive to organizational to global, and the approach was explicitly interdisciplinary.

Even though the prospectus was in hand, NSF had to wait to issue a call for proposals until Congress approved the budget for the new program as part of the overall NSF budget request. That step was taken in early 2007, and the first proposals were submitted later that spring. Husbands put together a quick peer review and funded the first round of proposals in the program by August. The program has now made three rounds of awards totaling about seventy-five grants,[5] and has moved from an ad hoc review panel to a standing one. It is spending about $8 million a year (Lane 2009, Lane 2010).

## 4. The Science of Science Policy Interagency Task Group (SOSP ITG)

While NSF was putting its program in place, Marburger's Office of Science and Technology Policy was delivering on its commitment to create an interagency task group (ITG) for the Science of Science Policy (SOSP). That group was formed in mid-2006 under the aegis of the Social Science Subcommittee of the National Science and Technology Council (which consists of top science officials from a number of agencies). By the summer of 2007, the co-chairs of the task group were Husbands of NSF and Bill Valdez of the Department of Energy (DOE). When Husbands left NSF in 2008, her successor, Julia Lane, took over as co-chair.

Valdez had been running a small program of policy-relevant research in his position as Director of Planning and Analysis at DOE.[6] He had started by commissioning a literature review of about twenty relevant topics, which showed him that the academic work in the area was scant and that other agencies were not doing much.[7] He found more

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[5] The list of awards is available at http://www.scienceofsciencepolicy.net/w/scisipawards/default.aspx as well as on the NSF web site.
[6] This section based on an interview with Bill Valdez, December 23, 2009.
[7] This was just the time when NSF's efforts were at their low point.

on technology programs than science programs, but even that literature was not oriented to key policy and management questions. So he began to commission work – á la RDA – to fill the gaps he perceived. When OSTP was first exploring Marburger's interest, Valdez's program was virtually the only relevant research being funded anywhere in Washington. Valdez had also interacted with Marburger even before he came to the White House on planning and evaluation issues – Marburger had been the head of one of the main DOE laboratories before being appointed Presidential Science Advisor.

The interagency group has seventeen members, from a wide range of agencies (see www.scienceofsciencepolicy.net for the current list). Their work began with a commissioned literature review, prepared by ~~the OSTP support staff, who are located at~~ the Science and Technology Policy Institute (STPI), a Federally Funded Research and Development Center (FFRDC) that supports OSTP. They also undertook an examination of the data that are available for analysis, and a survey among federal agencies on their efforts related to the science of science policy. The responses provided useful input to the final product from the ITG's first round of work: a roadmap for the science of science policy.

The Roadmap (SOSP 2008) was unveiled at the ITG's first workshop, in early December 2008. The timing of this workshop was crucial: after the November presidential elections but before the new administration began its work. A major challenge for science policy studies programs over the years in various countries has been instability at the time of political party change in power. The initiatives are often the favorite project of one enlightened and powerful individual, and are often threatened if that individual leaves office. In the case of SOSP, the Roadmap workshop was a strong and concrete demonstration of the constituency for the initiative, independent of Marburger's position. He was clearly in his last days in office at the time, but the SOSP initiative was just gaining momentum.

Over 200 people attended the event, from both agency and research communities. The organizers used the opportunity to get structured feedback from the participants on the plan itself, attempting to create broader ownership for the Roadmap. The Roadmap is organized in three themes, with key questions under each one:

**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?

Under this theme, the ITG recommended that federal agencies work in concert to establish a theoretical and empirical framework to understand the science and engineering enterprise within the context of the Science of Science Policy, through existing programs of investigator-initiated research and analysis of the portfolio of federal investments.

**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?

Recommendations for this theme focused on creating a community of researchers and practitioners, to assist science policy analysis and promote best practices, by developing a shared data infrastructure, pilot measurement standards, and standard methods for using bibliometric data.

**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?

Under this theme, the ITG recommended investing in data collection, analytical tools, and ways to present complex information, and specified certain core datasets, on businesses, workforce, and the links between workers and firms.

The Roadmap document includes a useful listing and evaluation of the current and potential toolkit for science and innovation policy, reviewing quantitative and qualitative analysis, visualization tools, data collection tools, and various metrics for their relevance and rigor.

The ITG held a second workshop in October 2009, this one focused on agency participants and sharing of best practices.[8] Again over 200 people participated from over sixty agencies. The success of SOSP in institutionalizing itself within the new administration was evident. Speakers included the Deputy Director for Policy of the White House Office of Science and Technology Policy, and several other new administration officials. Presentations from agencies covered how agencies set priorities, use metrics in management, and evaluate their programs.

In 2009, the SOSP ITG's original charter expired. Another sign of its success is that in the renewal process, it was made a standing committee under the National Science and Technology Council. The program was the only one mentioned by name in the joint OMB/OSTP memorandum to heads of agencies on science and technology priorities for the upcoming budget.[9]

## 5. The community of practice model

What emerges from these accounts of SciSIP and SOSP is an underlying model of the relationship between science policy problems and policy-relevant research that is quite different from the earlier RDA model. The key element of difference is that while the RDA model was *mediated* through a policy analysis staff, the new model is *distributed* through what the organizers call a community of practice. The term community of practice was first coined by Jean Lave and Etienne Wenger in 1991, in

[8] http://www.scienceofsciencepolicy.net/blogs/allevents/archive/2010/01/22/sosp-workshop-2009.aspx
[9] Interview with Julia Lane, January 5, 2010.

their work on situated learning. According to Wenger, "Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly."[10] Three characteristics are crucial: the domain, the community, and the practice. Communities of practice learn by solving problems together, requests for information, mapping knowledge and identifying gaps, and other activities.

The SOSP ITG has now launched a web site with the intent of stimulating interaction across the community of practice (http://www.scienceofsciencepolicy.net/). The site has been constructed for them by STPI (the Science and Technology Policy Institute, mentioned earlier in this paper as ~~the contractual support staff for~~ the FFRDC that supports OSTP). For this paper, I talked to STPI staff about how they see their own role in the community of practice, wondering whether they perform any of the same review and synthesis roles that RDA staff took up.[11] STPI ~~does~~ is tasked with about $6~~10~~ million in ~~contract~~ work for various agencies, including about $3 million from ~~the~~ OSTP ~~contract of about $3 million~~. They draw on results from the research community when it is relevant to that work and support federal agencies in making connections across the research community. The STPI staff ~~have no particularly strong relationship with the research community since they are~~ do not not commission~~ing~~ research, although they do contribute to such practice-oriented professional meetings as the American Evaluation Association and the Atlanta Conference on Science and Innovation Policy. Their role is thus quite different overall from the role RDA staff played, with a crucial difference being the lack of a funding role.

The NSF SciSIP program is shaping its portfolio of grants using the SOSP Roadmap. Program Director Julia Lane reports that the standing review panel has studied the roadmap carefully and uses its themes and questions as criteria for rating projects they are evaluating.[12] Projects that are scientifically excellent but peripheral to the Roadmap are unlikely to be rated high, and some are chosen specifically because of their centrality to Roadmap issues. In addition, Lane is working with colleagues in the Science Policy Division of the American Association for the Advancement of Science (AAAS) to create direct communication links between researchers supported by the program and policy audiences.[13] AAAS organized a first workshop of grantees in March 2009, in which they presented their work to each other. They are now putting together a set of smaller gatherings between selected grantees and staff members from Congress and agencies for dialogue on specific issues. The SciSIP panel has also suggested holding webinars, with video links provided to a distributed audience and four to five grantees presenting results on a theme. SciSIP is participating in the STAR Metrics Project, which is helping to build the data infrastructure through agency-university collaboration.[14] One grantee has had the opportunity to brief Ben Bernanke, the Federal Reserve Chairman, on his findings on use of information technology by U.S. firms at home and abroad and findings have been

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[10] http://www.ewenger.com/theory/
[11] Interview with Allison Laskey and Ashley Brenner, STPI Research Assistants, December 18, 2009.
[12] Interview with Julia Lane, January 5, 2010.
[13] Interview with Albert H. Teich, AAAS, December 10, 2009.
[14] http://nrc59.nas.edu/star_info2.cfm

covered in such widely read news sources as Chemical and Engineering News (Lane 2010).

SciSIP has also hosted a listserv, to which policy staff can post questions and get responses from anyone in the community of practice. To those steeped in the mediated model, this kind of exchange can appear counter-productive, since it lacks several critical elements that policy analysts have found important in communicating with their policy clients in the past: professional evaluation of information, condensation into the main relevant points, and brief communication in plain language. The major contributors to the listserv have been policy researchers, not policy staff or analysts.

## 6. Discussion and conclusions

This review of the development of the knowledge base for science policy making in the United States has reported on the experience at the National Science Foundation, the agency that has taken the lead in both generations described here in building a research community interested in policy issues and linking that community to policy practice. Two distinct models have been used at NSF: an earlier, staff-mediated model, with strategic direction to research that was known to fill policy-relevant gaps; and a later, distributed model that is trying to build a larger community of practice through virtual and face to face interaction. In the author's experience, those who are familiar with the older model are skeptical about whether distributed communication will provide sufficient focus. But the new model draws on new capabilities, more familiar to the newer generation of researchers the initiative is trying to draw in. They are not mutually exclusive, and both commend themselves to other countries for serious consideration.

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Feller, Irwin, American Association for the Advancement of Science, December 15, 2009

Husbands Fealing, Kaye, University of Minnesota, January 13, 2010

Lane, Julia, SciSIP Program Director, National Science Foundation, January 5, 2010

Laskey, Allison, and Ashley Brenner, Science and Technology Policy Institute, December 18, 2009

Regan, Priscilla, George Mason University, January 5, 2010

Roessner, J. David, SRI International, December 7, 2009

Teich, Albert H., American Association for the Advancement of Science, December 10, 2009

Valdez, William, Department of Energy, December 23, 2009

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