THE SMALL BUSINESS INNOVATION RESEARCH PROGRAM

# SBIR

## PROGRAM DIVERSITY AND ASSESSMENT CHALLENGES

Report of a Symposium

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

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## REPORT OF A SYMPOSIUM

CHARLES W. WESSNER, EDITOR

Committee on
Capitalizing on Science, Technology, and Innovation:
An Assessment of the Small Business Innovation Research Program

Policy and Global Affairs Division

NATIONAL RESEARCH COUNCIL
*OF THE NATIONAL ACADEMIES*

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# Preface

Today's knowledge economy is driven in large part by the nation's capacity to innovate. One of the defining features of the U.S. economy is a high level of entrepreneurial activity. Entrepreneurs in the United States see opportunities and are willing and able to take on risk to bring new welfare enhancing, wealth generating technologies to the market. Yet, while innovation in areas such as genomics, bioinformatics, and nanotechnology present new opportunities, converting these ideas into innovations for the market involves substantial challenges.[1] The American capacity for innovation can be strengthened by addressing the challenges faced by entrepreneurs. Public-private partnerships are one means to help entrepreneurs bring new ideas to market.[2]

The Small Business Innovation Research (SBIR) program is one of the largest examples of U.S. public-private partnerships. Founded in 1982, SBIR was designed to encourage small business to develop new processes and products and to provide quality research in support of the many missions of the U.S. government. By including qualified small businesses in the nation's R&D effort, SBIR grants are intended to stimulate innovative new technologies to help agencies meet the specific research and development needs of the nation in many areas, including health, the environment, and national defense.

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[1]See Lewis M. Branscomb, Kenneth P. Morse, Michael J. Roberts, and Darin Boville, *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-Based Projects.* Washington, D.C.: Department of Commerce/National Institute of Standards and Technology, 2000.

[2]For a summary analysis of best practice among U.S. public-private partnerships, see National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report*, C. Wessner, ed., Washington, D.C.: The National Academies Press, 2002.

As the SBIR program approached its twentieth year of operation, the U.S. Congress, asked the National Research Council to conduct a "comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet federal research and development needs" and make recommendations on improvements to the program.[3] This conference report is the first in a series to be published by the National Academies in response to the Congressional request and the first report to provide a comprehensive overview of the program's operations at the five agencies responsible for 96 percent of the program's operations.

As part of the first phase of the National Academies study, *Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program*, reviewing the Small Business Innovation Research Program at the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, the National Institutes of Health, and the National Science Foundation, this report will summarize the proceedings of an initial symposium designed to provide an overview of the program's operation and current issues.

## PROJECT ORIGINS

The current assessment of the SBIR program follows directly from an earlier analysis of public-private partnerships by the National Research Council's Board on Science, Technology, and Economic Policy (STEP). Gordon Moore, Chairman Emeritus of Intel, guided STEP's eleven volume study of public-private partnerships. This study reviewed the drivers of cooperation among industry, universities and government; operational assessments of current programs; emerging needs at the intersection of biotechnology and information technology; the current experience of foreign government partnerships and opportunities for international cooperation; and the changing roles of government laboratories, universities, and other research organizations in the national innovation system.[4]

This analysis of public-private partnerships included two published studies of the SBIR program. Drawing from expert knowledge at a 1998 workshop held at the National Academy of Sciences, the first report, *SBIR: Challenges and Opportunities,* examined the origins of the program and identified some operational challenges critical to the program's future effectiveness.[5] The report also highlighted the relative paucity of research on this program.

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[3]See SBIR Reauthorization Act of 2000 (H.R. 5667 - Section 108).

[4]For a summary of the topics covered and main lessons learned from this extensive study, see National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* op. cit.

[5]See National Research Council, *SBIR: Challenges and Opportunities,* C. Wessner, ed., Washington, D.C.: National Academy Press, 1999.

Following this initial report, the Department of Defense asked the NRC to assess the Department's Fast Track Initiative in comparison with the operation of its regular SBIR program. The resulting report, *SBIR: An Assessment of the Department of Defense Fast Track Initiative,* found that DoD's Fast Track Initiative was achieving its objectives and recommended that the program be continued and expanded where appropriate.[6] The report also recommended that the SBIR program overall would benefit from further research and analysis.

These two NRC reports highlighted the need for an analysis of SBIR—a program that had grown over its 20 year history to be the largest U.S. program for innovation awards. As a part of the 2000 reauthorization of the SBIR program, Congress called for a review of the SBIR programs of the agencies that account collectively for 96 percent of program funding. The five agencies meeting this criterion, by size of program, are the Department of Defense, the National Institutes of Health, the National Aeronautics and Space Administration, the Department of Energy, and the National Science Foundation.

HR 5667 directs the NRC to evaluate the quality of SBIR research and evaluate the SBIR program's value to the mission of the agencies that administer it. It calls for an assessment of the extent to which SBIR projects achieve some measure of commercialization, as well as an evaluation of the program's overall economic and non-economic benefits. It also calls for additional analysis as required to support specific recommendations on areas such as measuring outcomes for agency strategy and performance, increasing federal procurement of technologies produced by small business, and overall improvements to the SBIR program.

One of the central challenges in evaluating the SBIR program is that while it operates under a common structure with the same broad goals, it is operated by a very diverse group of agencies and departments, with equally diverse goals and priorities. To capture both this commonality and diversity, the NRC brought together—at a symposium held at the National Academy of Sciences in October 2002—the officials and managers responsible for the operation of SBIR at the agencies, successful award winners, and academic experts to discuss the program's operations, accomplishments, challenges, and opportunities. The resulting report describes some of the accomplishments, challenges, and potential of this program. In doing so, it provides a point of departure for the analysis of the program and the identification of potential improvements in the program.

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[6]See National Research Council, *SBIR: An Assessment of the Department of Defense Fast Track Initiative,* C. Wessner, ed., Washington, D.C.: National Academy Press, 2001. Given that virtually no published analytical literature existed on SBIR, this Fast Track study pioneered research in this area, developing extensive case studies and newly developed surveys.

## ACKNOWLEDGMENTS

On behalf of the National Academies, we express our appreciation and recognition for the insights, experiences, and perspectives made available by the participants in the symposium. We particularly appreciate that Congressman Bartlett, who brought his personal experience as an entrepreneur and as a leading Congressional advocate for small business, was present to open the proceedings. We are also very much in debt to officials from the leading departments, including Charles Holland of the Department of Defense, Joseph Bordogna of the National Science Foundation, Milton Johnson and Robert Berger of the Department of Energy, Robert Norwood and Carl Ray of NASA, and Jo Anne Goodnight of the National Institutes of Health. Appendix B of this volume provides a full list of participants.

A number of individuals deserve recognition for their contributions to the preparation of the conference and this report. These include Alan Anderson, Sujai Shivakumar, Christopher Hayter, David Dierksheide, and Tabitha Benney. Special thanks are due to Sujai Shivakumar for his many contributions to the Introduction and to the review process. Without their collective efforts, amidst many other competing priorities, it would not have been possible to prepare this report.


## NATIONAL RESEARCH COUNCIL REVIEW

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity and evidence. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We wish to thank the following individuals for their review of this report: Irwin Feller, Pennsylvania State University; Thomas Pelsoci, Delta Research, Inc.; Lori Perine, Interpretech; Todd Stewart, Ohio State University; and Richard Wright, National Institute of Standards and Technology.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. The review of this report was overseen by Mark Myers, The Wharton School, University of Pennsylvania, who was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

**Jacques S. Gansler** **Charles W. Wessner**

# Executive Summary

As the Small Business Innovation Research (SBIR) program approached its twentieth year of operation, the U.S. Congress asked the National Research Council (NRC) to carry out a "comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet federal research and development needs" and make recommendations on improvements to the program.[1]

An initial conference to launch this assessment was convened in Washington, D.C. on 24 October 2002. It provided an opportunity for agency officials from each of the five departments and agencies accounting for 96 percent of SBIR program funds to provide an overview of their goals, operations, and challenges. It also included contributions from other agencies with SBIR programs. As the first comprehensive perspective on the SBIR program, the conference captured new information and understanding of its operation, challenges, and potential. It also reviewed the many measurement challenges involved in assessing the impact of this varied and complex program. Finally, the conference drew attention to the fact that while SBIR operations and accomplishments are sometimes discussed in general terms, the actual implementation of the program is carried out in agencies with quite distinct missions and interests.

This volume provides a summary of the program's history leading up to the current assessment, a précis of SBIR's role in the nation's innovation system, and—based on the proceedings of the conference—an overview of SBIR's operations at different agencies, and the methodological issues and challenges facing the current NRC assessment.

[1]See Public Law 106-554, Appendix I–H.R. 5667, Section 108.

# I

# INTRODUCTION

# Introduction

As the Small Business Innovation Research (SBIR) program approached its twentieth year of operation, the U.S. Congress asked the National Research Council (NRC) to carry out a "comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet federal research and development needs" and make recommendations on improvements to the program.[1] The NRC's charge is to examine SBIR's contributions and how it can be improved; not to debate its rationale.[2]

An initial conference to launch this assessment was convened in Washington, D.C. on 24 October 2002. It provided an opportunity for agency officials from each of the five departments and agencies accounting for 96 percent of SBIR program funds to provide an overview of their goals, operations, and challenges while including input from smaller agencies. As the first comprehensive perspective on the SBIR program, the conference captured new information and understanding of its operation and potential. It also reviewed the key challenges involved in measuring and assessing the impact of this varied and complex program.

[1]See Public Law 106-554, Appendix I–H.R. 5667, Section 108.

[2]The nature of this charge was emphasized at the conference launching the study by Committee Chairman, Jacques Gansler, as well as by Kenneth Flamm and James Turner. See the Proceedings section of this volume for summaries of their remarks. Indeed, Mr. Turner noted that the study by the NRC is not expected to question whether the program should exist. "We're 20 years into the SBIR now," he said. "It is a proven entity; it's going to be with us." He suggested that the appropriate goals for the study would be to look ahead and craft a series of sound suggestions on how to improve the program and to give good advice to Congress on what legislative changes, if any, are necessary.

This volume, which reports on the conference of October 24, 2002, is the first in a series to be published by the National Academies in response to the Congressional mandate. This introduction provides a summary of the program's history leading up to the current assessment, a précis of SBIR's role in the nation's innovation system, an overview of SBIR's operations at different agencies, and the methodological issues and challenges facing the current NRC assessment—the themes of the launch conference.

## A BRIEF HISTORY OF THE SBIR PROGRAM

### The Founding

In the 1980s, the country's slow pace in commercializing new technologies—compared especially with the global manufacturing and marketing success of Japanese firms in autos, steel, and semiconductors—led to serious concern in the United States about the nation's ability to compete. U.S. industrial competitiveness in the 1980s was frequently cast in terms of American industry's failure "to translate its research prowess into commercial advantage."[3] The pessimism of some was reinforced by evidence of slowing growth at corporate research laboratories that had been leaders of American innovation in the postwar period and the apparent success of the cooperative model exemplified by some Japanese *kieretsu*.[4]

Yet, even as larger firms were downsizing to better compete, a growing body of evidence, starting in the late 1970s and accelerating in the 1980s, began to indicate that small businesses were assuming an increasingly important role in both innovation and job creation. Research by David Birch and others suggested that national policies should promote and build on the competitive strength offered by small businesses.[5]

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[3]David C. Mowery, "America's Industrial Resurgence (?): An Overview," National Research Council, *U.S. Industry in 2000: Studies in Competitive Performance*. David C. Mowery, ed. Washington, D.C.: National Academy Press, 1999, p. 1. Mowery examines eleven economic sectors, contrasting the improved performance of many industries in the late 1990s with the apparent decline that was subject to much scrutiny in the 1980s. Among the studies highlighting poor economic performance in the 1980s are Dertouzos, et al., *Made in America: The MIT Commission on Industrial Productivity*, Cambridge, MA: The MIT Press, 1989 and Eckstein, et al., *DRI Report on U.S. Manufacturing Industries,* New York: McGraw Hill, 1984.

[4]Richard Rosenbloom and William Spencer, *Engines of Innovation: U.S. Industrial Research at the End of an Era*. Boston: Harvard Business Press, 1996.

[5]David L. Birch, "Who Creates Jobs?" *The Public Interest*. 65(1981):3-14. Birch's work exercised major influence on the perception of the role of small firms. Over the last twenty years, it has been carefully scrutinized, leading to the discovery of some methodological flaws, namely making dynamic inferences from static comparisons, confusing gross and net job creation, and admitting biases from chosen regression techniques. See S. J. Davis, J. Haltiwanger, and S. Schuh, "Small Business and Job Creation: Dissecting the Myth and Reassessing the Facts, Working Paper No. 4492, Cam-

Meanwhile, federal commissions from as early as the 1960s had recommended the direction of R&D funds toward small businesses.[6] These recommendations, however, were opposed by traditional recipients of government R&D funding.[7] Although small businesses were beginning to be recognized by the late-1970s as a potentially fruitful source of innovation, some in government remained wary of funding small firms focused on high-risk technologies with commercial promise.

The concept of early-stage financial support for high-risk technologies with commercial promise was first advanced by Roland Tibbetts at the National Science Foundation (NSF). As early as 1976, Mr. Tibbetts advocated that the NSF should increase the share of its funds going to small business. When NSF adopted this initiative, small firms were enthused and proceeded to lobby other agencies to follow NSF's lead. When there was no immediate response to these efforts, small businesses took their case to Congress and higher levels of the Executive branch.[8]

In response, a White House Conference on Small Business was held in January 1980 under the Carter Administration. The conference's recommendation to proceed with a program for small business innovation research was grounded in:

- Evidence that a declining share of federal R&D was going to small businesses;
- Broader difficulties among small businesses in raising capital in a period of historically high interest rates; and
- Research suggesting that small businesses were fertile sources of job creation.

In addition to these policy rationales, some would suggest (e.g., see Kenneth Flamm) that there was political appeal in seeing R&D dollars "spread a little more widely than they were being spread before." Congress responded under the Reagan Administration with the passage of the Small Business Innovation Research Development Act of 1982, which established the SBIR program.[9]

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bridge, MA: National Bureau of Economic Research, 1993. At the same time, these methodological fallacies "have not had a major influence on the empirically based conclusion that small firms are over-represented in job creation," according to Per Davidsson. See Per Davidsson, "Methodological concerns in the estimation of job creation in different firm size classes." Working Paper, Jönköping International Business School, 1996.

[6]For an overview of the origins and history of the SBIR program, see James Turner and George Brown, "The Federal Role in Small Business Research," *Issues in Science and Technology*, Summer 1999, pp. 51-58.

[7]See Roland Tibbetts, "The Role of Small Firms in Developing and Commercializing New Scientific Instrumentation: Lessons from the U.S. Small Business Innovation Research Program," in *Equipping Science for the 21st Century*, John Irvine, Ben Martin, Dorothy Griffiths, and Roel Gathier, eds. Cheltenham, UK: Edward Elgar Press, 1997. For a summary of some of the critiques of SBIR, see "Assessing SBIR" in this Introduction.

[8]Ibid.

[9]Additional information regarding SBIR's legislative history can be accessed from the Library of Congress. See http://thomas.loc.gov/cgi-bin/bdquery/z?d097:SN00881:@@@L.

**Box A: Small Businesses as Engines of Growth and Job Creation**

Confirming Birch's initial insight, small businesses are now widely recognized as the engines of growth and job creation. A recent report by the Organisation for Economic Cooperation and Development (OECD) notes that small and medium-sized enterprises are attracting the attention of policy makers because they are seen as major sources of economic vitality, flexibility, and employment. Small business is seen as especially important as a source of new employment, accounting for a disproportionate share of job creation.[a] This perception is reflected in Congressman Roscoe Bartlett's introduction to the conference, where he credited small businesses with creating more than 90 percent of new jobs in the recovery that followed the recession of the early 1990s.[b] Recent analysis by the Census Bureau notes that "new firm start-ups play a far more important role in the economy than has previously been recognized. According to recent U.S. Census data (1999-2000), small businesses created three-quarters of U.S. net new jobs (2.5 million of the 3.4 million total). This small business share varies from year to year, reflecting economic trends. Over the decade of the 1990s, the U.S. Census reports that small business net job creation fluctuated between 60 and 80 percent.[c]

[a]For an account of the growing importance of the small firm in employment and innovation, see Zoltan J. Acs and David B. Audretsch, *Innovation and Small Business,* Cambridge, Massachusetts: MIT Press, 1991, p. 4. For specifics on job growth, see Steven J. Davis, John Haltiwanger, and Scott Schuh, "Small Business and Job Creation: Dissecting the Myth and Reassessing the Facts," *Business Economics* 29(3):113-122. See OECD, *Small Business Job Creation and Growth: Facts, Obstacles, and Best Practices*, Paris, 1997.

[b]See the presentation by Congressman Roscoe G. Bartlett in the Proceedings section of this volume.

[c]See Small Business Administration, "Small Business by the Numbers," SBA Office of Advocacy, May 2003. See also "David Birch," *Fortune Small Business,* December 1, 2002. See U.S. Bureau of the Census; Administrative Office of the U.S. Courts; *Endogenous Growth and Entrepreneurial Activity in Cities* by Zoltan Acs and Catherine Armington, Center for Economic Studies, U.S. Bureau of the Census, Working Paper #CES-WP-03-2, January 2003.

### The SBIR Development Act of 1982

The new SBIR program initially required agencies with R&D budgets in excess of $100 million to set aside 0.2 percent of their funds for SBIR. This amount totaled $45 million in 1983, the program's first year of operation. Over the next six years, the set-aside grew to 1.25 percent.[10]

[10]The set-aside is currently 2.5 percent of an agency's extramural R&D budget.

The legislation authorizing SBIR had two broad goals:

- "To more effectively meet R&D needs brought on by the utilization of small innovative firms (which have been consistently shown to be the most prolific sources of new technologies) and
- To attract private capital to commercialize the results of federal research."

### SBIR's Structure and Role

As conceived in the 1982 Act, SBIR's grant-making process is structured in three phases:

- Phase I is essentially a feasibility study in which award winners undertake a limited amount of research aimed at establishing an idea's scientific and commercial promise. Today, the legislation anticipates Phase I grants as high as $100,000.[11]
- Phase II grants are larger—normally up to $750,000—and fund more extensive R&D to further develop the scientific and technical merit and the feasibility of research ideas.
- Phase III. This phase normally does not involve SBIR funds, but is the stage at which grant recipients should be obtaining additional funds either from a procurement program at the agency that made the award, from private investors, or from the capital markets. The objective of this phase is to move the technology to the prototype stage and into the marketplace.

Phase III of the program is often fraught with difficulty for new firms. In practice, agencies have developed different approaches to facilitating this transition to commercial viability; not least among them are additional SBIR awards.[12] Some firms with more experience with the program have become skilled in obtaining additional awards. Previous NRC research showed that different firms have quite different objectives in applying to the program. Some seek to demonstrate the potential of promising research. Others seek to fulfill agency research requirements on a cost-effective basis. Still others seek a certification of quality (and the

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[11]With the accord of the Small Business Administration, which plays an oversight role for the program, this amount can be higher in certain circumstances; e.g., drug development at NIH, and is often lower with smaller SBIR programs, e.g., EPA or the Department of Agriculture.

[12]NSF, for example, has what is called a Phase II-B program that allocates additional funding to help potentially promising technology develop further and attract private matching funds. As with venture-funded firms, Phase III is likely to include some mix of economically viable and non-viable products, ultimately to be determined by the relevant agency mission requirements or private markets.

investments that can come from such recognition) as they push science-based products towards commercialization.[13]

Features that make SBIR grants attractive from the firm's perspective include the fact that there is no dilution of ownership or repayment required. Importantly, grant recipients retain rights to intellectual property developed using the SBIR award, with no royalties owed to the government, though the government retains royalty free use for a period. Selection to receive SBIR grants also confer a certification effect—a signal to private investors of the technical and commercial promise of the technology.[14]

From the perspective of the government, the SBIR program helps achieve agency missions as well as encourage knowledge-based economic growth.[15] By providing a bridge between small companies and the federal agencies, especially for procurement, SBIR serves as a catalyst for the development of new ideas and new technologies to meet federal missions in health, transport, the environment, and defense.[16] It also provides a bridge between universities and the marketplace, thereby encouraging local and regional growth.[17] Finally, by addressing gaps in early-stage funding for promising technologies, the program helps the nation capitalize on its substantial investments in research and development.[18] While SBIR operations and accomplishments are sometimes discussed in general terms, the actual implementation of the program is carried out in agencies with quite distinct missions and interests. There is, therefore, significant variation in objectives and mechanisms.

### Box B: SBIR—Addressing Small Business Concerns

In addition to its legislative goals, SBIR can also help address three concerns of small businesses, as highlighted by Kenneth Flamm in his conference remarks:

First, it addresses *imperfections in the capital markets.* For structural and institutional reasons, small businesses may have difficulty accessing the capital markets, and this could be a handicap in commercializing their innova-

[13]See Reid Cramer, "Patterns of Firm Participation in the Small Business Innovation Research Program in Southwestern and Mountain States," in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, C. Wessner, ed., Washington, D.C.: National Academy Press, 2000.

[14]This certification effect was initially identified by Josh Lerner, "Public Venture Capital," in National Research Council, *The Small Business Innovation Program: Challenges and Opportunities*, C. Wessner, ed. Washington, D.C.: National Academy Press, 1999.

[15]See, for example, the presentation of Robert Norwood of NASA, summarized in the Proceedings.

[16]See the presentation of Kenneth Flamm, summarized in the Proceedings.

[17]See the presentation of Christina Gabriel, summarized in the Proceedings.

[18]See the presentation by Joseph Bordogna, summarized in the Proceedings.

tions. Dr. Flamm cited a recent National Academies study to point out that the SBIR program could play some role in rebalancing specific kinds of capital market imperfections in some documented instances.[a]

Second, SBIR addresses *"contracting overhead" asymmetries*. Small companies must learn to deal with a complex and sometimes "arcane" contracting system characterized by many rules and procedures when dealing with agencies such as the Department of Defense. SBIR can assist small firms who lack the financial resources to invest in "contracting overhead." The program effectively defrays some of the fixed costs of accessing the government procurement system.[b]

Third, SBIR *helps overcome small firm disadvantages in access to the procurement process.*. The major defense contractors, notably, have active Washington operations that are skilled at lobbying on Capitol Hill and at the Pentagon. An outsider, without the overhead to maintain a well-staffed Washington office and cultivate appropriate connections at the Pentagon on a regular basis, is likely to enter the contracting system at a disadvantage. Small firms cannot afford the expense of traditional lobbying; the SBIR affords a route for small firms to enter the procurement system directly.

[a]See the conference presentation by Professor Flamm, summarized in the Proceedings section. See also Robert Archibald and David Finifter, "Evaluation of the Department of Defense Small Business Innovation Research Program and the Fast Track Initiative: A Balanced Approach," in National Research Council, *SBIR: An Assessment of the Department of Defense Fast Track Initiative,* op. cit., pp. 211-250.

[b]Charles Kolb of Aerodyne Research makes the related point that SBIR helps small businesses penetrate large agencies: "If I want my technology to go to NASA, I have to have a champion inside NASA, who's going to push it." This official can go to an internal NASA meeting and argue that this technology is a better way to do a part of NASA's mission, he noted. See the Proceedings section of this volume for a summary of Charles Kolb's conference presentation.

### SBIR Reauthorizations

The SBIR program approached reauthorization in 1992 amidst continued worries about the U.S. economy's capacity to commercialize inventions. Finding that "U.S. technological performance is challenged less in the creation of new technologies than in their commercialization and adoption," the National Academy of Sciences at the time recommended an increase in SBIR funding as a means to improve the economy's ability to adopt and commercialize new technologies.[19]

Following this report, the Small Business Research and Development Enhancement Act (P.L. 102-564), which reauthorized the program until

[19]See National Research Council, *The Government Role in Civilian Technology: Building a New Alliance,* Washington, D.C.: National Academy Press, 1992, p. 29.

September 30, 2000, doubled the set-aside rate to 2.5 percent.[20] This increase in the percentage of R&D funds allocated to the program was accompanied by a stronger emphasis on encouraging the commercialization of SBIR-funded technologies.[21] Legislative language explicitly highlighted commercial potential as a criterion for awarding SBIR grants. For Phase I awards, Congress directed program administrators to assess whether projects have "commercial potential" in addition to scientific and technical merit when evaluating SBIR applications.

With respect to Phase II, evaluation of a project's commercial potential was to consider, additionally, the existence of second-phase funding commitments from the private sector or other non-SBIR sources. Evidence of third-phase follow-on commitments, along with other indicators of commercial potential, was also sought. Moreover, the 1992 reauthorization directed that a small business' record of commercialization be taken into account when considering the Phase II application.[22]

The Small Business Reauthorization Act of 2000 (P.L. 106-554) again extended SBIR until September 30, 2008. It also called for an assessment by the National Research Council of the broader impacts of the program, including those on employment, health, national security, and national competitiveness.[23]

## The NRC Assessment

The NRC assessment represents a significant opportunity to gain a better understanding one of the largest of the nation's early-stage finance programs. Despite its size and 20-year history, the SBIR program has not been comprehensively examined. There have been some previous studies focusing on specific

[20]For fiscal year 2003, this has resulted in a program budget of approximately $1.6 billion across all federal agencies, with the Department of Defense having the largest SBIR program at $834 million, followed by the National Institutes of Health (NIH) at $525 million. The DoD SBIR program, is made up of 10 participating components: (see Figure 1 in the Proceedings): Army, Navy, Air Force, Missile Defense Agency (MDA), Defense Advanced Research Projects Agency (DARPA), Chemical Biological Defense (CBD), Special Operations Command (SOCOM), Defense Threat Reduction Agency (DTRA), National Imagery and Mapping Agency (NIMA), and the Office of Secretary of Defense (OSD). NIH counts 23 institutes and agencies making SBIR awards.

[21]See Robert Archibald and David Finifter, "Evaluation of the Department of Defense Small Business Innovation Research Program and the Fast Track Initiative: A Balanced Approach," op. cit. pp. 211-250.

[22]A GAO report had found that agencies had not adopted a uniform method for weighing commercial potential in SBIR applications. See U.S. General Accounting Office, 1999, *Federal Research: Evaluations of Small Business Innovation Research Can Be Strengthened,* AO/RCED-99-114, Washington, D.C.: U.S. General Accounting Office.

[23]The current assessment is congruent with the Government Performance and Results Act (GPRA) of 1993: http://govinfo.library.unt.edu/npr/library/misc/s20.html. As characterized by the GAO, GPRA seeks to shift the focus of government decision making and accountability away from a preoccupation with the activities that are undertaken—such as grants dispensed or inspections made—to a focus on the results of those activities. See http://www.gao.gov/new.items/gpra/gpra.htm.

aspects or components of the program—notably by the General Accounting Office and the Small Business Administration.[24] There are, as well, a limited number of internal assessments of agency programs.[25] The academic literature on SBIR is also limited.[26]

Writing in the 1990s, Joshua Lerner positively assessed the program, finding "that SBIR awardees grew significantly faster than a matched set of firms over a 10-year period."[27] Underscoring the importance of local infrastructure and cluster activity, Lerner's work also showed that the "positive effects of SBIR awards were confined to firms based in zip codes with substantial venture capital activity." These findings were consistent with both the corporate finance literature on capital constraints and the growth literature on the importance of localization effects.[28]

To help fill this assessment gap, and to learn about a large, relatively underevaluated program, the National Academies' Committee for Government-Industry Partnerships for the Development of New Technologies was asked to review the SBIR program, its operation, and current challenges. Under its chairman, Gordon Moore, the Committee convened government policy makers, academic researchers, and representatives of small business for the first comprehensive discussion of the SBIR program's history and rationale, review existing research, and identify areas for further research and program improvements.[29]

The Committee chaired by Moore reported that:

- SBIR enjoyed strong support in parts of the federal government as well as in the country at large.
- At the same time, the size and significance of SBIR underscored the need for more research on how well it is working and how its operations might be optimized.

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[24]An important step in the evaluation of SBIR will be to identify existing evaluations of SBIR. See for example, GAO, *Federal Research: Small Business Innovation Research Shows Success But Can Be Strengthened*. Washington, D.C.: U.S. General Accounting Office, 1992; and GAO, *Evaluation of Small Business Innovation Can Be Strengthened*, Washington, D.C.: U.S. General Accounting Office, 1999. There is also a 1999 unpublished SBA study on the commercialization of SBIR surveys Phase II awards from 1983 to 1993 among non-DoD agencies.

[25]Agency reports include an unpublished 1997 DoD study on the commercialization of DoD SBIR. NASA has also completed several reports on its SBIR program. Following the authorizing legislation for the NRC study, NIH launched a major review of the achievements of its SBIR program. See Appendix C for a list of agency reports.

[26]See the bibliography in Appendix C.

[27]See Joshua Lerner, "The Government as Venture Capitalist: The Long-Term Effects of the SBIR Program," *Journal of Business* 72(2) July 1999.

[28]See Michael Porter, "Clusters and Competition: New Agendas for Government and Institutions," in *On Competition*, Boston: Harvard Business School Press, 1998.

[29]See National Research Council, *The Small Business Innovation Research Program: Challenges and Opportunities*, op. cit.

- There should be additional clarification about the primary emphasis on commercialization within SBIR, and about how commercialization is defined.
- There should also be clarification on how to evaluate SBIR as a single program that is applied by different agencies in different ways.[30]

Subsequently, at the request of the Department of Defense, Moore's committee was asked to review the operation of the SBIR program at Defense, and in particular the role played by the Fast Track Initiative. This resulted in the largest and most thorough review of an SBIR program to date. The review involved substantial original field research, with 55 case studies, as well as a large survey of award recipients. The response rate was relatively high, at some 72 percent.[31] It found that the SBIR program at Defense was contributing to the achievement of mission goals—funding valuable innovative projects—and that a significant portion of these projects would not have been undertaken in the absence of the SBIR funding.[32] Moore's committee's assessment also found that the Fast Track Program increases the efficiency of the Department of Defense SBIR program by encouraging the commercialization of new technologies and the entry of new firms to the program.[33]

More broadly, Moore's committee found that SBIR facilitates the development and utilization of human capital and technological knowledge.[34] Case studies have shown that the knowledge and human capital generated by the SBIR program has economic value, and can be applied by other firms.[35] And through the certification function, it noted, SBIR awards encourage further private sector investment in the firm's technology.

Based on this and other assessments of public-private partnerships, Moore's committee's *Summary Report* on U.S. Government-Industry Partnerships recommended that "regular and rigorous program-based evaluations and feedback is essential for effective partnerships and should be a standard feature," adding that "greater policy attention and resources to the systematic evaluation of U.S. and foreign partnerships should be encouraged."[36]

The legislation mandating the current assessment of the nation's SBIR program focuses on the five agencies that account for 96 percent of program expenditures, although the National Research Council is seeking to learn of the views

[30]Ibid.

[31]See National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* op. cit., p. 24.

[32]Ibid, See Section III, Recommendations and Findings, p. 32.

[33]Ibid, p. 33.

[34]Ibid.

[35]Ibid.

[36]See National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* C. Wessner, ed., Washington, D.C.: The National Academies Press, 2002, p. 30.

and practices of other agencies administering the program as well. The mandated agencies, in order of program size, are the Department of Defense, the National Institutes of Health, the National Aeronautics and Space Administration, the Department of Energy, and the National Science Foundation.

## Logic of the Study

The current NRC assessment is structured in three phases, with the first phase to focus on fact-finding. This conference report is a key element in this first study phase. As noted, it is designed to:

- Provide agencies an opportunity to describe program operations, challenges, and accomplishments;
- Highlight the important differences in agency goals, practices, and evaluations carried out within the common framework of the program; and
- Describe the evaluation challenges arising from the diversity in program objectives and practice.

This conference—and this report capturing its deliberations—are an important point of departure because they provide a unique cross-agency perspective on the SBIR program as it approached its twentieth year of operation.

The second element of this first phase is the development of a study methodology, which is a complement of evaluation tools and research strategies. Following review and approval of this methodology by an independent National Academies panel of experts, the second phase will implement the research methodology, evaluate the results, and develop the overall recommendations and findings.[37] A third phase will involve the preparation of reports on the various agency programs and dissemination of the findings. Thus, in addition to this initial conference report, the Committee expects to publish reports evaluating SBIR at each of the five mandated agencies listed above. A final report will include the Committee's overall findings and recommendations, as well as a summary of the main points from the preceding reports.

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[37]For a description of NRC program assessment, see National Research Council, *Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, Project Methodology,* forthcoming. The NRC analysis will draw on existing reports and data sources, as well as from newly commissioned surveys of award recipients and program managers, and extensive case studies.

## SBIR IN THE U.S. INNOVATION SYSTEM

An innovation system describes a network of institutions in the public and private sectors, whose activities and interactions initiate, develop, modify, and commercialize new technologies.[38] Increasingly, governments around the world view the development and transformation of such systems as an important way to promote the competitiveness of domestic industries and services.[39] They have adopted a variety of policies and programs to make their innovation systems more robust, sometimes drawing on U.S. experience, but more often developing programs attuned to their own national needs and experiences. Nevertheless, in light of the perceived SBIR contribution to firm creation and role in bringing university research to market, policymakers in many countries are interested in the program.[40]

Below, we look at the role SBIR plays in the U.S. innovation system, noting the considerable uncertainty that surrounds early-stage financing in the United States.

### The Broader Policy and Regulatory Environment

In the United States, the environment for innovation is shaped by policies concerning areas such as taxation, capital markets, intellectual property, as well as a host of regulations—often critical for new firms—concerning market entry, labor standards, and of course bankruptcy. Such policies and regulations define the risk-reward ratio for aspiring entrepreneurs. Together, they condition the willingness of entrepreneurs to take on the risk of firm creation. They can also condition the willingness of investors to support entrepreneurs as they move an idea from the laboratory to the marketplace. The generally supportive nature of these policies (buttressed by accommodating social and cultural attitudes) is one of the defining features of the U.S. innovation system. [41]

The availability of early-stage financing and its interaction with other elements of the U.S. innovation process are the focus of growing analytical efforts.[42]

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[38]Richard Nelson has played a leading role in developing and disseminating the concept of a national innovation system. See R. R. Nelson, *National Innovation Systems: A Comparative Analysis*. New York: Oxford University Press, 1993.

[39]OECD, *Dynamising National Innovation Systems,* Paris: OECD, May 2002.

[40]The European Research Advisory Board (EURAB), for example, recently recommended a mechanism for public funding of innovation in Europe similar to that of the U.S. Small Business Innovation Program. See EURAB Advice 2001-2002, Chapter 5, "Improving Innovation."

[41]See, for example, Richard Nelson (ed.) *National Systems of Innovation,* New York: Oxford University Press, 1997.

[42]The growth and subsequent contribution of venture capital have begun to attract the serious study needed to illuminate the dynamics of high-technology firm evolution. See for example, the work of Jeffrey Sohl and colleagues and the University of New Hampshire's Center for Venture Research, described at http://www.unh.edu/cvr.

The growth of the SBIR program into the largest of the government's efforts to draw on the inventiveness of small, high-technology firms underscores the need to better understand this element of the nation's innovation system.

### Uncertainties in Early-Stage Financing

In the United States today, the beneficial effects of science-based innovations are apparent in almost every arena—from health care and communications to leisure and defense applications. Given that many of these visible successes are products grounded in government-funded research and procurement, there is an understandable desire to ensure that federal policies smooth the path toward commercialization.[43]

This federal role is important, especially as it affects potential investors' perceptions of risk, keeping in mind that commercializing science-based innovations is inherently a high-risk endeavor.[44] One source of risk is the *lack of sufficient public information* for potential investors about technologies developed by small firms.[45] Potential investors seek to learn about the growth potential of small firms, yet in many cases, the entrepreneur—especially in high-technology startups—is likely to better understand the technology and may well foresee its probable application better than potential investors. And even this understanding may not include a competent assessment of commercial potential.[46]

A second related hurdle is *the leakage of new knowledge* that escapes the boundaries of firms and intellectual property protection. The creator of new knowledge can seldom fully capture the economic value of that knowledge for his or her own firm. This leakage, or spillover, can inhibit investment in promising technologies for large and small firms—though it is especially important for small firms focused on a promising product or process.[47]

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[43]For an overview of the importance of federal contributions to technology development, see Vernon Ruttan, *Technology, Growth and Development: An Induced Innovation Perspective,* New York: Cambridge University Press, 2001. See also Audretsch et al., "The Economics of Science and Technology," *Journal of Technology Transfer*, 27:155-203.

[44]See, for example, Lewis M. Branscomb, Kenneth P. Morse, Michael J. Roberts, and Darin Boville. *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology-Based Projects.* Washington, D.C.: Department of Commerce/National Institute of Standards and Technology, 2000.

[45]Joshua Lerner, "Evaluating the Small Business Innovation Research Program: A Literature Review," in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* op. cit. For a seminal analysis on information asymmetries in markets and the importance of signaling, see Michael Spence, *Market Signaling: Informational Transfer in Hiring and Related Processes*, Cambridge, Harvard University Press, 1974.

[46]Joshua Lerner, "Public Venture Capital: Rationale and Evaluation," in National Research Council, *The Small Business Innovation Research Program: Challenges and Opportunities,* op. cit.

[47]Edwin Mansfield, "How Fast Does New Industrial Technology Leak Out?" *Journal of Industrial Economics,* 34(2):217-224.

The challenge of incomplete and insufficient information for investors and the problem for entrepreneurs of moving quickly enough to capture a sufficient return on "leaky" investments pose substantial obstacles for new firms seeking capital. The difficulty of attracting investors to support an imperfectly understood, as yet-to-be-developed innovation is especially daunting. Indeed, the term, *Valley of Death* has come to describe the period of transition when a developing technology is deemed promising, but too new to validate its commercial potential and thereby attract the capital necessary for its development.[48]

### Role of Government Funding in Early-Stage Technology Development

Despite these challenges, some firms do find their way through this Valley of Death with financing from wealthy individual investors (business "angels") or, later in the development cycle, from venture capital firms. Recognizing the important role played by these business angels and venture capital firms, academic researchers and others have initiated new research on their impact.[49] In this regard, one recent study found that while the ratio of funding provided by venture capital groups to the total funding for R&D has averaged less than 3 percent in recent years, venture capital accounts for about 15 percent of industrial innovations.[50]

As the figure below shows, within the last decade, the number of venture capital firms that invest primarily in small business has tripled, and their total investments have risen eight-fold.[51] As the figure illustrates, the last two years have seen sharp contractions in the venture capital market, especially for new start-ups as low valuations and a contraction in IPO activity concentrated fund managers' attention on existing investments. (See Figure 1.)

Although business angels and venture capital firms, along with industry, state governments, and universities provide funding for early-stage technology development, the federal role may well be larger than is generally thought. Recent

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[48]See Vernon J. Ehlers, *Unlocking Our Future: Toward a New National Science Policy, A Report to Congress by the House Committee on Science* (Washington, D.C.: GPO, 1998). Accessed at http://www.access.gpo.gov/congress/house/science/cp105-b/science105b.pdf.

[49]See Jeffrey E. Sohl's 1999 article "The early-stage equity market in the USA" in *Venture Capital: An International Journal of Entrepreneurial Finance*, 1(2):101-120. Dr. Sohl estimates that of the total populations of business angels and of venture capital funds, each of the two groups invests approximately the same annual amounts in small firms ($30-40 million), but the funds of business angels are spread over some 50,000 firms, while those of venture capital groups are focused on some 4,000 firms. The typical "deal size" for angels is approximately $50,000-$1 million and for venture capital firms $8-9 million. See also Jeffrey Sohl, John Freear and W.E. Wetzel Jr., "Angles on Angels: Financing Technology-Based Ventures—An Historical Perspective," *Venture Capital: An International Journal of Entrepreneurial Finance,* 4(4):275-287.

[50]Samuel Kortum and Josh Lerner, 1998. "Does Venture Capital Spur Innovation?" NBER Working Papers 6846, National Bureau of Economic Research, Inc.

[51]Jeffrey Sohl, http://www.unh.edu/cvr/.

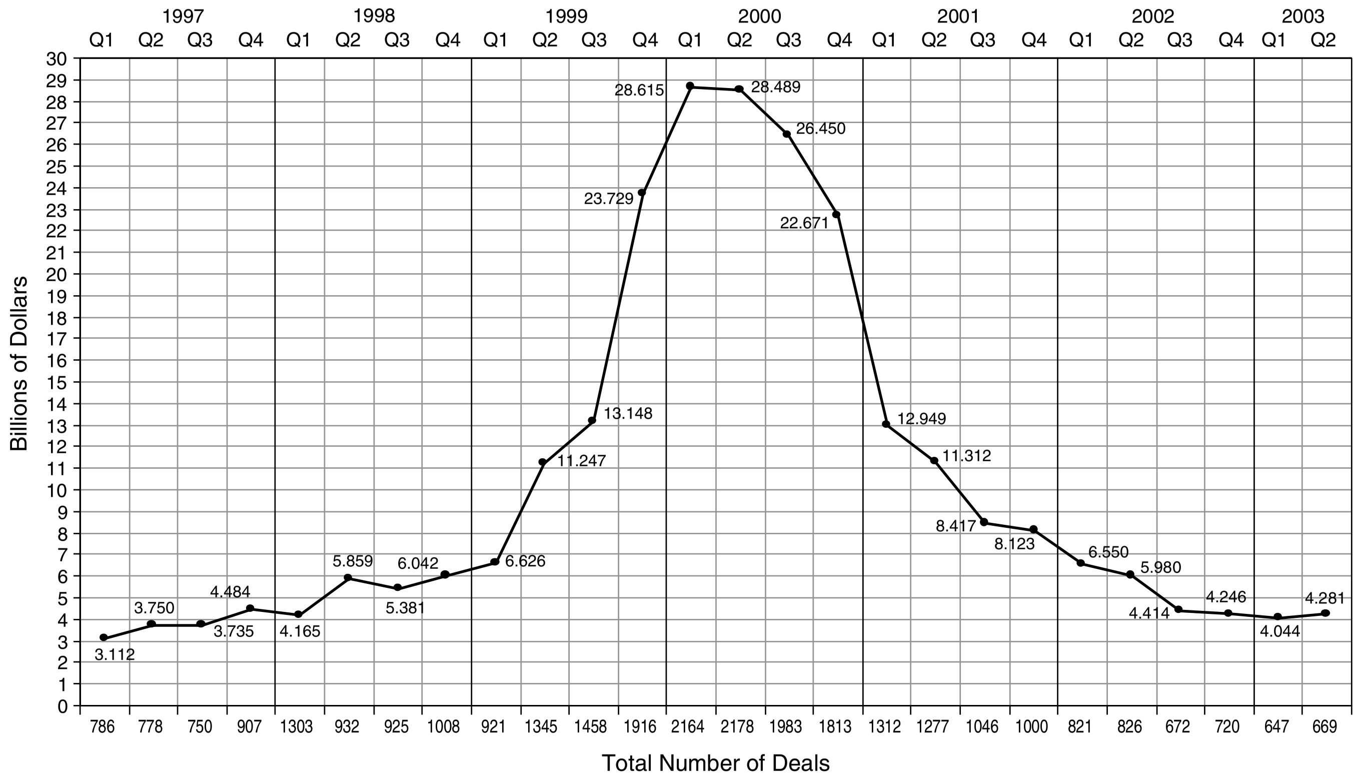


FIGURE 1 Venture capital market rise and contraction. SOURCE: Price Waterhouse Coopers/Venture Economics/National Venture Capital Association Money Tree Survey, 2003.

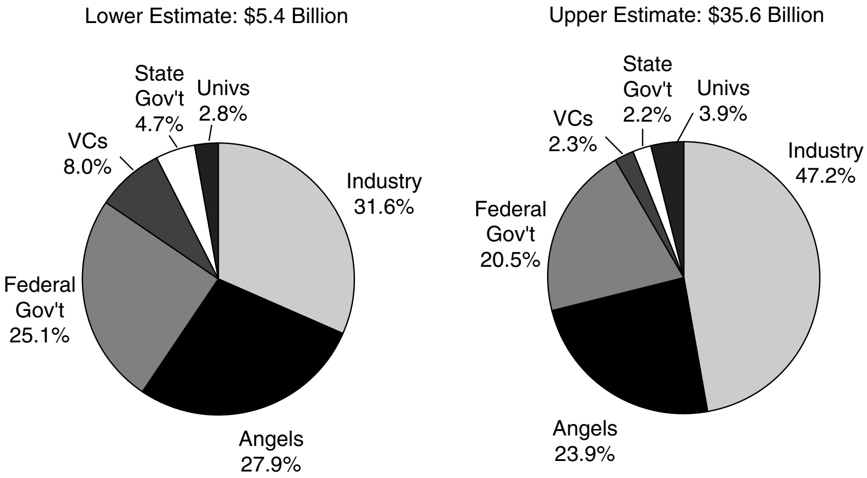


FIGURE 2 Estimated distribution of funding sources for early-stage technology development. SOURCE: Branscomb & Auerswald, *Between Invention and Innovation: An Analysis of Funding for Early-Stage Technology Development*, NIST, 2002, p. 23.

research by Branscomb and Auerswald estimated that the federal government provides between 20 to 25 percent of all funds for early-stage technology development—a substantial role by any measure.[52] (See Figure 2.)

This contribution is made more significant in that the government awards address segments of the innovation cycle that private investors often find too risky. Because technology-based firms are a significant source of innovation and competitive advantage for the United States, it is important to improve our understanding of how public-private partnerships policies—in this case, innovation awards—can play in encouraging small-firm growth.[53]

[52]The authors stress the "limitations inherent in the data and the magnitude of the extrapolations…" and urge that the findings be interpreted with caution. They note further that while the funding range presented for each category is large, these approximate estimates, nonetheless, provide "valuable insight into the overall scale and composition of early-stage technology development funding patterns and allow at least a preliminary comparison of the relative level of federal, state, and private investments." For further discussion of the approach and its limitations, see Lewis M. Branscomb and Philip E. Auerswald, *Between Invention and Innovation, An Analysis of Funding for Early-Stage Technology Development,* Gaithersburg, MD: NIST GCR 02–841, November 2002. pp. 20-24.

[53]See National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* C. Wessner, ed., Washington, D.C.: The National Academies Press, 2002, passim.

## The Role of Government Partnerships

Partnerships in general are cooperative relationships involving government, industry, laboratories, and (increasingly) universities, organized to encourage innovation and commercialization. The long-term goal of these public-private partnerships is to develop industrial processes, products, and services, and thereby apply new knowledge to government missions such as improved health, environmental protection, and national security.[54]

### *Overcoming Investment Barriers*

A key purpose of public-private partnerships is to help entrepreneurs overcome the financial and other obstacles they face in developing new technologies for the market.[55] In the case of a research consortium, the government can facilitate cooperation among firms in developing pre-competitive platform technologies by providing, for example, matching funds and selective exemptions to antitrust laws.

Innovation awards—another important type of government-industry partnership—are intended to encourage the development of promising technologies that might otherwise be perceived to be too financially risky. As noted above, even the largest firms may not be able to recapture an investment in a technology that "leaks" too soon to too many users.[56] Recent assessments of innovation award programs support the view that these government-industry partnerships can help firms overcome barriers to investment for promising, high-spillover technologies.[57]

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[54]Ibid.

[55]Lewis M. Branscomb and Philip E. Auerswald, *Taking Technical Risks: How Innovators, Managers, and Investors Manage Risk in High-Tech Innovations,* Cambridge, MA: MIT Press, 2001.

[56]Technological knowledge that can be replicated and distributed at low marginal cost may have a gross social benefit that exceeds private benefit—and in such cases is considered by many as prone to be undersupplied relative to some social optimum. See Richard N. Langlois and Paul L. Robertson, "Stop Crying over Spilt Knowledge: A Critical Look at the Theory of Spillovers and Technical Change," paper prepared for the MERIT Conference on Innovation, Evolution, and Technology, August 25-27, 1996, Maastricht, Netherlands.

[57]See Albert N. Link, "Enhanced R&D Efficiency in an ATP-funded Joint Venture," in *The Advanced Technology Program, Assessing Outcome, op. cit.* For a review of why firms might underinvest in R&D, see Albert N. Link, "Public/Private Partnerships as a Tool in Support of Industrial R&D: Experiences in the United States," Final Report to the Working Group on Innovations and Technology Policy of the OECD Committee for Scientific and Technology Policy, January 1999. For specific reviews of programs such as SBIR, ATP and SEMATECH, see National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* op. cit.; National Research Council, *The Advanced Technology Program: Assessing Outcomes,* C. Wessner, ed., Washington, D.C.: National Academy Press, 2001; and National Research Council, *Securing the Future, Regional and National Programs to Support the Semiconductor Industry,* C. Wessner, ed., Washington, D.C.: The National Academies Press, 2003.

Indeed, Moore's government-industry partnerships committee found that such public-private partnerships "can play an instrumental role in accelerating the development of new technologies from idea to market."[58] It further identified several broad conditions contributing to successful partnerships: As applied to SBIR, these include:

- *Industry initiation*: Individual researchers and firms develop proposals in response to government solicitations that are fairly broad, or, in some cases, purely at their own initiative. This bottom-up, self-selection approach is a source of strength for award programs, allowing great flexibility and encouraging diversity.
- *Competitive Selection Mechanisms*: The SBIR program, while relatively large, remains highly competitive.[59] Normally, under 15 percent of Phase I candidates are successful.
- *Shared Cost Commitments*: SBIR awards can encourage innovation, leverage company investments, attract other sources of capital, and ensure management commitment because awardees retain control of the intellectual property.
- *Objective and ongoing assessments*: Regular evaluations of the partnership programs at the operational and well as the policy level can help ensure that programs such as SBIR remain well adapted to the needs of its users (both agencies and the firms) and that the policy community remains aware of the role the program plays in supporting national missions.

*Capitalizing on National Investments in Research*

Reaching similar conclusions, a study by the National Academies' Committee on Science, Engineering and Public Policy found partnerships to be an essential tool in the mix of policies needed to capitalize on the nation's investments in scientific research.[60] It observed that partnerships contribute to a relatively open flow from fundamental breakthroughs to first demonstrations to product applications. This openness was seen as a particular strength of the U.S. innovation system. Citing the development of monoclonal antibodies, and the semiconductor technologies underlying personal computers and the Internet as examples, the report identified four conditions favorable for effective commercialization of the fruits of research. These are the presence of:

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[58]See National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* op. cit.

[59]The SBIR program now disburses $2.0 billion in awards annually. By comparison, the Advanced Technology Program, the nation's other leading innovation program, awarded $2.1 billion in funding to companies between 1990 and 2003.

[60]The analysis was carried out by the NRC's Committee on Science, Engineering, and Public Policy (COSEPUP). See National Research Council, *Capitalizing on the Results of Scientific Research*, Washington, D.C.: National Academy Press, 1999.

- Mechanisms for research and capitalization that support cooperation between the academic, industry, and government sectors;
- A strong, diverse national portfolio of science and technology investments;
- A favorable environment for capitalizing characterized by strong incentives for innovation and free movement of ideas and people; and
- A skilled, flexible science and engineering human resource base.

The report further noted that nearly all the successful examples of capitalization examined depended on the collaboration of scientists and engineers who had diverse perspectives, time frames, and talents, drawn from the whole web of public, private, and educational institutions. This web of institutions, it said, had become far more complex in recent years, as many large corporations reached outside the firm to rely on universities, suppliers, and subcontractors as sources of research. Similarly, technology-oriented start-ups too small to support basic research programs often depended on close contacts with university researchers.

The report concluded that governments, industries, and universities should continue to experiment with partnerships and consortia, with the goals of conducting mutually beneficial research, invigorating education, and capitalizing on research for the benefit of society. During the partnership phase, industry should share costs and take the initiative in research directions—criteria met by the SBIR program.

**BOX C: SBIR Haiku**

Without measurement metrics
SBIR remains
As unknowable as the surface of the sea.
William Bonvillian

*Meeting New National Challenges*

Partnerships can also be a versatile tool for achieving specific national objectives. For example, they can accelerate the development of technologies required to meet the challenges of national security. As a recent report of the National Academies notes,

> For the government and private sector to work together on increasing homeland security, effective public-private partnerships and cooperative projects must occur. There are many models of government-industry collaboration—cooperative

**Box D: Partnerships and NIAID's Response to Counter Bioterrorism**

For the current war on terrorism, partnerships have a demonstrated capacity to marshal the ingenuity of industry to meet new needs for national security.[a] Because they are flexible and can be organized on an *ad hoc* basis, partnerships are an effective means to focus diverse and innovative technologies rapidly to help counter new threats.

In her conference presentation, Carol Heilman of the National Institute of Allergies and Infectious Diseases at the National Institutes of Health observed that SBIR has been harnessed as an important element in their expanded efforts in support of research on possible bioterrorism.[b] Specifically, NIAID has expanded research and development on countermeasures—including vaccines, therapeutics, and diagnostic tests—needed to control the release of agents of bioterrorism.

[a]See National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* op. cit., p. 77. See also National Research Council, *The Advanced Technology Program, Assessing Outcomes,* op. cit., and National Research Council, *The Small Business Innovation Research: An Assessment of the Department of Defense Fast Track Initiative,* op. cit.

[b]See the presentation by Carol Heilman, summarized in the Proceedings section of this volume.

research and development agreements, the NIST Advanced Technology Program, and the Small Business Innovation Research Program, to cite a few.[61]

Numerous public-private partnerships at the federal, state, and local levels have made contributions to U.S. national missions in health, energy, the environment and defense, while also strengthening the nation's ability to capitalize on its R&D investments.[62]

## ASSESSING SBIR

As noted earlier, the SBIR program has not been comprehensively assessed to date, despite its size and 20-year history. Even so, there are numerous views of the program that have developed despite the absence of credible data and analy-

[61]See National Research Council, *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism,* Washington, D.C.: The National Academies Press, 2002.

[62]For an overview of the scope of cooperative activity at the federal and state levels, see C. Coburn and D. Berglund, *Partnerships: A Compendium of State and Federal Cooperative Technology Programs,* Columbus, OH: Battelle Press, 1995; and the RaDiUS database: http://www.rand.org/services/radius/.

sis. The current NRC assessment has the potential to contribute to a greater understanding of the program by improving knowledge about its practices, potential, and constraints based on the evidence it will collect. This knowledge may help illuminate some commonly held opinions about SBIR as well as suggest ways to improve the operation and impact of the program.

### Some Contrasting Views of the Program

While generally enjoying bipartisan support in Congress and strong support in the small business community, SBIR is seen in some quarters as a "tax" on agency R&D funds. Given the demands for extramural R&D funding, some agency staff believe that a mandatory 2.5 percent set-aside for small companies interferes with effective management of agency R&D programs—although this view is not shared by agency SBIR managers.[63] In any case, the degree to which the set-aside causes a negative impact on R&D management is as yet undocumented.[64] At the same time, it is likely that if the program is poorly managed or misaligned with the agency mission, then its results may well be sub-optimal in terms of overall agency research goals.[65]

At least in the program's early years, the federal R&D agencies and the Small Business Administration, which administers the SBIR program, were seen to be addressing different constituencies. The R&D agencies and, in the Congress, the science committees saw themselves as the stewards of the public dimension of the nation's scientific and research enterprise—a constituency by nature different from the small business community.[66] This perception has evolved in recent years, with much greater attention paid today to SBIR's role in bringing ideas grounded in university research to the market.

There have been concerns too that the SBIR's mission to serve small business renders the program susceptible to "capture" by small firms that become adept at special interest pleading.[67] Some critics, for instance, object that multiple

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[63]See Kenneth Flamm's conference presentation in the Proceedings section of this volume.

[64]The view that the SBIR "tax" on agency extramural R&D budgets reduced program manager flexibility was noted by William Bonvillian at the conference. See his remarks in the Proceedings section of this volume. Commenting on the issue at the NRC conference, Charles Holland of the Department of Defense noted that program managers on major defense programs such as JSF see SBIR as a tax, where the funds from the program are assigned elsewhere. Vinny Sharper, SBIR program manager for the U.S. Navy, averred that when a program such as JSF is "taxed," the money typically goes back into the program where it originated. See a summary of their comments in the Proceedings section of this volume.

[65]See National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, op. cit.

[66]See George Brown and James Turner, "Reworking the Federal Role in Small Business Research," *Issues in Science and Technology*, Summer 1999, pp. 51-58.

[67]For a classic statement of the problem of "capture," see Sam Peltzman, "Towards a More General Theory of Regulation," *Journal of Law and Economics* (19):211-240, 1975.

award winners, or SBIR "mills," receive many awards yet generate little in product commercialization.[68] Some multiple award winners are largely contract research organizations, meeting the research requirements of agencies, yet not focusing on the commercial goals of the program. Given the diversity of the SBIR program's goals, the main question is simply whether the quality and value of this research is in alignment with agency needs and priorities—essentially a question of management rather than program concept. The actual operation of the program in this respect and its relevance to agency missions needs to be clarified—one of the goals of the current study.

Some have also suggested that the failure rate of SBIR awards is too high, which suggests, in turn, that the program funds R&D of marginal value. This is a challenging point. Measuring the impact and results of an R&D program is intrinsically difficult.[69] What constitutes an acceptable failure rate for a program designed to make high-risk, potentially high payoff investments is, of course, a central question—one that is especially difficult for those with a fiduciary responsibility for public funds. High-risk R&D investments are, indeed, high-risk—project failures in such initiatives are inevitable and not necessarily indicative of program failure.

Still, the question of what an appropriate return on investment in new technologies remains. One benchmark may be the venture capital market, where only about 10 percent of investments in new firms succeed. A key question in assessing SBIR is whether this comparison is appropriate.[70] Another recurrent question is whether a project or firm failure is indicative of a complete loss on federal investment—as it sometimes is—or if the loss is mitigated by knowledge generated by the SBIR grant that is then transmitted through less direct ways to the overall benefit of society. This second scenario takes into account potential indirect knowledge spillovers that were not a part of the original research design or intent. Consider, for example, the case of a principal investigator who takes the knowledge gained from work at a "failed" firm, and uses it at a new firm to guide product development in an entirely new market.[71]

[68]Kenneth Flamm refers to this issue in his presentation. See a summary of his remarks in the Proceedings section of this volume. The Department of Defense Fast Track Initiative addresses this issue. It attracts significantly more new, first-time applicants to the program. See National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, op. cit.

[69] See National Research Council, *Capitalizing on the Results of Scientific Research,* op. cit., 1999.

[70] Despite the growing popularity of the idea of "public venture capital" programs, SBIR cannot be considered a venture capital program because awards do not involve equity ownership, management input, or an exit strategy, involving sale of the firm. For a description of a public venture initiative, see the presentation of the CIA's In-Q-Tel by Gilman G. Louie, "In-Q-Tel A "Nonprofit Venture Capital Fund," in National Research Council, *A Review of the New Initiatives at the NASA Ames Research Center,* C. Wessner, ed., Washington, D.C.: National Academy Press, 2001.

[71] Relatedly, see the discussion of David Audretsch, Duncan Moore, and Paula Stephan on the challenges of "Gauging Commercial Success," summarized in the Proceedings and highlighted in this Introduction.

An additional concern is that SBIR awards might "crowd out" or replace private capital. While theoretically possible, recent work by Bronwyn Hall, Paul David, and Andrew Toole suggests that the overall empirical evidence for "crowding out" is at least equivocal.[72] Interestingly, there is some positive evidence that programs like SBIR can prompt "crowding in" of private capital. Awards have a "halo effect" that attracts private investors, who see the awards as a certification of technical quality, reducing the uncertainty inherent in early-stage investment.[73]

Finally, some object to the SBIR program more broadly as an unwarranted and unnecessary intervention in capital markets.[74] Yet, as noted above, it is widely recognized that capital markets are imperfect with significant gaps (or asymmetries) in information between the potential investor and the prospective entrepreneur.[75] Venture capital markets, in particular, tend to focus on later stages of technology development than SBIR—though venture-based companies can and do obtain SBIR awards—and venture funds in the aggregate seem to be prone to herding tendencies. In particular, the attention of private investors does not necessarily extend to all areas of socially valuable innovation.[76]

Perhaps the most significant point to retain from these various perspectives on SBIR is how much uncertainty surrounds early-stage finance in the U.S. economy. As noted, some recent work suggests that the federal role in early-stage firm development is more significant than commonly believed, while also affirming the analytical uncertainty surrounding the funding and development of early-stage firms. Strong affirmations about the "appropriate" role of government support for innovation are not borne out by the history of innovation and industrial development in the United States or, indeed, recent experience.[77]

Indeed, while the appropriateness of the government's role in fostering new industry has been debated since the origins of the republic, American policy has tended to be fairly pragmatic in practice, meeting national needs from the tele-

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[72]See Paul A. David, Bronwyn H. Hall and Andrew A. Toole. "Is Public R&D a Complement or Substitute for Private R&D? A Review of the Econometric Evidence," No 7373, NBER Working Papers, 1999.

[73]See Maryann P. Feldman and Maryellen R. Kelley, "Leveraging Research and Development: The impact of the Advanced Technology Program," in National Research Council, *The Advanced Technology Program: Assessing Outcomes*, C. Wessner, ed., Washington, D.C.: National Academy Press, 2001.

[74]See, for example, Scott Wallsten, "Rethinking the Small Business Innovation Research Program," in Branscomb and Keller, eds., *Investing in Innovation*. Cambridge, MA: The MIT Press, 1998, pp. 194-220.

[75]See Michael Spence, *Market Signaling: Informational Transfer in Hiring and Related Processes,* op. cit. 1974.

[76]See case studies in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense's Fast Track Initiative,* op. cit.

[77]See the discussion of this question in the Introduction to the review of the Advanced Technology Program in National Research Council, *The Advanced Technology Program: Assessing Outcomes*, op. cit., and National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, op. cit.

graph to railroads to radio to the Internet.[78] Likewise, debates about public-private partnerships, especially the type that emerged in the 1980s and 1990s, have sometimes been more ideological than analytical in nature. Yet, as Berglund and Coburn have noted, "the [policy] debate should address not whether these [partnership] programs will endure, but whether they are shaped properly—at the program and aggregate levels—to achieve the desired benefits."[79] This is essentially the approach taken in the legislation that launched this review of SBIR.[80] The task of the Committee is, thus, not to determine if the nation should have an SBIR program; that decision has repeatedly been taken by the Congress. Rather, the Committee's charge is to assess its operations and accomplishments, and to consider how it might be improved.

## KEY ISSUES FROM THE CONFERENCE

To address this task, the Committee convened a conference on October 24, 2002 to gather new information and agency perspectives on the operation and potential of the SBIR program. Participants at this conference discussed the diverse goals of SBIR awards and highlighted key issues to be addressed and the challenges faced by the NRC's assessment of the SBIR program. The presentations by senior officials from the participating agencies drew attention to the administrative flexibility and operational diversity that characterizes this innovation program.

### Administrative Flexibility

Does the statutory language establishing SBIR provide the government agencies implementing the program the flexibility needed to play an effective role within a complex innovation system? In reviewing the meaning of the original two-page statute that Congress issued in 1982, **James Turner** of the House Science Committee noted in his conference comments that many of SBIR's features—particularly the three-phase structure—were based on an assumption of a linear model of research and development.[81] In the linear model, innovation begins with basic research supplying a steady stream of fresh and new ideas. Among these ideas, those that promise technical and economic feasibility become innovations. Such innova-

[78]See LeBow, op. cit. For a more general discussion, see David M. Hart, *Forged Consensus: Science, Technology and Economic Policy in the United States, 1921-1953,* Princeton: Princeton University Press, 1998.

[79]See Dan Berglund and Christopher Coburn, *Partnerships, A Compendium of State and Federal Cooperative Technology Programs*, Columbus, OH: Battelle Press, 1995.

[80]SBIR has been reauthorized until the end of fiscal year 2007. The SBIR legislation, contained within H.R. 5667, can be viewed on-line at: http://thomas.loc.gov/home/omni2000/omni2000.html.

[81]This view was echoed by Duncan Moore: "Innovation does not follow a linear model. It stops and starts." See the summary of comments by Dr. Moore in the Proceedings section of this volume.

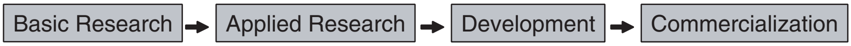


FIGURE 3 The linear model of innovation.

tions, when further developed by firms can become marketable products driving growth. The schematic in Figure 3 depicts this linear model of innovation.[82] While it undoubtedly has conceptual value, it substantially simplifies reality.

Indeed, as the National Science Foundation's **Joseph Bordogna** observed, innovation almost never takes place through a protracted linear progression from research to development to market. Research and development can drive technological innovation, but it can also happen in the reverse direction. True innovation, he noted, can spur the search for new knowledge and create the context in which the next generation of research identifies new frontiers.

Taking this point, **Mr. Turner** remarked that we now understand that knowledge moves in more complex and circular fashion, with numerous feedback loops between the marketplace and the laboratory.[83] As Figure 4 illustrates, the innovation process is neither linear nor unidirectional.[84] Applied research can be a source

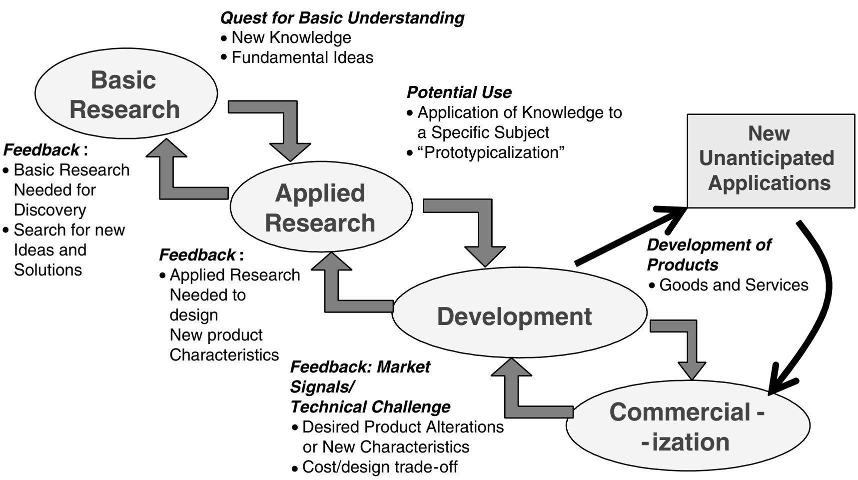


FIGURE 4 A non-linear model of innovation.

[82]For a discussion of the limits of this model and its potential impact on policy, see Donald E. Stokes, *Pasteur's Quadrant, Basic Science and Technological Innovation*, Washington, D.C.: Brookings Institution Press, 1997, p. 10.

[83]See George E. Brown Jr. and James Turner, op. cit.

[84]The schematic in Figure 4 was developed by Adam K. Korobow. The model captures added features, but not all of the complexities, of the innovation process.

of knowledge as well as technological advance. The progression of a SBIR project from Phase I to II to III is often marked with discoveries or questions that may stimulate new or additional research, with new research sometimes suggesting new applications. It is also littered with conceptual and practical dead-ends. The nature of the research process and the unique missions of diverse agencies underscore the advantages of a program that can be flexibly implemented.

**Christina Gabriel** of Carnegie Mellon University noted that when she worked at Bell Laboratories, she and her colleagues implicitly believed in the linear model. "We didn't think it was important for the researchers to talk to the rest of the company," she said. "My personal opinion is that that's why we don't have Bell Labs and the original research labs any more. Some of the large companies never understood how to connect their research to the rest of the company in a productive way. So small businesses and Japanese companies and others outside the labs were the ones who commercialized almost all the innovations that came out of our labs." However, she thought it was remarkable that the SBIR, even though it was founded in an earlier era, continued to serve the nation in an effective way—not least because it has been able to maintain great flexibility.

As **Mr. Turner** concluded, the challenge for the NRC Committee would be to recommend ways to amend some of the "statutory impediments" that reflected the earlier, linear model of innovation, that we now know impacts overall program effectiveness. Such impediments, he noted, include narrow time-frames, fixed amounts of money, and a "one-size-fits-all" approach to the program. How can we amend the rules, he asked, to nurture the best ideas and make award winners into market winners?[85]

Although formally structured on a common three-phase template, SBIR operations have come to reflect in many ways the non-linearity that characterizes real research and development as well as the diversity of missions and cultures of the federal agencies that administer the program. Agencies administering SBIR are coping with these exigencies by decentralizing important aspects of SBIR's administration. As noted at the conference, the need to deal with operational complexity is particularly acute in larger and more diverse agencies.

To illustrate the need for flexibility in an environment characterized by diversity, **Jo Anne Goodnight** of the National Institutes of Health pointed out in her conference presentation that time and funding requirements to develop new products can vary significantly among firms in different technology sectors. While NIH-supported projects to develop pharmaceuticals require an average of 12 years and hundreds of millions of dollars to complete, some Department of Defense

[85]In fact, anecdotal evidence suggests that the program is evolving—at least incrementally. To meet this need for greater flexibility, agencies can and do obtain permission from the Small Business Administration to modify standard practice to meet particular research requirements, e.g., larger awards for drug development.

supported military products (e.g., software) are typically developed for more immediate use.[86] Similarly, the development time-line for NSF-supported information technology products is relatively short, while time taken to plant and grow crops under a USDA-supported SBIR can be considerably longer. The nature of the product and the pace of market competition (such as in the information technology sector) can, in addition, leave some firms more vulnerable to lags in funding between SBIR Phase I and Phase II.[87]

These realities preclude a "one-size-fits-all" approach to administering the SBIR program. While SBIR's overall three-phase approach is designed to implement national policy goals across federal agencies and sub-agencies, the program must be implemented taking into account the multiple agency goals and operational requirements to meet their diverse objectives. Capturing this point, **David Finifter** of the College of William and Mary observed that "one must understand programs at the agency level in order to understand the policy effects of the program at the national level."

## Operational Diversity

SBIR's operational diversity reflects its adaptation to the non-linear realities of science, technology, and agency practice. **Charles Holland** noted that officials with the Army, Navy, Air Force, Missile Defense Agency, DARPA, and other agencies that participate in SBIR at the Department of Defense independently develop topics that address their own agency's strategic efforts to develop the nation's war-fighting capabilities. At the same time, he noted that this decentralization was coordinated through his office to ensure that they are in line with the department's overall Defense Technology Area Plan. Similarly, **Jo Anne Goodnight** noted that while the operation of NIH's SBIR program was coordinated through her office, each of the 23 individual institutes and centers that administer SBIR at NIH develop topics that relate to own specialized missions. These missions, she said, range from promoting public health to the investigation of particular diseases such as cancer to addressing broader areas of concern such as aging. Describing the case for NASA, **Robert Norwood** noted that while SBIR is closely tied to the agency's overall missions in space science, earth science, and aerospace technology (among others), officials at each of NASA's 10 major centers are responsible for writing SBIR proposal solicitations. This diversity, by more accurately reflecting the interests of NASA's component enterprises, increased the likelihood that SBIR-supported technologies would realize commercial success.

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[86]NIH also supports a broad range of other applications from diagnostic software, to audiovisual material, to biosensors with shorter lead times.

[87]See comments by Linda Powers in the summary of Proceedings in this volume.

Recognizing this need for operational flexibility, Ms. Goodnight said, the Small Business Administration—which oversees the administration of the SBIR program—allows for different ways of supporting agency missions. Rather than limiting ideas to those that can be conducted under prescribed budgets and timelines, this latitude allows companies to propose research and development in fields that have the most commercial promise.

In the context of the current assessment, the presence of such operational diversity among agencies in program implementation provides opportunities for identifying best practices—some of which might be replicated in other contexts.[88] At the same time, recognition of the diversity of the program's goals and administration cautions against a "one-size-fits-all" approach to a complex program that is focused on a critical phase of the innovation process.

## Measurement and Assessment Challenges

The program diversity in goals and practice must be taken into account as the program evaluation is developed. How can the impact of innovation awards to small businesses be measured? What metrics are most useful in this regard? And is there a need to look beyond these indicators to achieve a balanced understanding of the limits and contributions of SBIR? In keeping with the conference theme, "Measuring Outcomes," conference participants considered the possibilities and limitations of available measurement tools. In addition, they assessed to the broader dimensions of the program's impact.

### *Tracking Awards*

One way to measure the value of SBIR is to track awards to see if they have resulted (variously) in new publications, citations, patents, products, licensing, sales, and increased employment for firms receiving awards. While data relating to these metrics promise to give information of some significance on SBIR's impact, conference participants noted that accurate data might be difficult to procure for a variety of reasons.

For instance, program realities can complicate the task of tracking data. As NIH's **Jo Anne Goodnight** pointed out, SBIR recipients can get, in some cases, a Phase I award from one agency and a Phase II award from another. She noted that additional assessment challenges could also arise in cases where multiple SBIR awards are provided to bring a particular product to market, or when the SBIR award is one among other federal and non-federal sources of funding.

[88]The Committee subsequently held a public conference on May 28, 2003 at the National Academies, entitled, "Identifying Best Practice." Given that the variety in implementation across agencies affords an opportunity to identify best practices, conference participants had an opportunity to consider which aspects can be successfully replicated by other agencies.

The issue of causality becomes more complex. Awards are given to firms for projects; yet, specific projects funded by SBIR can be difficult to track. **MaryAnn Feldman** of Johns Hopkins University observed that firms that are granted SBIR awards can merge, fail, and change their name before a product reaches the market. In addition, key individuals can change firms, carrying their knowledge of the project with them. In this way, an SBIR investment in one firm may translate into a valuable product from another firm. Especially when the process from discovery to market is long, as is the case for drug development, these transitions are difficult to track.

### *Measuring Indirect Impacts*

The indirect effects of SBIR awards are also difficult to measure and assess. **Rosalie Ruegg** of TIA Consulting suggested, however, that evaluation techniques, such as those developed for the assessment of NIST's Advanced Technology Program, can help measure these impacts: She cited newly developed econometric techniques could help gauge the impact of *halo effects*. (The halo effect refers to the ability of a firm that has received a federal grant to attract new private or public funding by signaling the technical and commercial potential of its product.) She made note that recent models based on "fuzzy logic" that appear to improve assessments of *knowledge spillovers*. Finally, she referred to a new index method that promises to provide better estimates of *market spillovers*. While Ms. Ruegg conceded that "we cannot hope to do a comprehensive measure of all indirect effects," she expressed optimism that new assessment techniques will increasingly provide the means to capture snapshots and indicators of the full range of SBIR's impacts.

### *Gauging Commercial Success*

Even the apparently straightforward task of assessing commercial success can be elusive. For example, **David Audretsch** of Indiana University pointed out that research enabled by a particular SBIR award may take on commercial relevance in new unanticipated contexts. Illustrating this point, **Duncan Moore** of the University of Rochester noted how his SBIR-funded research in gradient index optics was initially a commercial failure when an anticipated market for its application (35mm SLR camera lenses) did not emerge. However, the technology later found substantial commercial success in the boroscope, a device used to look inside materials and structures. As **Paula Stephan** of Georgia State University concluded, "today's dead end often can be a key to tomorrow's success, or what is seen as a failure today can be seen as a success tomorrow."

In the case of public procurement, the challenge is one of developing a satisfactory measure of how useful an SBIR-funded innovation has been to an agency mission. Relatedly, it is important to assess just how compatible success in meeting an agency mission has or has not been with commercial success for an SBIR company. Success in such cases varies depending on the nature of the product, the type of research, and its utility for the agency mission. In some cases, the appropriate metric is likely to vary with the specific mission of the agency or sub-unit. For the Department of Defense, **Charles Holland** noted that one way of measuring commercialization success would be to count the products procured by the agency—although, as he acknowledged, large procurements from major suppliers are more easily tracked than products from small suppliers such as SBIR firms. Gauging commercial success accurately is made more challenging since successful development of a technology or product does not always translate into successful "uptake" by the procuring agency, often for reasons having little to do with product quality or potential contribution.

Indeed, the conference highlighted varying approaches to the concept of commercialization. While the concept of "commercial" at the Department of Defense most often relates to the use of a new product or process by government, the concept more conventionally refers to the means by which a new product or process—provided by a viable business enterprise—enters the market on an independent, third party, competitive basis. These differing interpretations also reveal the differing pathways to commercialization. For some products, this path is akin to a long, complex, winding, and uncertain road. For others, the pathway is more immediate with visible linkages to mission, industrial and commercial applications.

*Program Effectiveness*

The value of the SBIR also derives from how well it serves firms seeking to cross the Valley of Death. Efficient evaluation of proposals and the prompt disbursement of funds can be important to small businesses in this phase of development. **Jon Baron** of the Coalition for Evidence Based Policy noted that SBIR's reputation for accurately gauging the technical quality and commercial potential of a proposal is key to an award's usefulness as a signal to capital markets. **Linda Powers** of Toucan Capital observed that long time lags in program award cycles could be fatal for small firms facing capital shortages: "The reason why so many companies die trying to cross the Valley of Death," she noted, "is that it is so wide and takes companies so long to cross it." She noted that firms can ill-afford to spend long periods waiting for grant cycles and other agency procedures. A Phase II SBIR award of $750 thousand is expected to last for two years, but such grants, she said, are too small to support a company during delays, adding that, in some cases, "even in an early stage, companies are burning that much per month."

**Milton Johnson** of the Department of Energy noted that despite resource constraints, his agency has been able to provide on-time service with modest time lags between Phase I and Phase II funding. **Robert Norwood** of NASA reported that his agency had recently implemented an Electronic Handbook System that integrated all elements of SBIR administration. The system is designed to speed the processing of grant applications, improve transparency, and generate data for future evaluation.

Program effectiveness is also affected by how well state and local governments leverage SBIR to foster local development. Noting that some states were better at using the SBIR program than others, **John Williams** of the U.S. Navy wondered how state outreach programs run by SBIR agency managers could best be evaluated.

*Realistic Expectations*

An assessment of SBIR must be based on an understanding of the realities of the distribution of successes and failures in early-stage finance. **Jon Baron** noted that the program is characterized by a highly skewed distribution of successes. This includes a few genuinely large successes that generate returns that would cover, in themselves, the cost of the entire program. He cited two examples of such successes—Science Research Laboratory Inc., which had reported over a billion dollars in sales from a new technology that increased the number of circuits on a computer chip by thirty percent, and Digital System Resources, whose technology had improved the computing power of sonar technology by twenty percent leading to its adoption across the U.S. submarine fleet. Below these star performers were a number of more modest successes, followed by a large number of awards that had produced few or no results, he said. Given this skew, he noted that a purely random sample of individual project outcomes is likely to yield an imbalanced assessment of the SBIR program.

A related issue concerns the appropriate expectation for success or, indeed, failure. Providing a comparison from the private sector, **Gail Cassell** of Eli Lilly noted that the failure rate for biotechnology industry—from target identification to product launch—was about ninety percent. This held true even in the best of circumstances and even for large companies that had invested billions of dollars in research and development. Thus, in setting metrics for SBIR projects, she said, it is important to give a realistic expectation of success, especially for small firms investing in biotechnology. In his remarks, **David Finifter** of the College of William and Mary expanded on this point, noting that measures of success vary greatly by area of discipline and by federal policy objective.

Professor Finifter also noted that while a high success rate was gratifying, it could imply that the SBIR program does not have a sufficiently risky portfolio: The question of "how high is high" is therefore important to the program and to the study, he concluded. Similarly, **Greg Millman** of the National Institutes of Health noted that success alone would be a dangerous metric for assessing SBIR, arguing that if there were no risk taking, there would be no need for the SBIR program.

## ADDRESSING TOMORROW'S CHALLENGES

While it is important to know whether firms receiving SBIR awards are successful or not, **David Audretsch** reminded the conference audience that the larger purpose of the SBIR program is to improve the efficiency of the American economy "to make it more innovative than it would be otherwise." The creation of innovation firms, as a result of SBIR awards, is an important contribution of the program. Thus, a balanced assessment of SBIR has to go beyond measuring the operational impact of individual awards. It is also to consider the broader institutional role that SBIR plays in the United States economy. Given the need for administrative flexibility and the considerable operational diversity of SBIR, highlighted in the conference, an important question to ask is how agency-specific implementation practices support or detract from these broader program goals.[89]

Carnegie Mellon University's **Christina Gabriel** noted in this regard that SBIR plays an important role in bringing the contribution of university research to market. Pointing to the role that technology transfer from Carnegie Mellon has played in the revitalization of Pittsburgh's economy, she noted that job gains and regional economic growth could be realized by exploring ways by which SBIR can be better linked to the national innovation system.

Further to this point, **Joseph Bordogna** of the National Science Foundation observed that in addition to investing in the nation's scientists and engineers, SBIR also serves as a key institutional facilitator in the integrative research that increasingly characterizes innovation-led growth. This distinctive role for SBIR, he argued, is best understood as one element in the large-scale transformations taking place in the nation's research and innovation enterprise.

As the nation's innovation system continues to evolve towards greater collaboration and multi-disciplinary research, public-private partnerships such as SBIR may play an increasingly important role in bringing together the expertise from business, academia, and government, as well as from across disciplinary boundaries. As the innovation system changes, the ability of firms to traverse the Valley of Death also grows increasingly important, highlighting the role that SBIR can play in facilitating the transition of new ideas to commercial application.

In these respects, as Dr. Bordogna concluded, an SBIR assessment that takes the long view could well serve as a "revolutionary chart of the new paths we will follow in the twenty-first century." The conference launching the NRC assessment of SBIR is a first step in charting this ambitious path.

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[89]Understanding how the program, in its various agency contexts, supports the overall goals of the program is a key objective of the NRC study. The NRC's evaluations of SBIR at individual agencies are expected to contribute to an overall assessment of the program's effectiveness.

# II

# PROCEEDINGS

# Opening Remarks

*Charles W. Wessner*
*National Research Council*

Charles Wessner welcomed the participants, formally opened the symposium, and introduced Jacques Gansler, who has accepted the task of chairing the Committee charged with the Study of the SBIR program.[1]

## INTRODUCTION

*Jacques S. Gansler*
*University of Maryland*

Dr. Gansler extended Dr. Wessner's welcome and thanked the three groups of people who had gathered for the symposium: These were the members of the steering committee, who would serve for three years, beginning with this "kick-off" symposium; those who had agreed to do the actual research for the evaluation of the SBIR program; and the agency representatives, "who are going to be making the major contribution to this activity."

To all three groups, he expressed gratitude for their help and support in what he called a "participatory activity." The study, he said "would not be a GAO look-at-the-problem" exercise, or an attempt to ferret out incompetent people or teams. The panel would try to discern where best practices exist and how they can be improved "in what I personally believe to already be a very successful and important program." Obviously, he said, the study has the potential for a signifi-

[1]The Committee membership is listed on pp. v-vii, as are the members of the Research Team.

cant positive impact on the missions of the agencies as well as on the country. "I also personally believe the program can be improved, and that's the purpose of this overall effort."

The goal of this first formal session, he said, was to launch the evaluation itself. Each of the agencies had been asked to give the steering committee a description of what they were doing to assess their SBIR programs: what kind of data they were gathering, what kind of evaluations they were already doing or planning, and what views they had on how their activities and how the overall effort could be enhanced.

He said that the symposium would feature "full discussions of each of the five largest agency SBIR programs." These five accounted for some 96 percent of the $1.6 billion program, so that it "makes sense to pick them," he said. At the same time, he suggested, one would expect to find good ideas and best practices in the other SBIR agencies, and these would be incorporated into the study as well.

Dr. Gansler then introduced Roscoe Bartlett, a member of the House of Representatives from the Sixth District of Maryland.

## SMALL BUSINESS AND THE SBIR PROGRAM

*Roscoe G. Bartlett*
*U.S. House of Representatives*

Dr. Bartlett, who serves on the House Small Business Committee, said that he had been in the Congress for 10 years, having first run for public office at the age of 65. Before that, he had been a small-business person and was one of about three-dozen members of Congress who belong to the National Federation of Independent Businesses. He has a Ph.D. in science, holds 20 patents, and has worked for the federal government in several capacities. He said he wished the SBIR program had existed when he was involved in research and development and seeking patents for his inventions.

### An Introduction to SBIR Program

Dr. Bartlett began with an overview of the SBIR concept, describing it as a three-phased program: Phase I, with lower dollar amounts and a shorter period, is a phase of exploration to see if there is a potential for commercialization. Phase II is designed to bring a project to the point when it would be ready for introduction to the commercial market. Once in Phase III, a company should be ready to go into the commercial market and become eligible for venture capital funding.

The SBIR is a relatively new program, having been created in 1982, and 2002 was its twentieth anniversary. The goal of the program, he said, is to bring to the marketplace creativity and innovations from the small business community, particularly innovations that were at least partly the result of government contracting. He recalled that 19 of his 20 patents are military patents, awarded when he worked for the Navy, both as a physiologist at the School of Aviation Medicine in Pensacola, Florida, and later at the Johns Hopkins University applied physics laboratory, a "captive" Navy contractor. He said that growing up on a farm, where he had had to learn diverse mechanical and technical skills to succeed, he learned to see opportunities in problems and to solve them himself. In the same way, he saw opportunities for solving problems in human physiology when he worked for the Navy and won a series of patents in the area of life-support equipment.

## The Importance of SBIR to the Economy

He emphasized the importance of small business to the U.S. economy. Small business employs just over 50 percent of all workers in the country, he said, and after the recession of the early 1990s, he was astonished at the role played by small businesses in pushing the economic rebound. "I had to have my staff look at these numbers to verify them," he said, "because at first they were unbelievable." He categorized America's businesses according to size, with the largest group employing at least 5,000 people and the smallest employing zero to four employees. Within those categories, a few new jobs were created in the 5,000-plus group; in the progressively smaller groups of companies, no new jobs were created, until he reached the zero-to-four-employee category, where more than 90 percent of all of the new jobs were created. The smallest of small businesses were almost fully responsible for bringing the country out of recession. The country was again in a recession as he spoke, he said, and he expected that small businesses would once again lead the country out of it.

Small business is important to the U.S. economy not only because it employs more than half of all U.S. workers, he said. In addition, the percentage of scientists and engineers working in small businesses exceeds that in large businesses. From this he inferred that the opportunities for creativity are greater in small businesses. He said that he had worked for eight years at IBM, which he called a "great employer who did as good a job as a big bureaucracy can do in providing an environment where you can be creative." But he said that big organizations are inherently stifling by the very facts of their size and their bureaucracy. It is no accident, he said, that small companies create relatively more innovations and win more patents.

He said that he works hard in Congress to ensure that small businesspeople have adequate opportunities to work with government. And he expressed gratification that government had now agreed that 35 percent of all contract dollars would go to small business. But he argued that 35 percent was still not enough, given that more than half of all employees work for small businesses. "I know that small businesses can't build big airplanes and submarines and tanks, and so forth, but I suspect we could do better than we're doing, and I think the interests of the government would be better served if we did."

### The Importance of Intellectual Property Policy

There was neither an SBIR nor an STTR[2] program when he worked for the Navy, but the policy on intellectual property was more favorable to the inventor, he said. The inventor would receive all commercial rights to an invention, while the government retained what were called "march in shop rights." That is, the inventor's own agency—or any other agency of the government—could use the patent for any government purpose without paying royalties. The favorable point was that the inventor had the right to patent and market the invention. This is no longer true, however, largely because of Congress' feeling that if public money is used to support research, any resulting innovations or patents rightly belong to the taxpayers.

He offered an example from his own congressional district to illustrate the unfairness of this sentiment. A chemist working for the military had developed a cream to protect a person's skin from chemical or biological agents. Such a protection is necessary, especially in a battlefield environment, because even the tightest-fitting protective suit has junctions between boot and pants, between head shroud and coat, and between gloves and arm. Minute amounts of toxic fluid could penetrate the suit through these junctions, and the cream prevented this from happening.

In spite of the fact that this chemist was a small businessman as well as a military employee, he was refused the right to develop and market his invention. "I think there would be more such innovations, and that the taxpayers would be better served," said Dr. Bartlett, "if the inventor today had many of the same opportunities that previous inventors have had to exploit the commercial opportunities of their own invention."

### Trends in Women-owned Small Businesses

He noted that the fastest-growing sector of small business today is women-owned small businesses. These have been increasing at twice the rate of male-

[2]The smaller STTR (Small Business Technology Transfer) program is focused on the academic and not-for-profit research community. STTR reserves a specific percentage of federal R&D funding for award to small business and nonprofit research institution partners. Small businesses must meet certain eligibility criteria to participate in the STTR Program.. They must be a for profit American-owned and independently operated firm. While the principal researcher need not be employed by small business, company size is limited to 500 employees. The nonprofit research institution must also meet certain eligibility criteria, although there is no size limit for nonprofit research institution. They must be located in the U.S., and must be a nonprofit college or university, domestic nonprofit research organization, or federally funded R&D center (FFRDC) .

owned small businesses. He said that, on the basis of his work on the Armed Services Committee, the House Science Committee, and as vice-chair of the Small Business Committee in the Congress, he felt he could state that women-owned small businesses are "better employers than male-owned small businesses, and they're better corporate citizens." One reason for that, he went on, is that "women are more compassionate and more empathetic than men, and so it doesn't surprise me that they're better employers and their companies are better corporate citizens. They also have a lower bankruptcy-failure rate than male-owned small businesses. The banking world hasn't figured that out because women-owned small businesses still have a major problem with access to capital."

### "Bundling" and Small Business

He described a recent trend in government procurement toward "bundling," which is to draw up one major contract for a suite of services that were formerly divided among a dozen, fifty, or a hundred small contracts. This practice is generally more convenient for the contracting officer, who then has to deal with only one contractor. Another incentive for bundling is that it may speed procurement cycles.

He illustrated this practice by the example of the Navy and Marine Corps, the first organization to bundle "for a good reason rather than a bad reason." The Navy and Marine Corps let a single performance contract for acquisition and management of all of their data. The reason they did so was to shorten their procurement cycle, which was so long that by the time they had bought the data-handling equipment they needed, it was nearly obsolete. If a procurement cycle was fourteen months long and the lifetime of data-handling equipment is eighteen months, the procuring agency has state-of-the-art equipment for only four months. "So what they are doing is buying performance," he said. "The contractor they deal with can literally buy overnight something that the government needs a very long time to buy."

Dr. Bartlett said he understood the need to procure the latest equipment, but he expressed concern that small business might be excluded from such bundled bidding. When the Armed Services Committee explained this concern to the Navy and Marine Corps, their representatives, "to their great credit," agreed. They withdrew the request for proposals and issued another, guaranteeing that 35 percent of the contract money would go to small businesses and 10 percent of the money would be direct-pay.

The next organization to unbundle its contracts was the National Security Agency. This, "ground-breaker program," which attracted considerable publicity, influenced many other agencies. The NSA, which relies on having the most up-to-date technology, had also been held back by the long procurement cycles in government. In response, the agency was about to depart from its previous custom of letting hundreds of contracts and to consolidate them into a single contract. Small-business representatives were very concerned when they heard this, and presented the agency with the same arguments and the same proposition they had expressed to the Navy and Marine Corps. The NSA was skeptical that it would be able to meet their goals while doing more for small businesses. However, Dr. Bartlett and his delegation argued that the Navy and Marine Corps had had success with an even more dispersed system. As a result, the NSA is now attempting to meet the goal of directing 35 percent of its contracting to small business and 10 percent to direct-pay.

### Evaluations are Essential

He congratulated the NRC committee on holding its first meeting, and agreed that evaluations are essential to the health of programs. He said that the SBIR program has been successful in his opinion, but that "no matter how good a job you're doing, if you look carefully you probably can find ways to do an even better job." He encouraged the panel to focus on looking for opportunities to make a good program better.

"This is particularly important for two reasons," he said. "One is that we are now in a recession, and if small business performs now as it has in the past, it will provide most of the new jobs that will bring us out of this recession." But he also cited a new challenge, "one that we have not faced for nearly 200 years." That is, on September 11, 2001, a foreign entity had killed Americans on home soil in large numbers for the first time since the War of 1812. All the other wars we had fought, he said, were "over there," with minimal physical impact on this country. We were now engaged in a war like none other we had ever fought, he said, and it appeared clear that the wars of the future would be very different from past wars. "We're going to need new creativity, and new innovations, and it will be largely the small-business part of our private sector, I believe, that will be responsible for these new creativities."

He thanked the steering committee for inviting him to participate in the symposium, and for its "commitment to creativity." He closed by saying he wished he could participate more fully, contributing his experience in science and innovation, but the pressures of the congressional election cycle left him little time for any activities beyond campaigning.

# SBIR at the Department of Defense

Moderator:
*William B. Bonvillian*
*Office of Senator Lieberman*

Mr. Bonvillian introduced himself as legislative director and chief counsel for Senator Lieberman, who served on both the Armed Services Committee and the Small Business Committee. The senator, he said, "has been a close observer of this program, as have I, since the time he arrived in the Senate. He worked hard on the authorization in the early 1990s, as well as the more recent authorization."

### The Roots of SBIR

He began by outlining some of the history of the SBIR program. The program "prelude" took place at the National Science Foundation. This was stimulated by an observation made in 1976 by Senator Kennedy, who said that the portion of the NSF's R&D budget going to small business should be raised to 10 percent. That initial effort became the basis for the SBIR program itself in 1982 and 1983, said Mr. Bonvillian, even though that was a period of big government, big corporations, and big research universities. This program and its underlying philosophy "didn't fit with that pattern." R&D and its agenda were largely controlled by dominant government agencies, such as the Department of Defense; the large, traditional, and powerful corporate labs; and the major research universities. At the same time, there was a growing belief "that something interesting was going on in small firms."

### Delivering a "Huge" Return

The SBIR program started as a very modest, $45 million "tax" on R&D. It was systematically attacked by the large R&D organizations on the basis that government ought not to be funding private-sector activities, and also on the premise that it constituted a "raid" on more "legitimate" R&D activities. But when Roland Tibbets and others at the NSF evaluated the program, they found that it had delivered a huge return of approximately 30 times the government's initial investment—a total of $9.1 billion. The 1990s, he said, confirmed to many federal policy makers that federal economic policy should be "at heart an innovation policy," and that innovation was going to be the key to productivity gains and economic growth.

"It was not only a matter of changing the measures of capital and labor supply traditionally used by the economics profession," he said, "but bringing an understanding that innovation can change the entire curve of growth and fundamentally affect societal well-being. The SBIR program fit with an emerging view of capitalism that I think we've begun to see clearly in the 1990s, a kind of creative destruction process."[3]

### SBIR as a "Stealth" Program

The SBIR program has really been a "stealth" program, he said. "It's the least-known of the handful of federal government programs that are aimed at bridging what's known as 'the valley of death' between the R&D and the venture-capital funding stages." Its low profile was at least partly due to its decentralized nature and dispersion among many agencies. While this allowed flexibility and adaptation to the needs of different agencies, it had also resulted in a low level of oversight and evaluation. Thus there is little known about the following questions:

- Commercialization: Is a sufficient degree of commercialization being achieved by the agencies supporting the program? Should the success of the program be measured by the ability of companies to commercialize their products, or is some degree of usefulness to government a sign of success?
- Cost-sharing: Should there be more focus on obtaining cost-sharing or company participation by the companies participating in SBIR?
- Multiple awards: Are there too many repeat awards to recipients that have not commercialized their products?
- Program structure: Have the delays between Phase I and Phase II awards created a breakdown in program continuity and therefore a disincentive for program participation? Is there a need for a real "Phase III," with a continuing role for government?

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[3]The term, "creative destruction" originates with Schumpeter, See Joseph Schumpeter, *Capitalism, Socialism and Democracy*, New York: Harper, 1975, (orig. pub. 1942), pp. 82-85. See also Richard Nelson (ed.) *National Innovation Systems,* Oxford: Oxford University Press, 1993.

- Networking: Most SBIR awards deal with what economists refer to as complex technology, which is generated by complex science. Both complex technology and complex science are supported by networks and collaboration—for purposes of knowledge diffusion, knowledge application, collective learning, product development, and product evolution. Should there be improved networking for SBIR, with better cross-fertilization across SBIR agencies and partnerships among program participants?

## The Need for Thorough Evaluation

He said that after two decades of operation, Congress had realized the need for a thorough evaluation of the SBIR program. In the SBIR re-authorization of 2000 Congress required participating SBIR agencies to work with the National Research Council to develop program metrics and conduct a six-year assessment of program quality. Many of the SBIR agencies were not enthusiastic about this additional exercise in oversight, he said, and it took about a year to agree on an evaluation and another year to initiate the necessary funding. Nonetheless, this symposium signified that the process was now underway.

He turned to the SBIR program at the Department of Defense (DoD), the subject of this panel. The DoD SBIR program, whose budget had grown from $460 million in 1990 to $733 million in 2002, represented more than 50 percent of the entire SBIR program. He said that the DoD's SBIR leadership, through the work of symposium participants Jacques Gansler and Jon Baron, among others, championed the federal government's effort to explore the need for a thoughtful programmatic evaluation. That leadership, he said, was an important contribution that had helped to bring about this program-wide evaluation process.

Within DoD itself, the internal evaluation resulted in the addition of new program initiatives. One was the continuation of the Fast Track sub-program to provide funding continuity between Phase I and Phase II. And Congress had both authorized and appropriated $12 million for a "challenge program," intended as a Phase III transition period that provides some federal assistance. There had also been difficulties, he said. One sub-agency (the Missile Defense Agency) had not been enthusiastic about continuing to participate in SBIR, but had recently agreed to do so. And the SBIR office had faced staffing shortages and a 40 percent cut in its program administration budget.

## The Importance of SBIR to DoD

Despite these difficulties, Mr. Bonvillian affirmed that "SBIR is potentially very important to the Defense Department." "The Defense Department acknowledges a revolution in military affairs; it acknowledges a need for transformation. There are dramatically changing military rule sets, based upon new sources of power and how those new sources are applied." He described SBIR proponent Admiral Art Cebrowski, then working for Secretary Rumsfeld, as "one of the leading military thinkers of our time," and quoted a recent talk: "All the world's economies are moving from the industrial age to the information age. The issue for the U.S. military is how to sustain a competitive advantage in this rapidly changing area. The nation is entering an era where advantages are conferred on the small, the fast, and the many. Size shrinks because information is substituted for tonnage."

### Updating the Evaluation Model

That quote, he said, applied well to the defense innovation base that DoD needed to utilize more extensively. DoD still relied on essentially the same innovation system that evolved out of World War II, he said. Aside from several cold-war updates, notably DARPA, it still overwhelmingly depended on large platforms and the large defense contractors that could support these platforms. But in using this model, he said, DOD was having "profound problems" with technology transition—with moving technologies from the R&D stage to the service acquisition stage.

"SBIR is an interesting option for DOD," concluded Mr. Bonvillian. "It's a very open and surprisingly sizeable program now; it creates lots of opportunities to do innovation in new ways." He asserted that SBIR brought to DoD a new opportunity for innovation in technology transition, one of the department's "big problems." Arguably, he said, this would require a major effort by DoD to analyze the opportunities that SBIR creates, but one well worth making.

He closed with an "SBIR Haiku" that expressed what was to become a common sentiment at the symposium:

*"Without measurement metrics*
*SBIR remains*
*As unknowable as the surface of the sea"*

## ACHIEVEMENTS, OPPORTUNITIES, AND CHALLENGES

*Charles J. Holland*
*Department of Defense*

Charles Holland introduced himself as overseer of the Pentagon's science and technology programs that were executed by the service and defense agencies. He noted that he works for Ron Sega, Director of Defense Research and Engineering. Dr. Sega, in turn, works with Mr. Pete Aldrich, who oversees all acquisition technology and logistics, a position previously held by Dr. Gansler. Mr. Aldrich reports directly to the Secretary of Defense.

### The Mission of DoD's Science and Technology Program

The mission for the science and technology program, said Dr. Holland, was to provide superior and affordable technology to the people who execute defense missions in the Army, Navy, and Air Force. All the science and technology programs of the Department of Defense could be arranged on a spectrum of activities, beginning with basic research that is performed primarily by universities, small businesses, and the defense laboratories. Moving along the spectrum are progressively more applied new technologies and "spiral technologies," which typically have the goal of incorporating scientific ideas and technologies into systems.[4]

He illustrated the science and technology programs at DoD by describing the relatively small ACTD[5] program. This program examined mature technologies, such as the Global Hawk Predator, an unmanned spy aircraft. The approach of the program would be to buy several of these aircraft and try to ascertain both whether the technology truly worked and whether it was consistent with the doctrine and tactics of the Department of Defense. ACTD asked whether the technology was important as well as whether the DoD could make good use of it. It also examined major systems, such as the Joint Strike Fighter,[6] of which the U.S. and its military allies planned to buy more than 3,000 over the next 20 years. The program did "upgrades and refreshes" to those systems.

The ACTD program relied upon a considerable number of people who gave advice, including the Joint Staff and the war-fighters "who tell us what they really need and how they really want to operate in the future." It also received useful advice from Congress about what the program should be, and from the department's own requirements process. "So we get requirements from the top," he said, "and we try to do technology opportunity from the bottom." The objective was to ensure technology superiority across all phases of acquisition.

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[4]For budgeting purposes the Department of Defense divides its R&D spending into three categories: 6.1 (basic research), 6.2 (applied research), and 6.3 (advanced technology development). These categories are used more for convenience than to imply rigid divisions among research activities. Research is a complex process characterized by numerous overlaps and feedback loops.

[5]The Advanced Technology Concept Demonstrations program is budgeted at about $200 million a year. According to Sue Payton, Deputy Undersecretary of Defense for Advanced Systems and Concepts, the primary role of her unit at the Pentagon "to rapidly transition technology from defense and commercial developers into the hands of the war fighter."

[6]The Joint Strike Fighter, according the a DoD announcement, will be the world's "premier strike platform beginning in 2008, and lasting through 2040." A production contract was announced in Fall 2001 for a multi-version, "all-aspect stealth platform" designed to "replace the aging fleet of Air Force A-10s and F-16s, the early model Navy F/A-18s, and the Marine Corps AV-8Bs."

## Upgrading Technical Systems

He gave some additional examples of the systems that were studied by the ACTD program, including the F-22 fighter airplane, where "we try to quickly mature technology and do some operational demos and concept demonstrations." They also did "spiral modernization," in which they tried to upgrade technological systems. This was the motivation for the Joint Direct Attack Munitions (JDAM)[7] program, in which a family of unsatisfactory "dumb" bombs was converted to highly effective "smart" bombs through the addition of a guidance system. With this modification, the JDAM had become "really the GPS guided weapon of choice these days inside the department," he said.

One of the challenges for DoD, he said, was to look beyond single platforms and see them as parts of more complex systems. The Army, for example, was emphasizing rapid deployment, which meant that individual units must be smaller and more mobile than they had been in the past. This, in turn, meant that units must be networked to optimize their operational capability. This was one of the transformations to which Dr. Holland was contributing as the Army developed its future combat systems.

## "Success Stories"

He turned to some "examples of success stories" that allowed the U.S. military to be dominant across the spectrum of its activities. One was the emphasis on night vision and stealth aircraft that was initiated by Secretary of Defense William Perry in the late 1990s. The capability of phased radar, stealth aircraft, and other tools had allowed the military to "own the night" and gain a range of advantages through remote sensing, as well as to commercialize night-vision tools. These advances should increase in the future with the deployment of adaptive optics and lasers, both for weapons and for communication.

The strategic environment had changed, he went on: no longer was the military faced with a single large threat from the Soviet Union, but with a range of "asymmetric" challenges from smaller states, stateless entities, and even individuals.[8] The U.S. faced asymmetric challenges in having to defend itself against chemical-biological attacks as well as respond to them; in defending both military personnel and civilian populations; and in defending against "information

[7]The Joint Direct Attack Munition (JDAM) is a low-cost guidance kit that converts existing unguided free-fall bombs into accurately guided "smart" weapons that can be launched approximately 15 miles from the target. The weapon is intended to have high-accuracy, all-weather, autonomous, conventional bombing capability.

[8]"Asymmetric threat" describes the almost limitless range of challenges posed by groups or individuals unable or unwilling to oppose conventional military strengths directly ("symmetrically"). "Asymmetric warfare" describes strategies and tactics designed to thwart or counter these challenges, and is seen within the Pentagon as an urgent priority following the September 11, 2001 attacks.

warfare" attacks. Military personnel not only had to operate in war-time environments, but were also expected to perform a broader range of economic, political, and humanitarian activities. Finally, he said, the funding environment for military research and technology had changed significantly. The DoD had changed from being the nation's dominant funder of R&D to one of many funders. A relatively larger portion of R&D was now funded by the private sector, so that the military was challenged to quickly locate and procure on the open market the technology it needed and to incorporate it into war-fighting systems.

He then listed some new "war-fighting concepts" the military is using to change its battlefield strategies, including:

- Fuller dominance of space;
- "Network centric" warfare;
- Unmanned systems for land, air, sea, and underwater.

He also listed several areas in which the Department of Defense is placing additional research funding in order to "capture what's really going on in the basic research community":

- Nanoscience and advanced materials;
- Advanced power;
- Human dimensions and psychological factors;
- Directed energy.

## Planning Research Investments

He said that the way the department ensured an adequate, coherent investment in critical research areas was through joint planning across the military services and defense agency efforts. The Defense Technology Area Plan (DTAP) was one example—a document of about 400 pages that showed the focus, content, and principal objectives of the overall DoD science and technology efforts. The services jointly review the DTAP programs across the spectrum to monitor their own progress against goals. This allowed planners the ability to avoid duplication and terminate programs that are not making or contributing to progress. This plan also provided a basis for acquisition decisions and was structured to speed the transition of mature technology to the operational forces. Finally, the document was used to help optimize the contribution of the SBIR program.

In this way, the SBIR program fit naturally into agency-wide planning and strategic efforts, said Dr. Holland. The DTAP helped translate the overall R&D strategy into war-fighting capabilities and provided the framework for selecting SBIR topics. In the wording of the department, "SBIR topics will fall within one or more of DoD's key technology areas, as defined by DTAP. This will ensure that the SBIR projects are an integral part of the DoD R&D program." So although the SBIR program received only 2.5 percent of the R&D budget, by the rules of the program, the program was nonetheless "a very important component," he said, and its effect was to better integrate the overall R&D investment. Individual activities are administered by appropriate units in the Army, Navy, Air Force, and DARPA.

In practice, the Army, Navy, Air Force, and DARPA independently developed topics that were consistent with the DTAP and submitted them to Dr. Holland's office. His office then reviewed the topics to eliminate duplication and to ensure that the proposals were clearly written and responsive to the criteria of the plan. A program overseer and a small technical staff were responsible for these functions.

### DoD is the Major Participant in SBIR

He then showed a slide demonstrating that the DoD was a large participant in the overall federal SBIR /STTR program (see Figure 1). For SBIR, the department's share was $773 million. Of the ten components, the five largest, in order, were the Air Force, Navy, Army, Missile Defense Agency, and DARPA. He said that his office controlled a small amount of SBIR money for programs such as the University Research Initiative Program and the DoD High-Performance Computing Modernization Program. The agency also had a smaller STTR program, with a budget of $42 million and five participating components.

He discussed the results of the program, which he said showed a good rate of transition to commercialization (see Figure 2). Between 1994 and 1999, 57 percent of SBIR firms with recent Phase II projects had achieved sales and/or investments. While most had received sales and/or investment amounts of less than $1 million, several percent of the companies had sales and/or investment amounts of between $10 and $100 million.

He listed a series of web sites for some of the "success stories" of the DoD SBIR program.[9]

Finally, he said that the SBIR program should be seen as spanning the whole spectrum of R&D, from early research to acquisition to procurement. "But the real purpose of this program," he said, "is to harness the innovative talents of our nation's small technology companies" for the benefit of the U.S. military and U.S. economy. The trick to maximizing that benefit, he said, was to bring in enough topics that we included the ones that "make the big breakthroughs."

He said in closing that the SBIR program was not the only way the department benefited from small businesses, which also compete throughout the science and technology program and become important suppliers to acquisition pro-

[9] http://www.dodsbir.net/Materials/SuccessStories.htm, http://www.aro.army.mil/arowash/rt/sbir/stories.htm, http://www.navysbir.brtrc.com/success.htm, and http://www.afrl.af.mil/sbir/impact.htm.

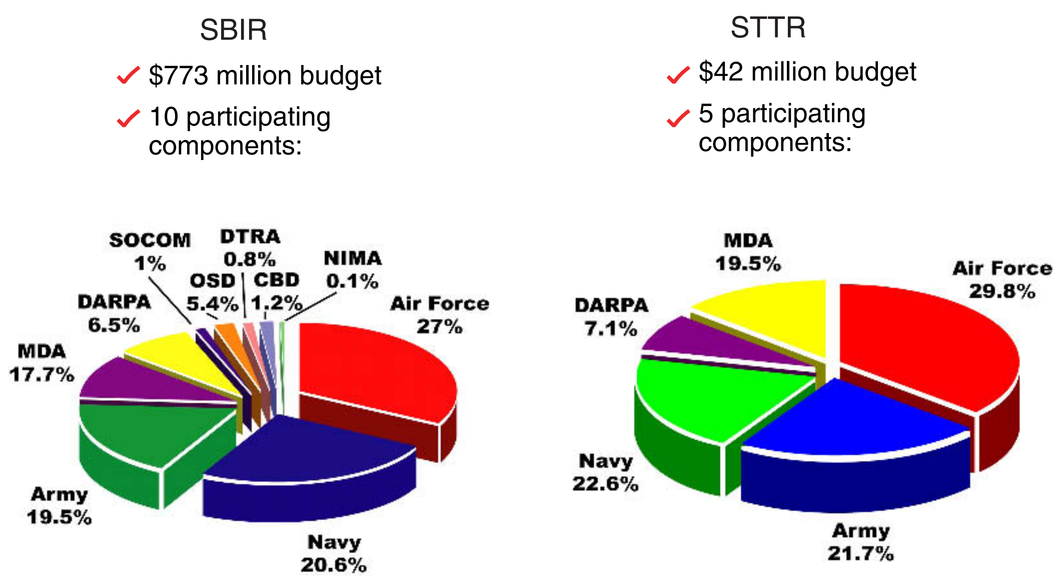


FIGURE 1 DoD FY2002 SBIR/STTR programs.

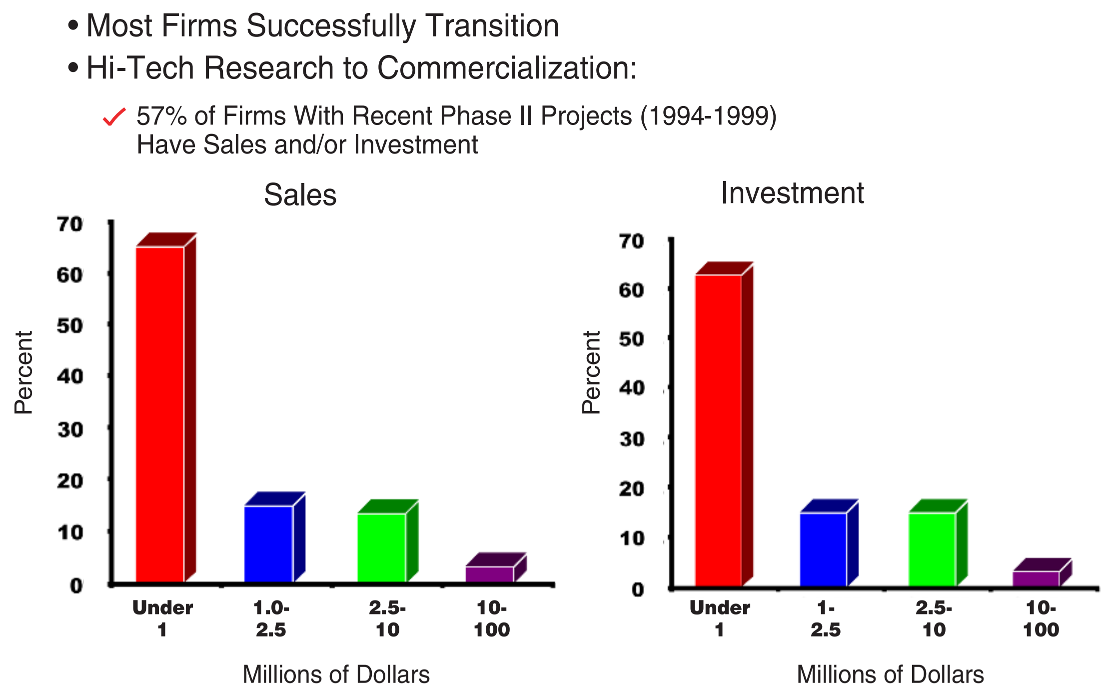


FIGURE 2 SBIR Projects attract sales and investment.

grams. He wished the study panel well in its evaluation, and said that he looked forward to the advice they would bring to the agencies.

As a final thought, he noted the relatively low levels of SBIR awards and recalled a condition in the law that would allow agencies to increase these levels with inflation. He asked the panel to look into the feasibility of this.

## A DEFENSE SUPPLIER PERSPECTIVE

*Richard Carroll*
*Digital System Resources*[10]

Richard Carroll said that he would speak on the SBIR program and "the impact of small, high-technology businesses and competition." He said first that innovation and competition were concepts "basic to America itself." Whereas the history of other countries is dominated by kings, queens, princes, barons, generals, and perhaps religious leaders, he said, American history is rich in inventors, entrepreneurs, innovators, scientists, engineers, and tinkerers of all kinds. Pioneer inventors include such familiar names as Benjamin Franklin, Eli Whitney, George Washington Carver, Thomas Edison, Samuel Morse, Alexander Graham Bell, Henry Ford, and the Wright Brothers. But equally significant are the names of entrepreneurs and inventors seen on products today, such as Singer, Otis, Westinghouse, Carrier, Eastman, Levi Strauss, Buick, Olds, Dodge, Colt, Browning, Sperry, and Birdseye. Most of the huge companies that now produce these products began in the form of small businesses whose founders had little more than a good idea.

### Innovation Drives the Economy

Innovation and competition continued to be the driving force of the U.S. economy, he said, as new innovations continuously destroyed existing ways of doing things and powered the growth of small firms into giants of industry. He cited well-known examples of this growth pattern in the field of information technology, where over the last 25 years influential high-tech businesses such as Apple, Microsoft, Dell, Compaq, AOL, and Netscape had developed from tiny companies to dominant names that changed the business paradigm and culture of their respective business domains.

He then mentioned the other side of innovation—the "surprise causalities." Virtually no one living in 1975 suspected that IBM would lose its dominance of the computer hardware business by 1995, he said. Nor did anyone living in 1990

[10]In 1982 Richard Carroll founded Digital System Resources, a computer hardware and software company that specializes in producing technology for national security. The company has grown to employ nearly 500 people, with revenues in 2001 of about $110 million.

think that Time Magazine and Warner Brothers would be owned by a computer on-line service in 2001. He noted that the public did not really care—as long as people had access to the most affordable and best performing products available.

### "Creative Transformation"

He returned to IBM as an example of what has been called "creative destruction," or, a phrase he preferred, "creative transformation." This process occurs when—through creativity, innovation, capitalism, intellectual property protection, and competition—a new paradigm emerges and destroys or transforms an old paradigm. Creative transformation happens to businesses and the marketplace they serve when the basic assumptions, concepts, values, and practices of their business changes to a new reality. This new business reality is more desirable for customers, and competing firms must either change in the same way or risk obsolescence.

In the case of IBM, the company was able to transform itself, and as a result it remains a powerful company. It adapted by offering its customers a new "value proposition." This change was so successful that IBM now plays a major role in integrating many of the same innovations that caused its transformation in the first place. It provides customers with even greater benefits than it could provide previously.

### The Creative Impact of Small Companies

IBM's creative transformation, he said, demonstrated the impact that small, high-technology businesses, innovation, and competition can have on the existing commercial business environment. That is, they provide healthy transformation of out-of-date methods into state-of-the-art methods that increase affordability, productivity, quality, and overall competitiveness. Dynamic new innovations are introduced, and the competitive power of these innovations causes competitors to innovate in response. Even when an innovation or innovator is not successful, the competitive threat of the innovation produces responsive innovation throughout the community. "I would even go so far as to say that this phenomenon is central to our overall government's incredible success since it's inception," he said. He noted that the principles fundamental to creative transformation, such as private ownership and intellectual property protection, were incorporated into our Constitution by the Founding Fathers.

### Large Firms Dominate the Government Marketplace

He turned from the commercial marketplace to the "federal government marketplace," and in particular, the government's research and development marketplace. The largest segment of this marketplace continued to be the Department of Defense (DoD), and while the DoD's share of the marketplace had shrunk greatly, the department still represented a major R&D investor for our country and a significant marketplace by itself.

He asked, "What is the impact of small, high-tech business and competition in the federal government marketplace?" He answered the question as follows: Although it is well known that the small, high-tech business sector has been the innovation sector for the commercial economy, the federal government marketplace for high-tech systems was increasingly consolidated and without competitive alternatives. It was a marketplace where the dominant companies were not growing larger by being better, he said; they were growing larger by buying each other and cornering strategic market areas within the industry.

### Two Large Firms Dominate DoD Research and Development

As an example, he summarized the situation in DoD research and development. In the year 2000, according to DoD figures, the top 100 defense R&D activities, including companies, non-profits, and universities, received roughly $16.2 billion in revenues. Of that amount, 66 percent went to the 10 largest defense contractors. The top two R&D companies received nearly $7 billion, or 42 percent of the total. In other words, just two companies received more than the combined R&D of the remaining top 96 R&D organizations.

To look at it another way, he said, the two leading DoD R&D companies employed roughly one-twentieth of 1 percent of the practicing engineers in the country, but received over 40 percent of the world's largest defense R&D budget. Are these few practicing engineers and scientists under adequate competitive pressure to keep all their creative juices flowing, he asked? He suggested that one way to determine whether adequate competitive pressure exists is to look for signs of creative destruction or creative transformation. In other words, do new companies emerge in the marketplace that are built around new innovations or new ideas that threaten the status quo? Are there new companies that are changing the paradigm for the defense industrial base? He said that everyone at the symposium could probably name several such companies in the commercial domain, but said that it would be difficult to identify even one such company in the DoD marketplace.

### Why Government Needs More "Creative Transformation"

During the 25 years that small businesses like Intel, Microsoft, Dell and many others took control of the commercial marketplace, he said, the federal government never spent more than 3 percent of its research and development budget on small, high-tech businesses. Nor has this amount exceeded 3 percent for the past 40 years.

He suggested that the federal government marketplace was lacking that healthy creative destruction or creative transformation that so rapidly and effectively transforms the commercial marketplace and strengthens the nation's economy. If this is the case, he said, it would mark a serious deficit, "because there is no doubt that the American entrepreneurial spirit is one of our most treasured assets and one that is envied throughout the world."

He said that hardly a day goes by in Washington without some mention of the need to "transform" the military so that military systems can be procured more quickly and cheaply. In testimony to the Senate Armed Services Committee, Defense Secretary Donald Rumsfeld said that he did not understand why the government could not modernize the development of technology for its military systems in the same way commercial industries did. Dr. Carroll said this was because the government does not create an environment that promoted the processes of creative destruction or creative transformation.

### SBIR Enables Creative Transformation

Luckily, he said, the SBIR program itself was designed to enable creative transformation; he said that he now thought of the SBIR program as "Government Engineered Creative Transformation." The new SBIR Policy Directive that implemented the provisions passed by Congress in the SBIR reauthorization in December 2000 would permit small companies to provide a much-needed competitive challenge to the status quo. He guessed that within five years, some large new companies would have emerged from the SBIR program to sell their inventions in the federal government marketplace. These new SBIR guidelines were designed to:

- Protect intellectual property;
- Provide a contractual pathway to purchase innovations;
- Allow SBIR companies to grow around innovations; and
- Empower serious competitive alternatives to the status quo.

In other words, he said, the new 2000 guidelines can open the door for SBIR companies to initiate creative transformations. Each SBIR topic that is published represents a potential opportunity for creative transformation in the world of small, high-tech business. "This," he said, "is powerful and exciting."

#### *New Tools for SBIR*

He described some of these new tools as follows:

- Intellectual Property Protection: From its inception, the SBIR program conveyed to the government the royalty-free right to use products developed by a small business under the program. At the same time, it prohibited the government from disclosing intellectual property to competitors for four years after the completion of the work. In reality, however, smaller companies that propose new ideas challenging the status quo have faced a real risk that their intellectual property would be appropriated and shared with competitors. The new SBIR guidelines made it clear that this is prohibited.

- Rights to data: The new SBIR Policy Directive also clarified that data rights associated with Phase I and Phase II SBIR awards continue in a Phase III award. This holds true for as long as the government continues to fund further development that is based on an extension of the research and development conducted under previous SBIR contracts. In other words, the government cannot ask small businesses to sign away their SBIR data rights in order to get a Phase III contract.
- Procurement advantages: The Congress also wanted to reward innovators for developing useful new technologies under the SBIR program. Thus the new directive states that whenever practicable, an innovation or technology developed by an SBIR business will be used by the government. The new regulations required the Small Business Administration to report to Congress every instance when a small business creates an innovation or technology under the SBIR program, and yet the government goes to another business to develop and produce it. This is a signal to SBIR agencies that are expected to reward the innovator by staying with them for development and production.

Mr. Carroll expressed the belief that these changes would energize the SBIR program so that it becomes a primary source of competitive alternatives for federal government solutions. "It is my hope that powerful new businesses will emerge from the SBIR program that will cause creative transformation throughout the federal government sector," he said, "just as we have seen in the commercial sector. I know this can happen. I also know that as a country we need to have it happen."

## DISCUSSANTS

*Gene Banucci*
*Advanced Technology Materials, Inc. (ATMI)*

Gene Banucci said that his company, located in Connecticut, was started in 1986 and went public in 1993, when it had about $7 million in revenues. By the time of the symposium it had grown to "somewhere in the $250-to-300-million-a-year range," with a market capitalization of about $500 million. He said that the company in its early years was a comprehensive user of the SBIR program.

### A Successful SBIR Company

He said that he believed his company to be one of the most successful SBIR applicants in both the Department of Energy (DoE) and EPA SBIR programs.

The project that he chose to describe, however, was supported by joint SBIR funding from the Department of Defense (DoD) and National Science Foundation.

With this support, the company was able to develop some significant technology that has greatly improved safety in the manufacture of night vision and sensing equipment. A key safety issue in these manufacturing processes had been the danger of toxic gases used to provide essential coatings. Initially, these gases were transported and stored under high pressure in metal cylinders that resemble SCUBA tanks, presenting a health hazard for people who worked with them. As the commercial value and production of night-vision and other sensing devices increased, the DoD SBIR program asked the small-business community for proposals about a safer way to handle these gases.

### A New Procedure Brings Safety, Productivity

After studying the problem, the engineers at Advanced Technology Materials proposed a procedure that has evolved into their SDS, or Safe Delivery System. The heart of the procedure is to remove the valve from each metal cylinder and insert a solid, spongy material that resembles activated charcoal in function. Once the spongy material is inserted, the toxic gas is placed in the cylinder. There the gas is basically adsorbed[11] by the spongy material and transformed from a gaseous to a solid state. Removing the gas, after it has been adsorbed onto the solid, depends on the fact that most of the equipment in the semiconductor industry uses vacuum conditions. The gas is simply allowed to sublimate off the solid; it returns to the gaseous state and can be deposited on surfaces.

The ATMI technique brings two advantages. The first is that one can safely open the tank without releasing any of the toxic material, because it is stabilized by adsorption onto the solid material. The cylinders never leak or release gas accidentally. They can be shipped safely without the expense and danger of shipping hazardous materials.

The second advantage is increased productivity. Storing the gases in a solid state requires about one-tenth the volume required to store them in a gaseous state. This means that a multimillion-dollar unit of manufacturing equipment can run for much longer without changing cylinders, lowering costs for manufacturers.

As a result of these advantages, the company had sold almost a quarter-billion dollars' worth of this product, which had become the core of ATMI's business. More importantly, the company was able to market the product with an operating profit of 50 percent. The product was adapted to the semiconductor industry, and ATMI now sells gases for most semiconductor applications. "It's a tremendous advance," said Dr. Banucci, "and given its penetration of the market-

[11]Adsorption occurs when molecular forces cause a connection between a gas and a solid medium.

place, I have no doubt that over the next 5 years it's going to be a billion-dollar product."

### An Unforeseen Success

He added that he had not foreseen this product, or its success, when he and his colleagues began to grapple with the challenge from the SBIR program. Yet the accomplishment was sufficiently notable that the two inventors of the product had just received a lifetime-achievement award for "most significant environmental safety and health advance in the semiconductor industry during the decade of the 1990s."

Mr. Banucci emphasized that he was a very strong proponent of the SBIR program—and "an even stronger proponent of making it better." He said that his own focus for ATMI was to develop a company that was performance-driven. He said that his company "benchmarks other companies, milestones where we are, look for best practices, and tries to execute them across the entirety of our organization." He said that he talks about these points to his company, especially the last phase of execution. The SBIR gives many companies the opportunity to "drive the ball, get it on the fairway, and get it on the green." But, he concluded, there is little value in those steps unless there is an incentive to "get the ball in the cup." He said that he would help the study panel in any way he could so that more SBIR companies were able to bring their products to market and find commercial success.

*Jon Baron*
*Coalition for Evidence-Based Policy*

Mr. Baron said he had left the SBIR program several years previously and that he was glad to be back as a member of the National Academies' Study Committee. He said he would offer observations on the program based on his experience as a Congressional staff member who worked on the reauthorization of the SBIR in 1992 and the initiation of the STTR program. He also served as SBIR program manager for the Department of Defense. He said he had benefited by being "a really avid consumer" of evaluations of the program by the Government Accounting Office, starting in 1993; by the DoD's Director, Defense Research and Engineering, in 1997; and by the National Research Council, which recently reported on the Fast Track portion of the DoD program.[12] All of these surveys, he said, helped companies and observers to understand what had happened to their SBIR products and technologies.

[12]National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* C. Wessner, ed., Washington, D.C.: National Academy Press, 2000.

**Five Observations**

He offered five observations about the SBIR program.

(1) Without data on program outcomes, it is difficult for anyone, including program managers, to know how well the program is doing.

As an example, he cited a DoD initiative led by Jacques Gansler to collect data whenever a company submitted a proposal for a new DoD SBIR proposal. The company would be asked to list all its previous Phase II awards, along with the sales, both commercial and DoD, that resulted from the awards and any additional investment the company had received. When that initiative was started, the database revealed that one company had reported over a billion dollars in sales. Officials were skeptical until they looked more closely and found that the company had in fact developed a new technology that increased the number of circuits on a computer chip by about 30 percent. The technology, which had been developed and licensed to another company to produce, was changing the state of the art in the industry and improving the computing power of virtually every commercial and defense system. It was an enormous success, and yet no one at the SBIR office had known about Science Research Laboratory, Inc. (SRL) of Somerville, Massachusetts, which licensed the technology to Cymer, Inc.

As another example, he said that DoD officials had found that a number of companies had participated in the SBIR program and won a large number of Phase II awards; had very good reputations in the program; but "had never commercialized anything to speak of." By contrast, there were a few companies that had a "terrible reputation" in the program but had a commercialization track record that was "mixed, or even a little bit above average."

Thus, without good data from the study panel, similar to what the GAO had produced in the past, it would be difficult to truly know what was happening in the program, beyond a history of anecdotes.

(2) Based on the data collected by DoD, many SBIR companies developed technologies that were not successfully commercialized in either government or commercial markets.

This is partly because of the nature of research and development, where most new technologies fail to be adopted. Another cause, revealed in the 1993 GAO study, the DDR&E study, and in DoD's commercialization data, was evidence of "systematic failure" in the program. Some companies repeatedly won SBIR awards but consistently failed to convert those awards into viable new products sold to commercial or government customers.

(3) Successes of the SBIR program have had an enormous impact on the economy and on defense systems.

He cited a technology produced by Digital System Resources that had improved the computing power of sonar equipment by a factor of 20, reduced the cost of that equipment by a factor of 2, and reduced the size of the equipment on submarines by a factor of 2. The technology had been installed on almost the entire fleet of Navy submarines.

(4) The program is characterized by a skewed distribution of successes.

At the top were a few "gigantic" successes, such as the two that had been described by panel members. Below those were perhaps a hundred modest commercial or defense successes. Farther below those successes, he said, the program had produced few results. He said that the major successes had more than paid for the government's entire investment in the SBIR program. Even so, however, it would be desirable to have a less skewed distribution of success. "I think the great challenge to the program," he said, "is to improve the success rate. Can the incentives be changed to make this happen?"

(5) He said that the DoD leadership did implement a number of program reforms that successfully shifted the incentives in the program, and thereby substantially increased successful commercialization in both military and commercial markets.

One positive change, he said, was the Fast Track initiative: a company that receives some matching funds from an outside investor toward the end of Phase I is awarded continuous Fast Track funding between Phase I and Phase II, along with the highest priority for a Phase II award. A National Academies study examining the Fast Track program found that the rate of preliminary commercialization was about seven times higher than the rate of a control group of regular SBIR participants. In addition, he said that a commercialization tracking system put in place by DoD seemed to be successful in identifying both companies that are "systematic successes" and companies that are not as likely to produce successful products.

### *Kenneth Flamm*
### *University of Texas at Austin*

Dr. Flamm (who had worked with the SBIR program at the DoD and had also participated in the National Academies study of the DoD SBIR Fast Track program) opened his remarks with the observation that the comments he had heard at the symposium had fallen into two basic categories: these are the rationale for the SBIR program and the operation of the SBIR program. He said that the current Academies study seemed to be focused primarily on the operations of the program, rather than on the rationale. He suggested that the two topics are organically related, and that a study of operations would have to consider the program's rationale, whether or not it was an explicit theme of the study. He said he would address both of those topics, "perhaps in blunter terms" than he might have used when he worked in Washington.

He noted that it would be naive to ignore the "significant political component in the SBIR program." It was funded by Congress, and small business is very popular with the nation's political leadership. He also said it would be ingenuous to pretend that initiation of the program had been preceded by a "grand, focused analysis" to specify exactly how the program should function. "The SBIR program is a politically popular program," he said, "and it was put in place because our political leadership liked the concept of having R&D dollars spread a little more widely than they were being spread before. I think you have to start with that acknowledgment."

### Addressing Capital Market Imperfections

Having said that, however, he noted that the SBIR did seem to address a number of legitimate purposes. One purpose, stressed in the first National Academies report, was to address imperfections in the capital markets. For structural and institutional reasons, small businesses may have more trouble accessing the capital markets, and this could be a handicap in commercializing their innovations. At the same time, he said, it is not clear that the SBIR program is an optimal response to the imperfections of capital markets, where such imperfections are not well-documented. But one result of the National Academies studies was to point out that the SBIR program did play some role in rebalancing these kinds of capital market imperfections in at least some documented instances.

### Defraying "Contracting Overhead"

A second issue was what he called "contracting overhead." When dealing with the Department of Defense—he said that he had had less experience with other agencies of the government—companies must learn to deal with a complex and sometimes "arcane" contracting system characterized by many rules and procedures. The large defense contractors that show up on the "Top 100" list were organizations that had made the strategic decision to make large investments in systems and overhead to manage the complex details of the contracting process. Given the difficulties of coping with the contracting process, he said, one could regard the SBIR program as a kind of subsidy to small firms who lack the financial resources to invest in "contracting overhead." The program had had the effect of defraying some of the fixed costs of accessing the government procurement system.

### Overcoming the Small-firm Disadvantage in Lobbying

A third rationale for the SBIR program, he suggested, was that in the DoD, as elsewhere, there is a strong political component in the contracting system. That is, all the major defense contractors have active Washington operations that are skilled at lobbying on Capitol Hill and at the Pentagon. In a delicate ballet, the services, the DOD, and the contractors engage in a continuous give and take that characterizes the federal budgeting process. An outsider, without the overhead to maintain a well-staffed Washington office and cultivate appropriate connections at the Pentagon on a regular basis, is likely to enter the contracting system at a disadvantage. In this sense, the SBIR program provides some rebalancing of market imperfections in a political sense. Because small firms cannot afford the expense of traditional lobbying, the SBIR affords a route for small firms to enter the procurement system directly.

### How to Characterize Successful Outcomes for SBIR?

He cautioned, however, that there is some risk in characterizing the SBIR program solely as a way of overcoming imperfections in the commercialization process. One of these risks is that "a reasonable proportion" of programs the SBIR agencies invest in have nothing to do with commercialization. Some are specialized R&D services that are purchased by government agencies from small contractors or other specialists. These can be commercialized in the sense of selling them or their output to the DoD, but the services are too specialized to stimulate a large commercial market. There is essentially only one very large customer for weapons systems in the United States, so a certain proportion of agency missions have nothing to do with selling commercial products, and the R&D that supports those missions, by itself, is not related to selling commercial products. It follows that the SBIR program should not require that all agency missions be commercialized.

A second issue, he said, is that "commercial" should not be confused with "small." A small business that is successful in commercializing new technology almost certainly will not remain small. Successful small, high-tech businesses gradually become large, high-tech businesses.

### Perceived Problems in the Program

Having made these observations, he turned to some of the problems in the SBIR program observed in 1993 and 1994, when the subject of reforms first arose. The SBIR program was, and still is, regarded by many R&D program managers within the Department of Defense as a kind of tax on R&D. These managers were required to set aside a portion of their budget to spend on this program, whether or not it suited their perceived needs. Those who have reviewed the SBIR program within the DoD have concluded that the amount of money set aside for SBIR is, taken together, considerable. Some have suspected that the SBIR funds were being used as a supplementary pension plan for laboratory workers. That is, laboratory scientists, after their retirement, would succeed in receiving an SBIR grant from their former employer as a pleasant way of topping off a long career at a defense laboratory. Whether or not this was really a common custom, the managers of the DoD SBIR program decided to make the contracting process much more transparent, including an open process of developing topics and soliciting bids on those topics, so that lab managers did not have the choice of hand-picking projects to benefit certain people.

The reformers were also concerned about "SBIR mills"—companies or individuals who repeatedly were able to win SBIR grants because of good contacts and bureaucratic skills. The SBIR management was concerned that a small group of players had learned how to repeatedly dip into the contract trough without producing large benefits for the Department of Defense.

### A Pathway to Commercial Innovation

At the same time, these reformers saw the positive aspects of the SBIR program. They were aware that many of the revolutionary technologies they wanted for military systems were likely coming from the commercial sector, especially in critical fields of information and communications technology. They saw that the DoD could use the SBIR program as a way to support better adoption and use of commercial, dual-use technology within military systems.

But they also recognized that not every technology needed by the military could or should be dual-use. There would always be a need for small, commercial firms that provide specialized services to the DoD. It did not seem useful to try to fit everything into a single mold if that would mean squeezing out firms that primarily performed specialized services for the DoD. The study panel, he suggested, should consider the continuing need for such firms when evaluating the SBIR program. A substantial number of small firms do specialized tasks for DoD, and broad requirements for commercialization should not preclude them from SBIR support.

In conclusion, the SBIR program has a diverse set of objectives, and requires a diverse set of firms to meet those objectives. It is desirable to use SBIR as a way to develop commercial technology and speed its use by the Department of Defense. It is also desirable to use SBIR to overcome some imperfections in capital markets and possibly in political dimensions of the contracting system. But it is also important to recognize that it is "logical and justifiable" for the SBIR to support different types of firms with varied products and goals.

"Not everybody has to be the next Microsoft operating system," Dr. Flamm observed. "The small guy working on DSP propeller recognition for the Navy may also be a valid and legitimate use of SBIR funds, even thought it may not result in the next commercial breakthrough. He ended by calling the SBIR program "a very complex beast, a program with many objectives, many fathers, and many different support bases. It seems to me that we have to recognize that diversity in our evaluation."

## DISCUSSION

### Metrics and Appropriate Rates of Success

Charles Wessner of the National Research Council said he had been "anxious to ask" what would be an appropriate rate of success for the SBIR program at DoD. He also asked how the panel should measure those successes, and how an agency could come to balance the research objective with the commercialization objective when making decisions to award grants to small companies.

Charles Holland of the Department of Defense agreed that the first task was to decide on a definition of success for SBIR awardees. "To me," he said, "success would be actually adding a sustained set of workers to the pool to support the mission of the Department of Defense and the overall economy." Here he said that a success rate of around 10 percent would be acceptable—if 10 percent of these activities, following a couple of Phase II awards, still had a certain fraction of people employed. Another way to measure success would be to count the products being bought by the Department of Defense. This would be easy to track for large procurements, such as the Joint Strike Fighter (JSF), but more difficult for the products of second-tier suppliers, which would include most SBIR firms.

### A Tax on Agency R&D?

He commented on the "tax issue," which pertains to major programs, such as the JSF. These are taxed in the sense that some portion of the R&D funds that might be spent on JSF work are assigned to someone else, according to the SBIR formula. To program managers, this is tantamount to a tax on the JSF program itself.

Jacques Gansler of the University of Maryland added that some programs, such as the Missile Defense Agency, actually keep SBIR dollars within the program to increase its flexibility. Vinny Shaper, SBIR program manager for the U.S. Navy, said that in the Navy SBIR program, when a program like JSF is "taxed," typically that money goes back to the program where it originated.

### Metrics and Success II

Jon Baron of the Coalition for Evidence-Based Policy, returning to the topic of measuring success, said that there are different ways of "succeeding" that meet technical objectives, such as producing new knowledge and attaining commercialization. Beyond those, however, he emphasized the importance of successes in the program that "change the world"—a sonar system that fundamentally changes the way submarines can operate, say, or a software technology that allows the use of a credit card at the gas pump, both developed under SBIR. That software technology had improved productivity across a number of industries, including the defense industry. Such successes, he said, change capabilities in a fundamental way and are the great achievements of the SBIR program.

Richard Carroll said he approved of searching for metrics that could be used to make historical comparisons within the SBIR program, but he thought that such a search would fail. One reason was that this kind of study is now being done for the other programs, and comparable data have not been found. Another reason is that the activity of the SBIR program is causing larger firms to become more innovative as well. This has been the case in the experience of his company, Digital Systems Resources, which produces sonar equipment for the submarine fleet. He said that Lockheed-Martin, a large company, was now competing against his small company for the same market. "They don't behave at all like they used to behave when we weren't around," he said. In other words, the impact in DoD had been that a large firm was now presenting alternatives to the products of a small SBIR firm, and the resulting "creative transformation" benefited the DoD by bringing a choice of products. Mr. Carroll said he could think of no effective way to measure this effect, but it was a significant and useful one.

## Intellectual Property

Steven Wallach of the law firm Penney and Edmonds asked Mr. Carroll about the intellectual property provisions that had been added to the SBIR program. As an IP lawyer, he said, this seemed like a good idea, but he also suggested that it might stifle innovation, particularly in software.

Mr. Carroll agreed that the IP issue was "absolutely essential here." From its inception, the SBIR program had conveyed to the government the royalty-free right to use the products developed by small businesses. But the program also contained a limitation with respect to disclosure of intellectual property developed under the program: the government is prohibited from giving the data away to the firm's competitors for a period of four years after completion of the work.

The small business, he said, is highly dependent on its product, market environment, competitive posture, and business strategy. In some cases, an SBIR company may be best served by retaining its own trade secrets, patents, copyrights, or some combination of these. In other cases, it may be best served by making intellectual property available, in part or in whole, to its customers or competitors. But it is critical, said Mr. Carroll, that such decisions are made by the company, not by the customers. This contrasts with the case of Linux, the open-source software system, where the inventors decided from the outset to give the technology away for the purpose of continual improvement by users.

He said that his own company was distinctive in that it had decided to give its software away—even though it was not required to because the IP was protected under the SBIR agreement. This approach was very different from that of larger companies, which tend to retain IP for themselves and even to use it against smaller firms. He suggested that the government may find superior benefits in intellectual property that is freely distributed to the R&D community, where creative synergies can advance the state-of-the-art for the common good. Again, he said, it should be the small business' decision to make.

### Taking Risks while Reducing Systematic Failure

Greg Millman, who said he was responsible for the SBIR program at the National Institute of Allergy and Infectious Diseases, returned to the topic of metrics and said that success alone could be a very dangerous metric to use for assessing the SBIR program. In many cases, he said, failure is actually desirable because it indicates that the program has taken risks. If there were no risk-taking, there would be no need for the SBIR program. The venture capital and commercial sectors would simply pay for the research needed to develop the products they expected. He agreed with Mr. Baron that a few outstanding successes justified the many failures, and that it was counter-productive to aim for a higher success rate by selecting less risky projects.

Jon Baron said he agreed with Dr. Millman's comments, and that the challenge for the program was not to decrease the failure rate per se; R&D is inherently risky, especially the kind that has the potential for the greatest payoff. The challenge for the program, he said, is to reduce "systematic failure," such the phenomenon of the company that participates in the program, moves from one contract to the next, and produces only a report or a prototype that is never used in any meaningful way. This kind of output is never developed into a product or used to increase the knowledge of the Department of Defense.

### Definition of Commercialization and Competition

William Bonvillian of Senator Lieberman's office asked whether, given the loss of competitive factors in defense contracting, SBIR should be described more explicitly as a competitive factor in the defense contracting business.

Jacques Gansler said he had always been "a big advocate" of competition. He agreed with the example of the sonar systems as an illustration of the importance of introducing alternative technologies on a continuing basis, not just at an initial auction. "The only way you can do that," he said, "is through the continuous development of new products, and obviously much of that comes from the small business community."

He did say he was concerned that he had heard from two different people at the symposium a concern that the total amount of R&D funding going to small businesses was being dominated by the SBIR program. In the past, a significant amount of R&D was generated through small business innovations outside the SBIR program. One way this happened was through unsolicited proposals from small firms that wanted to introduce new research ideas to compete with existing products. Dr. Gansler said he would be worried if that was happening, and asked the study panel to find out if it was. If so, it would indicate that the DoD was becoming overly dependent on SBIR for small business research, which was not a situation he would favor.

He also commented on Dr. Flamm's observation about "commercialization," and offered an alternative definition; namely, a product is "commercialized" if it is used by the government *or* the commercial marketplace. If NASA or the Defense Department uses a product, he said, it becomes part of the economy, generates employment, finds application, and therefore adds value to the nation and the agency. He urged the study panel not to judge the success of a company solely on whether its product finds uses in the commercial sector. Some government applications are obviously limited, he said, and yet the applications are highly useful.

Richard Carroll said first that he did believe the SBIR was displacing other small business R&D. But he asserted that overcapacity in the DoD was a serious problem: "A very fundamental principle in the Department of Defense is, you don't kill incumbencies." This is especially true at the level of large programs and bases where overcapacity may be caused by political pressures. A real problem for the department, he said, is that it tends simply to reallocate funding rather than take the more difficult route of canceling or closing unneeded programs.

## Tightening Definitions

Kenneth Flamm offered two comments. The first was a caution again an overly loose definition of product or commercialization: If a company does analytical services for a DoD lab and writes a report on its analysis, is that a product? "If you're broad enough to cover everything," he said, "then your definition loses meaning."

His second comment concerned competition. He said that participants had already discussed interesting examples where SBIR grants did provide some competition. However, he cautioned that this may be only a minor degree of competition "at the margins." He said it was unlikely that the Small Business Innovation Research program would truly provide competition against the large systems integrators and platform builders. "The bottom line," he said, "is that there has been significant concentration and consolidation in the U.S. defense industry, and there's no way around that." One irony, he said, was that this consolidation had been inspired in the early 1990s by the projection that reducing the number of contractors and their high fixed overhead would better use resources in a DoD procurement budget shrinking by 40 or 50 percent. In fact, the procurement budget had returned to the same high level of the early 1990s, with a significantly smaller number of contractors.

It is unrealistic, he affirmed, to expect small businesses to compete with the remaining large systems integrators, except “for bits and pieces of inputs into the systems projects.” He concluded that the faults of the DoD procurement system would not be solved simply by the SBIR program, but would require further analysis. “The competition issue is a real one,” he said, “and ought to be considered. The size and configuration of the defense industrial base is an issue of national importance, and I don’t think that relying on SBIR to provide competition at the margins is going to fix it.”

Richard Carroll said he did not disagree with Dr. Flamm’s general statement—that the SBIR could not be the only strategy for invigorating the procurement system—but he reaffirmed his view that SBIR companies can provide significant competitive pressures against large companies. He recalled the case of IBM, which misread the competitive pressure of Microsoft’s operating system, and reaffirmed the importance of creative transformation and the role of small businesses in bringing it about.

# SBIR at the National Institutes of Health

Moderator:
*James Turner*
*House Science Committee*

Mr. Turner introduced the panel by relaying the Chinese term for a perfect plan as a "garment made in heaven," because "that's the only place a garment can be seamless." He acknowledged that the SBIR was not yet either perfect or seamless; nor was it "a patchwork quilt" of disparate elements, though it might have become such during its creation by five separate committees of Congress.

He said that his own committee, the House Science Committee, was one of those five, and that Congress had re-examined the SBIR program three times since its inception in 1982. Thanks to the efforts of the program managers responsible for each agency's SBIR activities, he said, the program had worked quite well and produced strong results. Mr. Turner noted that the SBIR program itself is not in doubt: The Congress had not questioned the program's value during its last authorization, and it is not expected to do so during the next authorization. Further, the upcoming study by The National Academies is not expected to question whether the program should exist. "We're 20 years into the SBIR now," he said. "It's a proven entity; it's going to be with us. The question is how to get as close as possible to a garment made in heaven, here on earth."

Mr. Turner said that the program has faced, and will continue to face, many challenges, including "its schizophrenic origins," rapid changes in the small business community, broad challenges to the R&D system stemming from terrorism, and the substantial economic and technological changes that occurred since the program's origin. He suggested that appropriate goals for the study would be to look ahead and craft a series of sound suggestions on how to improve the program so that, when it is time for its next review by Congress, good advice will be available to committees on what legislative changes, if any, are necessary.

## ACHIEVEMENTS, OPPORTUNITIES, AND CHALLENGES

*Jo Anne Goodnight*
*National Institutes of Health*

Ms. Goodnight introduced herself as the SBIR/STTR coordinator for the National Institutes of Health (NIH). She expressed her pleasure at having the opportunity to participate in this symposium to discuss the "congressionally mandated, comprehensive study of the SBIR program." She said she would discuss the achievements and goals of the SBIR program, the role the small business research community plays in the mission of the NIH, and the opportunities and challenges of the upcoming SBIR study.

NIH is comprised of 27 institutes and centers, 23 of which participate in the SBIR program. Each of the components that awards SBIR grants has a mandate with well-defined priorities that address science and health issues from a specific perspective, such as minority health issues, health disparities, particular disease areas, such as cancer, and broader areas of concern, such as aging. Because NIH is primarily a granting organization, about 95 percent of its SBIR awards are made through its grant mechanism. Some 4 to 5 percent of awards are made by contract and a few are made through cooperative agreements.

The individual institutes and centers of the NIH develop topics that relate to their missions and could be considered "NIH-generated ideas." But NIH also seeks to encourage "investigator-initiated" ideas that fall within the mission of any of the awarding components.

The NIH mission, she said, is to improve human health through biomedical and behavioral research, research training, and communications. In carrying out this mission, the NIH supports basic, applied, and clinical research to better understand the complex processes underlying human health and to acquire new knowledge that will help prevent, diagnose, and treat human diseases and disabilities.

### "From the Test Tube to the Medicine Cabinet"

The SBIR program plays an integral role in the NIH mission, said Ms. Goodnight, particularly the goal of translating scientific findings from concept to societal benefit. She said that one might think of this process as "moving from the test tube to the medicine cabinet." Small technology firms are prolific innovators which are recognized as unique resources not only for the development of enabling technologies, but also for creating "disruptive technologies"—those that displace entrenched techniques and have the potential to create new industries.

She said that SBIR is a perfect program to allow the entrepreneurial research community to "go out on a limb and challenge paradigms." In the health arena, disruptive technologies are often capable of changing the landscape of health care. Because of these technologies, for example, nurse practitioners, general practitioners, and even patients can perform procedures in less expensive, decentralized settings that could once be performed only by specialists. While these disruptive technologies may face initial resistance from doctors, insurance companies, and hospitals, they clearly have the potential to bring enormous benefits to society.

## SBIR Achievements

The SBIR program at NIH has achieved much since its inception in 1983, she said, highlighting the following acheivements:

- The program is well integrated into the overall scientific programs and goals of the NIH, as is the case for many agencies. It continues to receive positive support from the NIH leadership. As it has evolved, it has benefited from an enhanced collaborative effort among the SBIR agencies and the research community.
- Agencies are collaborating more closely to develop trans-agency initiatives in areas such as nanotechnology, assistive technology, and biodefense. The small business community can respond quickly to the changing nature of science because of its own flexibility and adaptability. It also encourages multidisciplinary approaches, which are needed to address some of the more complex research questions.
- Another achievement is that the SBIR program and certainly the STTR program have each created avenues for connecting basic knowledge to the marketplace through university-industry partnerships, which is an important dimension in our rapidly evolving economy. Another achievement is that the SBIR has assisted NIH, and indeed all federal agencies, in addressing agency-critical technology research areas and in responding to national priority areas. Examples of such areas include biodefense and nanotechnology, as well as imaging, bioengineering, bioinformatics, and biomaterials.
- The flexibility of the Small Business Administration allows different ways to support various agency mission outcomes. This latitude, which is supported by the SBA, allows companies to propose research and development in fields that have the most biological promise, rather than limiting ideas to those that can be conducted under prescribed budgets and timelines.

The 1982 legislation that initially authorized the SBIR program included four primary goals:

1) To encourage small businesses to stimulate technological innovation;
2) To encourage small businesses to meet federal R&D needs;

3) To foster and promote additional participation by minorities and disadvantaged individuals in creating technological innovation; and
4) To increase commercialization of these federally funded R&D innovations in the private sector.

## Reauthorization Brought Changes

As a result of the December 2000 SBIR program reauthorization, there was now greater emphasis on outputs, outcomes, and commercialization. There is also continued support for outreach and technical assistance for the small businesses. One mandate of the current evaluation was to study this new emphasis on outcomes. This study presents a number of opportunities to evaluate the program's effectiveness across the ten federal agencies that make SBIR awards. These agencies have collectively invested more than $12 billion in SBIR projects since 1983. The NIH investment exceeds $2.5 billion.

With the current structure of the SBIR, most small companies are able to view the federal government as a transparent "technology clearing house." This allows the companies to consider SBIR opportunities across agency boundaries and align their technical competencies with the needs of multiple agencies.

The SBIR structure also allows new companies an excellent chance of gaining awards. Based on the experience of the Department of Defense SBIR, about one-third of the companies entering the program each year are first-time recipients of awards. NIH data show that 75 to 80 percent of the companies receiving the awards have earned between one and three previous awards.

## Opportunities for the Study Panel

The plan for the comprehensive SBIR study, said Ms. Goodnight, presents a number of desirable opportunities. She hoped that the study will:

- Describe the trans-agency program while highlighting how each agency uses the program to accommodate its particular culture;
- Provide hard information on how well legislative goals are linked to program outcomes;
- Assess the degree to which each agency's operational and administrative activities support SBIR goals;
- Offer a means to quantify both the economic or direct commercial benefits and the non-economic or societal benefits of the program.

Given the enormity and complexity of this study, she said, a number of considerations are worth highlighting. First, it is critical that the evaluation framework incorporate all SBIR legislative intents across all the agencies—not merely the mission and goals of a select subset. "Important outcomes could easily be over-looked," she said, "if this study does not take into consideration the investments made by all 10 agencies." She stated that the synergistic benefits of the national SBIR program as a whole are greater than the sum of its parts, and hoped that the study would verify this. A second consideration, said Ms. Goodnight, is that the methodology of the study must address how agencies incorporate their own culture and processes in achieving the congressionally mandated goals of the program.

## Challenges for the Study Panel

While the SBIR study brings numerous opportunities, she said, it also poses a number of challenges, including the following:

- Identifying commonalities and unique features of each agency's programs;
- Developing a systematic and comprehensive methodology that adheres to the goals of the study;
- Reconciling existing knowledge bases within agencies while maintaining an independent and unbiased global study;
- Appreciating redundancies and avoiding undue burdens on respondent companies, where appropriate.

Some additional challenges, she said, included identifying the actual direct and indirect value of SBIR-supported R&D in creating commercial and societal benefits. In some cases, for example, it might be shown that multiple awards were needed to bring a product to market. Or it might emerge that SBIR funding was only one step in bringing a product to market, which also required other federal or nonfederal funding.

## Technologies Progress at Different Rates

An important topic for the study to consider is the rate at which various companies move toward commercialization, from Phase I to Phase III. It is already known that these rates vary for some technologies and agencies. For example, NIH-supported projects to develop pharmaceuticals require an average of 12 years and hundreds of millions of dollars to complete, while DoD-supported military products are developed for more immediate use. The development timeline for NSF-supported information technology products is relatively short, while the timeline to plant and grow crops under a USDA-supported SBIR can be considerably longer. In studying these varying commercialization timelines, it is likely that the progression from Phase I to II to III is not always linear. That is, discoveries or questions in the developmental or commercialization phases may stimulate new or additional research, while new research may suggest new applications.

Ms. Goodnight said in closing that she fully appreciated the importance of an objective and comprehensive evaluation of the SBIR program. In light of the R&D investments made by NIH over the last 20 years, during which some 50,000 awards have been made to some 12,500 firms, the study represents a unique opportunity to evaluate the economic and societal benefits of the SBIR program. She concluded that the agencies had worked thoughtfully, responsibly, and collaboratively for the past year to take full advantage of this opportunity, and expressed pleasure at the prospect of working out the next steps with the National Research Council.

## THE NIAID PERSPECTIVE

*Carole A. Heilman*
*National Institute of Allergy and Infectious Diseases*

Dr. Heilman, Director of the Division on Microbiology and Infectious Diseases at the National Institute of Allergies and Infectious Diseases, focused on the long-term relationship of NIAID with public-private partnerships. Within that context, she addressed both the role of the SBIR within the broader range of partnerships and within the nation's biodefense research needs.[13]

### High Hurdles for Companies

She began by emphasizing a point made by Ms. Goodnight–that many of the products developed by the National Institutes of Health require an extremely long time and a large amount of money to discover, develop, test, and approve. NIH is involved in both basic and, to a lesser extent, applied research that attracts the interest of both large and small companies that develop products for the marketplace. Among the most important DHHS agencies with respect to product development are the FDA, which is responsible for approving biological or intervention products for marketing, and the CDC, which is responsible, in the case of newly licensed vaccines, for deciding who is recommended to receive them. For products developed for the commercial market, both steps are high hurdles that must be overcome. For products developed for biodefense, the Office of Emergency Preparedness, within DHHS, plays a key decision-making role with respect to the purchase of products.

NIAID supports both basic and applied research, but unlike many of NIH's component institutes, a major part of its mission is to focus on applied translational research, which it has done for about four decades. Thus NIAID,

[13]The National Institutes of Health supports research using both grants and contracts. About 95 percent of NIH SBIR awards are made through the grant (assistance) mechanism, and about 5 percent of NIH SBIR awards are made through the contract (procurement) mechanism.

even before the SBIR began, had had considerable experience interacting with industry and translating the information developed by basic research into products.

## Three Mechanisms to Help Companies

The Institute used three general mechanisms to help translate discoveries into products. Dr. Heilman illustrated these mechanisms by three examples from the post-September 11 rush to develop biodefense products. Three of the initiatives it was asked to undertake concerned smallpox: (1) a smallpox vaccine dilution study, including a determination of whether the vaccine already stored was of good quality and whether it could be diluted so as to protect everybody in the United States; (2) whether the Institute had any compounds that could be used as therapeutic agents in the event of a smallpox attack; and (3) whether the Institute could enlist industry as well as academia in moving immediately into the biodefense field. She used these three examples to show how the public-private partnerships of NIAID have worked.

## Three Examples of Public-Private Partnerships

1) Launching the vaccine study in record time required an infrastructure that had been in existence for over 40 years. It had been used routinely to assist companies in deciding whether to pursue particular products. The infrastructure had a core of clinical research capability, but to get to that point requires a huge investment in both basic research and product development, including preliminary information that the product may indeed be of value. "No company is going to invest hundreds of millions of dollars in a concept," she said, "until there is a good idea how that concept works." In order to speed concept development, the Institute offers a contract process that includes opportunities to test a certain product at a preclinical stage. NIAID tests the product for the company, which then decides internally if the product is worth pursuing. The Institute can also assist the company in approaching the FDA and applying for investigational new drug (IND) status for the product. Further, it can help the company do NIH Phase I and Phase II clinical studies, and in some cases Phase III through Phase IV studies, which entail most of the expense of product development. The Institute also makes available to the company its extensive academic expertise.

2) For the task of surveying existing, already-licensed compounds as well as compounds under development that might be useful against smallpox, the Institute used a second existing mechanism. This mechanism, which is a series of *in vitro* and *in vivo* antiviral screening contracts, is used for evaluating a compound a company may have developed or is considering developing to determine if it has value. These contracts can provide information as to whether compounds

inhibit certain viruses. If the product candidate performs well in tissue culture, the Institute can assume responsibility for moving it to animal studies, which are more elaborate and expensive. The resulting data is given to the company, which again decides internally whether to proceed to the next stage. During the post-9/11 period, this survey process produced a promising candidate in the drug cidofovir—drug that had already been licensed for the relatively rare application of combating CMV (cytomegalovirus) retinitis in AIDS. It was found also to be very active against smallpox. The Institute worked with the company to develop an IND application for the FDA that would allow the use of this drug in case of a smallpox event.

3) A third general mechanism of NIAID is to prompt companies as well as academia to invest effort in areas considered to be important (see Table 1). As an example, within about two months of September 11 the Institute published a request for applications in a variety of areas of high priority. A specific request was targeted at the small business community, asking companies to select certain platform technologies they had been developing and move them in the direction of the Institute's Category A biodefense activities. At that point, very few investigators in the academic or business worlds were working on biodefense products, and the request was intended as a quick stimulus to the non-military research community.

TABLE 1 FY2002 NIAID Biodefense Initiatives

| Initiative Title | Target Audience |
|---|---|
| NIAID Small Business Program on Bioterrorism-Related Research (SBIR/STTR) | Small Business |
| Rapid Response Grant Program on Bioterrorism-Related Research | Academia |
| Exploratory/Developmental Grants: Technology Applications | NIAID-Funded Researchers |
| Partnerships for Novel Therapeutic, Diagnostic, and Vector Control Strategies in Infectious Diseases | Small and Large Businesses |
| Investigator-Initiated Small Research Grants | New Researchers/changing fields |
| U.S.-Based Collaboration in Emerging Viral and Prion Diseases | Academic and Industrial Researchers |
| Development & Testing of Vaccines Against Anthrax | Industry |

### The High Quality of Small-business Research

For a small firm, movement into such a new area would require not only commitment but also the flexibility that small businesses uniquely have. NIAID put out the request under the SBIR, asking companies to respond within six weeks. They knew that responding to their request would require a huge amount of effort on the part of companies: redirecting research in rapid fashion, learning basic principles of biodefense, and asking consultants to determine whether a company's approaches would be amenable to peer review. Nonetheless, the Institute received 184 applications within the short published time limit, revealing both a commitment toward biodefense and very high quality of small-business research. NIAID was able to fund 40 of these applications—a high (22 percent) approval rate, given the stringency of peer review and the requirement that only appropriate topics could be funded. "Usually," said Dr. Heilman, "only a small business is able to shift that quickly and be responsive to a request like that."

For FY2003, the Institute expected a "huge" increase in the President's budget for biodefense (see Figure 3). Because some 80 to 90 percent of NIH's dollars go outside the agency to support academic and industrial research, there was an urgent need for this community to be invested in the new emphasis on biodefense. NIAID accomplished this by bringing people from both communities to NIH and enlisting their help in identifying the critical knowledge and developmental gaps that needed to be filled. This "NIAID Research Agenda" explained its strategic plans and research needs to these academic and industry researchers allowing

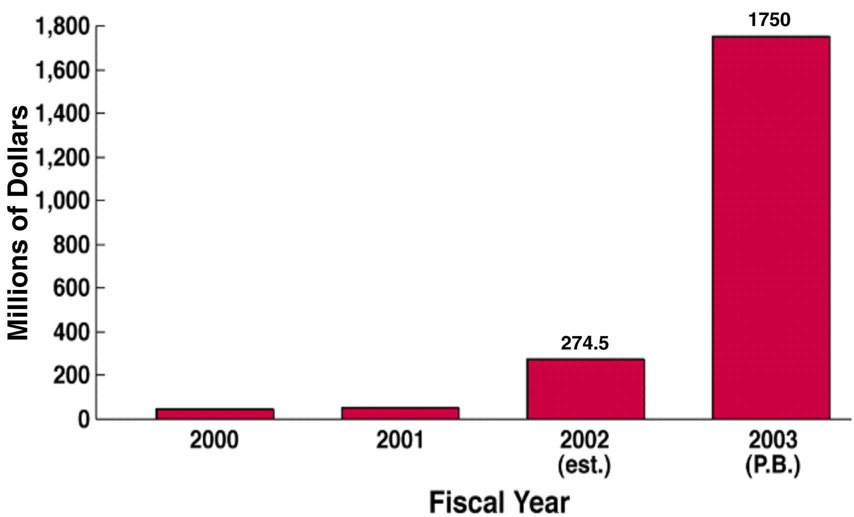


FIGURE 3 NIH Biodefense research funding, FY 2000-2003.

them to better plan for the kinds of expertise and approaches they wanted to invest in. Copies of this Research Agenda can be found on the NIAID web site.

## Helping Outside Partners

Summarizing the Institute's strategy for public-private partnerships, Dr. Heilman said that NIAID needed to be able to understand enough about the pathogens that are involved in biodefense to be able to develop new products. The Institute had recognized that it needed to be able to help outside partners in the development of new products by making available the right research resources, such as a vaccine infrastructure or screening process. This allows companies to avoid duplicating or developing processes that are very expensive, and instead to focus their attention on the part of the process they do best, which is research application. She said that the Institute had planned to issue 28 new requests of this nature in FY2003 and would also be expanding features of its existing infrastructure.

In the areas most relevant to industry, the Institute was asking firms to begin looking at some of the targets that recent advances in genomic information have brought into focus. A goal was to allow scientists to expand the roster of effective drugs, vaccines, and diagnostics. NIAID also wants to partner with industry to help them move toward new targets identified in initial testing to see if these targets are feasible for development by industry.

## A New Model: The Partnership Grant

Dr. Heilman described a new model created by NIAID called the partnership grant, which allowed larger amounts of money to go to industry. These grants required that industry make a serious commitment to working in a particular area, in terms of the number of people who would work on a product or a particular suite for the process development of the product. If a company could demonstrate this commitment, the Institute was willing to take the risk of spending more money to help the company by means of a development partnership. The industry would need to understand that the partnership grant would be milestone-driven, but that the Institute would work closely with the industry to decide whether the project would be a "go" or "no go" at every step of development. Partnership grants are much more cooperative than other types of grants, and the Institute leverages all of its resources to make the company as successful as possible.

## Agreements with Industry

The Institute already exercises many agreements with industry. At the time of the symposium, it held more than 100 agreements for research on investigational new drugs (INDs), and at any particular time it was performing about that number of clinical protocols. The Institute was approximately the size of a medium-sized company, and included an IND group, clinical groups, and other resources typical of a commercial research organization. NIAID already had many behaviors, she said, by which it "thinks" as a company. It developed pre-clinical agreements with companies, agreements to test and hold confidential the kind of information that is required in pre-clinical agreements, and clinical agreements that allowed companies to test their clinical products in NIAID's clinical system "in ways they are comfortable with." The Institute had many resources to expedite clinical testing, from proper reagents to standardized tests and various specimens. The Institute had also had CRADAs (cooperative research and development agreements) with both large and small companies, most of which are now large companies. All of these steps encouraged companies to work with NIAID to achieve company objectives.

**Larger Issues Requiring Public-Private Collaboration**

She listed several larger issues on which NIAID was prepared to work collaboratively with industry:

- Liability: In the case of interventions, especially for vaccines that are to be given to healthy people, the potential for liability suits becomes a substantial barrier for companies that might want to invest in product development. She said that it costs a company nearly a billion dollars to develop a vaccine, and that such products have not historically had a high potential for economic return. When liability risk is added to that "huge, huge investment," the choice to pursue a vaccine product adds up to a considerable economic risk to the company. NIAID's help in planning, testing, and consulting can help reduce this risk.
- The question of control: Each company has a different philosophy on the ownership of their products. The Institute was prepared to work out well-defined agreements that specify exactly what the company wants to do and how the Institute can help—while staying within the customs, abilities, and restrictions of government behavior.
- Building a clinical infrastructure: Many small companies make the reasonable decision not to make substantial investments in clinical infrastructure until they actually have a product with commercial promise. By that point, however, it may be too late to begin building that infrastructure. A company is best positioned if it has already begun thinking about how it wants to develop a product to the clinical stage. NIAID is prepared to help the company to do its planning early by being a partner and advising about the steps that must be taken to comply with regulations.

She emphasized that public-private partnerships can succeed only when both sides understand them and are able to keep to their commitments. NIAID had initiated CRADA agreements that had been broken by companies that unexpectedly changed organizational structure. For its part, NIAID has also encountered difficulties in staying with an agreement when government goals or responsibilities changed with a new annual budget cycle. Some breakdowns are inevitable, she conceded, but "we each have to be as fair and committed as we can."

Dr. Heilman concluded by mentioning a potential difficulty for partnerships that has been brought to her attention by her industrial colleagues. The FTC regulations presently bar certain kinds of cooperation and sharing among companies, and companies have expressed their concern that this might constitute an impediment to public-private partnerships of the kind envisioned by NIAID. She suggested that this may be of importance to the committee.

## DISCUSSANTS

*Henry (Pete) Linsert, Jr.*
*Martek Biosciences Corporation*

Pete Linsert, chairman and CEO of Martek, said he would illustrate the value of the SBIR program to his company by summarizing the history of Martek and the commercial success of the two compounds it markets. Martek is headquartered in Columbia, Maryland, and has research facilities in Boulder, Colorado, and a fermentation plant in Winchester, Kentucky.

"Martek is prospering these days," he began, "largely as a result of four SBIRs. I doubt if Martek would be here without them."

### The Story of Martek

The story of Martek began in the mid-to-late 1980s, when scientists were studying the physiological value of two fatty acids: arachidonic acid (ARA) and docosahexaenoic acid (DHA). About 60 percent of the brain is composed of fats, and the most abundant of those are DHA and ARA, in that order. DHA also makes up about 60 percent of the components of the retina, especially the rods and cones; it is also found in heart, blood and muscle cells and, in males, in the testes and sperm. ARA is the principal omega-6 fatty acid in the brain and is abundant in other cells throughout the body. ARA is important for proper brain development in infants and is a precursor to a group of hormone-like substances called eicosanoids, which are important in immunity, blood clotting and other vital functions.

Most humans ingest ARA in common foods, such as meat, eggs and milk, but DHA is found in only a few foods, such as fatty fish and organ meat. Both

DHA and ARA occur naturally in breast milk and exhibit health benefits that extend from prenatal development through adult life.

In the late 1980s, scientists at the National Institutes of Health issued a call for proposals for new sources of these fatty acids through the SBIR program. Martek, a spin-off of Martin-Marietta, had previously worked, as part of Martin, on a NASA contract to study the use of algae in the space station, both to reduce carbon dioxide in the station's atmosphere and to provide a nourishing food source for its inhabitants. The Martek scientists, working in suburban Baltimore, knew that algae could make DHA and fungus, ARA. They proposed the development of a process to do this commercially. The company won a Phase I SBIR grant for DHA in 1988, and after meeting the milestones required by the contract, won a Phase II grant to continue development. A similar sequence of events occurred for ARA. The DHA project was later awarded the 1995 SBIR Award of the Year for both biotechnology and for all SBIR classes.

## Capturing a New Market

Today Martek is the sole large-scale commercial manufacturer of these fatty acids, which are sold in various forms, including brands of infant formula, in 70 countries. According to Mr. Linsert, double-blind, placebo-controlled studies show that infants who are fed formula with DHA show an IQ that is six to seven points higher than infants fed formula without DHA, and they also develop better eyesight. The United States approved the use of DHA in formula only this year—making it one of the last countries to do so—and formula containing DHA from Martek is now sold nationwide. The company had also applied for the use of DHA as supplements for pregnant and lactating women as studies done on DHA supplemented women in pregnancy and lactation show improved mental development in their infants.

Mr. Linsert concluded by saying that the success his company derived from two Phase I and two Phase II grants from the NIH "had consequences beyond anyone's expectations." "Babies' lives will be improved, future humans will be improved, and we will be touching millions of lives around the world."

## *Gail Cassell*
## *Eli Lilly and Company*

Dr. Cassell said that she had served as Vice-President for Scientific Affairs at the University of Alabama at Birmingham School of Medicine for 30 years and chaired the department for 10 years. In academic life, she said, she had collaborated with small businesses that received SBIRs, and that she had become "a fan of what this program can do to enhance technology transfer." As a department chair in a medical school, she saw the impact of faculty who were able to transfer a technology to the private sector, start small companies, and apply for SBIR grants that led to the success of the companies. She had served on the board of the university research foundation from its outset, where she "developed a feel for what it takes to make small businesses progress and thrive." After moving to Lilly, she had the opportunity to end-license a number of potential products that were the outcomes of funding through the SBIR program, especially those of the NIH, primarily NIAID.

### The Economic Impact of Licensing

During the fall of 2002 she was asked to give a presentation in Tokyo to the U.S. ambassador and a group of people from the U.S. and Japan on the role of biotechnology. She talked about not only scientific advances but also the economic impact of biotechnology in the United States, and specifically the economic impact of universities. She used the University of Alabama at Birmingham (UAB) as an example to describe technology transfer from universities and the impact she had observed on local economies. UAB is relatively small compared to some biotech powers, such as the University of California at San Francisco (UCSF), where approximately 400 patents in biotechnology had resulted in licensing and royalty fees totaling approximately $495 million in income for the university. UCSF is now the second largest employer in the Bay Area, where it had an economic impact amounting to about $2 billion. The economic impact of UAB was also considerable, she said, and the university had grown to be the largest employer in the state, with an economic impact on the local economy of about $1 billion each year.

### The Importance of Bayh-Dole

Dr. Cassell suggested that it was important, in trying to assess the impact of SBIR grants, not to consider them in isolation, but as part of a continuum. In her Tokyo talk, she said that she described the Bayh-Dole Act of 1982 and its impact on technology transfer.[14] At the time of her talk, she did not know that Japan had recently revised national policies in favor of larger support for basic research; she said that Japan had come to invest considerably more in basic research than any other country, including the United States. Japan had not, however, succeeded in translating that support into global competitiveness. As a result, the country has recently changed its legislation to mimic the Bayh-Dole Act, setting aside money for interactions among small companies, large companies, universities, and gov-

[14]The Bayh-Dole Act is widely perceived to have helped stimulate academic research by allowing universities and academic researchers to patent and benefit financially from the results of government-funded research. For one assessment of the effect of Bayh-Dole, see David Mowery and Arvids A. Ziedonis, "Numbers, Quality, and Entry: How has the Bayh-Dole Act Affected U.S. University Patenting and Licensing?" in *Innovation Policy and the Economy,* Vol. 1, Adam Jaffe, Joshua Lerner, and Scott Stern, Eds., Cambridge, MA: MIT Press, 2001.

ernment labs. She said that many other countries, recently including Ireland and Korea, had visited the U.S. to learn more about Bayh-Dole and its impact.

As a result of the well-studied impact of Bayh-Dole, she recommended that the upcoming SBIR study make careful attempts to quantify the impact of technology transfer from academic institutions, calculate how many small companies actually result from academic technology transfer, and estimate the overall impact of SBIR funding. Doing this properly, she suggested, would require a better understanding of the continuum and the synergies among granting mechanisms. She seconded Dr. Heilman's assertion that the needs of biodefense have placed unprecedented importance on the need for interaction between institutions and creation of public-private partnerships to stimulate new research and tools to counter terrorism. Because of the complexity of biodefense, and the urgent need for countermeasures, she said, the nation needs to engage the entire spectrum of industry.

### Setting Realistic Expectations for "Success"

Her final remarks concerned the need to think about metrics for SBIRs. Most of the SBIRs she had reviewed personally while on an NIH study section had been related to the development of diagnostics, products, medicines, biologics, and vaccines. In these areas, she said, the failure rate for industry—from target identification to the launch of a product—was approximately 90 percent. This held true even under the best of conditions, and even for projects in which large companies had invested billions of dollars. In setting metrics for SBIR projects, she said, it was important to give a realistic expectation of "success," especially for small companies investing in biotech. Most of these small companies that NIH would be funding are narrowly focused, so that the failure rate is likely to be especially high.

Even in this area of risky research, however, Dr. Cassell asserted that "the successes will more than pay for the failures." She recalled a suggestion by the Ad Hoc Group for Biomedical Research and the Joint Economic Commission that a new cancer drug that would only improve life expectancy in one-third of cancer patients would be worth a trillion dollars to Americans—a figure larger than the national debt. In light of the expected outcomes of SBIR-supported companies, she concluded, "I would argue that investment in NIH overall is well worth it, and that investment in the SBIR program also is well worth it."

### *Maryann Feldman*
### *Johns Hopkins University*

Dr. Feldman began by soliciting the "advice and counsel" of all participants as the complex SBIR study goes forward. She noted that in studying 10 different agencies, it would require extensive input to understand the differing contexts of the SBIR program within each agency. As an example, she cited the "NIH umbrella" which comprises 27 different centers and institutes, 23 of which participate in the SBIR with many differences and also "a lot of synergies."

## A Mission Relevant to SBIR

The mission of NIH, as she described it, was to "expand fundamental knowledge of living systems." The Institutes provide a comprehensive program of intramural research, extramural research, and grants that together strengthen the biomedical capability in this country. NIH is not only the largest funder of basic research in the world, but also develops strategies for improving the diagnosis, treatment, and prevention of diseases. It is these strategies that lead most directly to commercialization and have greatest relevance to the SBIR.

Despite the diversity of the NIH centers, she said, there are commonalities that would assist in studying the program. One is a uniform peer review process for the SBIR program run by the Center for Scientific Review. This center is "very comfortable" for academic scientists, who are accustomed to using peer review in many aspects of their work. There are also common NIH databases (CRISP, IMPAC)[15] that provide resources and common criteria for judging success that transcend different programs.

## The Challenge of Measuring "Invisible" Activities

She stressed the unique challenge of studying the success of the NIH in commercializing various products. That is, both drug products and commercial drug companies vary widely in their payoffs and outcomes. Under the best of conditions, the lag time between discovery and commercial realization of a drug candidate is very long. She cited a study estimating that it takes 10 to 15 years to develop a new drug and costs $800 million to take it through the FDA approval process. Even after approval, the path to market is usually circuitous and uncertain. A firm might win an SBIR award, but many firms merge, fail, and change their names before a product reaches the market. When firms change their names, it is difficult to track their progress. In addition, while companies often fail, key individuals tend to move on to other firms where their success in the previous firm may translate into valuable but "invisible" activity. In short, many aspects of the process of discovery and experimentation that are key to the biomedical enterprise are difficult to track.

Dr. Feldman said that the study panel, through its understanding of this complexity, would try to understand in the broadest sense how the NIH SBIR program has contributed to expanding our fundamental knowledge of health. This would include not only the metrics of products, patents, licenses, sales, and other traditional SBIR measures of commercial success, but also publications, citations of those papers, the contribution of companies in training human capital, and other ways of measuring the larger spillover effects of the program.

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[15]CRISP, the Computer Retrieval of Information on Scientific Projects, is a searchable database of federally funded biomedical research projects conducted at the NIH. IMPAC Medical Systems, Inc. provides information technology solutions for cancer care.

### Beginnings of the Biotech Industry

She said that the biotech industry essentially had begun when the Cohen-Boyer Patents, filed in 1973, established the industry's commercial potential. Subsequently, the concept of patenting life forms was upheld in court cases. The industry grew through academic breakthroughs, the work of "star scientists in dedicated biotech firms," and the use of intellectual property licenses from universities. The NIH SBIR program, which began in 1983, provides a mechanism to translate academic science into commercial discoveries.

The current SBIR study, she said, could bring fascinating and useful information about the biomedical revolution and the role of the NIH SBIR program in advancing that revolution. It would also provide an important new perspective on how individual researchers move from the support of university research grants toward the support of SBIR grants, using this new mechanism to translate their academic science into useful products.

### Tracking Award Recipients

As a test of the kinds of data that might enhance the value of the study (after all, she said, "to a researcher, having data is as fundamental as having air"), she had asked her research assistant to review any available information about the 1983 SBIR award winners. Using the CRISP on-line data, she found that 120 companies had received SBIR Phase I awards in 1983, and asked the question, Where are they now? It turned out that seven (6 percent) were publicly traded companies—"names you would recognize" (see Table 2). Twenty-one (18 percent) had changed their identities through merger or acquisition, but could still be followed; 38 were still independent. Fifty-four (45 percent) had ceased to exist as companies, but for 80 percent of these, interim data existed that showed their last SBIR award or patent application.

TABLE 2 Publicly Traded Companies—1983: NIH SBIR Awards

| Company | Year Founded | Employees | Revenues ($) |
|---|---|---|---|
| Genzyme Corporation | 1981 | 5500 | 1 billion |
| Maxwell Laboratories, Inc. | 1965 | 483 | 78 million |
| Enzon | 1981 | 127 | 76 million |
| Bioanalytical Systems, Inc. | 1975 | 260 | 25 million |
| Surmodics, Inc. | 1979 | 143 | 23 million |
| Bioqual, Inc. | | | 13 million |
| PAR Technologies Corporation | | | 118 million |

In conclusion, she said that this kind of "industrial forensics" offered a basis for thinking "that we may be able to get in and look at these companies in more detail."

## DISCUSSION

Mr. Turner, who played a central role in framing each of the amendments to the SBIR legislation in 1982, applauded the efforts and understanding of the research team so far, and called it "quite an undertaking—a massive charge, looking at such diverse programs." He also affirmed the difficulty of tracking companies that change rapidly. He cited the case of Mr. Linsert and his company Martek as an example of a successful firm that emerged around a single individual whose initial work on a product had begun for quite different reasons. "One trick," he said, "is how we find the Pete Linsert's out of all the SBIR applicants. When he got his first SBIR grant he did not know what he had. His company would not have made it had he not gotten the grant, but it did, and we have a wonderful company because of that. How can we direct more of our funds in that direction?"

### A Few Successes Outweigh Many Failures

He agreed with Dr. Cassell that the study panel should not be overly concerned about the high failure rate of SBIR companies because "a handful of successes in these programs more than compensate for all the failures. He echoed Dr. Feldman's view that determining the value of an SBIR company is a complex undertaking, as illustrated by the frequency of company changes: "Just because a company disappears doesn't mean we don't gain benefit from its research."

In reviewing the meaning of the original two-page statute that Congress issued in 1982, Mr. Turner said that many of its rules were based on the assumption of the linear model of research and development—the idea that knowledge moves in a straight line from the laboratory to the marketplace. Echoing Ms. Goodnight's earlier comment, he noted that we now understand that knowledge moves in more complex and circular fashion, with numerous feedback loops between the marketplace and the laboratory. A challenge for the study panel would be to recommend ways to amend some of the "statutory impediments" that reflected the earlier, linear model, that we now know impact the overall program effectiveness, such as narrow time frames, fixed amounts of money, and a "one-size-fits-all" program. "How do we sort of bend or change the rules," he asked, "to nurture the best ideas and make winners into tremendous winners?"

### Congress Would Like to Improve Effectiveness

He said that one thing Congress anticipates in the study is a baseline review. The purpose of such a review would be to raise basic questions about the quality of the research, its value to the federal government, its economic benefits, and small business's "share of the pie."

In addition, Congress would like to see two sets of recommendations. The first set would respond to the Government Performance and Results Act (GPRA). That is, how efficient and effective is the program? What improvements should be made to improve efficiency and effectiveness? One of the goals of GPRA is to measure the outcomes of government programs. Even though the SBIR program does not receive an annual review by the Office of Management and Budget, Congress does consider it a program that falls under the GRPA statutes. He asked the study panel for "anything you can do to help us understand how to improve efficiency" and also suggested that there was no reason to wait until the end of the study to use a result that becomes apparent early.

### Strengthening Phase III

The second set of recommendations that Congress would like to see, he said, is "bottom-line recommendations." Small business has much to offer, and yet the small-business sector in general is not respected in some parts of government, especially in the procurement arena. He noted that his colleagues on the Small Business Committee had tried for years to raise the awareness of the potential contributions of small business and to "force more doors open for small business." He said that anything the study panel could do to help strengthen "Phase III" and make it as important as the first two phases may be the most valuable contribution it could make to the SBIR program.

He elaborated on the premise that the statute itself had been written during a different era, and that it might very well contain ideas that should not be pursued today. The statute was also written as part of a political process, which meant that it contained ideas that were generated by a small minority of participants—ideas that had to be included to ensure passage through the legislature. He suggested that the current study would provide an excellent opportunity to reinforce the best of the statute and to add positive correctives.

### The Challenge of Many SBIR Programs

Finally, Mr. Turner addressed the challenge of studying all facets of a complex and multi-faceted program. The study panel was charged with examining the five agencies with large SBIR programs, as well as the five with much smaller programs. And yet in practical terms, Mr. Turner suggested, there are probably 40 to 50 SBIR programs in all. This is because NIH alone has 23 SBIR "subprograms," and some of them are larger than the entire SBIR programs of several agencies; similarly, a few other agencies have a large number of separate programs. He conceded that there was no practical way to study all 40 or 50. The most effective compromise would probably be to spend most of the panel's time on the largest programs, searching for suggestions on better ways to run them, and to spend at least some time on the smaller programs in the event that good suggestions are to be found among them as well.

"It will be great if you have suggestions for all the programs," he concluded, "but we realize that resources are limited. We know that we have a wonderful team and we're looking forward to the results."

## Stimulating Translational Research

Greg Millman of the National Institutes of Health commented that a key aspect of the NIH SBIR program was its ability to stimulate translational research. He noted that formation of companies like Martek Biosciences was an outcome, but not the overall objective. The objective was to have as much translational research as possible, of which only a few will lead to the Martek-like successes; many will fail.

To measure translational research, he suggested, one could do a simple experiment: first, find the funding of NIH by ZIP code, which is available on the NIH web site. Second, plot the nation's major academic centers. Third, look at the distribution of SBIR companies. They tended to cluster around the same ZIP codes and academic centers, which suggested a great deal of interaction between the NIH SBIR companies and major academic centers. That interaction, he said, is a truer measure of success than a tally of functional companies.

Gail Cassell of Eli Lilly and Company emphasized that the SBIR program performed an essential function in providing "a great training mechanism for young investigators" who would stay in industry. Even if their company failed, she said, they would go to other companies. Smaller companies were more willing to take risks in hiring young people, which is something that should be considered by the study panel in trying to assess the impact of SBIR.

## Agency Studies of SBIR

Michael Borrus of the Petkevich Group, LLC, returned to Ms. Goodnight's point that some of the panel's evaluation would necessarily be less quantitative and more qualitative. He noted that she had described some of the broader goals of the research program at NIH, specifically the SBIR component, as "translating medicine from the test tube to the medicine cabinet," generating disruptive technologies, and meeting specific national needs that are high priority areas, such as biodefense. He recalled that DoD had done considerable self-assessment of its own program, and asked whether the NIH had also collected quantitative data to measure outcomes at NIH against its specific goals. He also asked whether the NIH had analyzed such data and whether it was available to the public.

Jo Anne Goodnight of NIH responded to the three questions with "Yes, yes, and yes." She said that a number of studies had already been done on the program, basically measuring it against the goals identified in the initial legislation. Those studies were in report form and available from the GAO, SBA, and others. The studies also showed that NIH, which is rarely if ever the customer, had one of the highest rates of commercialization among SBIR agencies.

In addition, the NIH did collect extensive data on its own R&D investments, and was at the end of a study of its Phase II awardees. She said that the agency would be happy to share those data and outcomes. Some other agencies, including some of the smaller ones, had also done their own SBIR evaluations. She suggested that their data should be factored into the recommendations that emerge from the study, because those recommendations would affect all ten SBIR agencies as well as the SBA—not just the five largest. The other reason to look at all ten, she said, was that it was now possible to fund a Phase II award to a company whose Phase I funding came from a different agency. She demonstrated how this new practice could lead to erroneous study results unless all agencies are included. For example, one might see that a company received only a Phase I grant from a particular agency and conclude that it failed to get a Phase II grant. In fact, that company might have received a Phase II award from a different agency and gone on to be successful.

"We do have data like this," she reiterated, and "we have success stories. We are more than happy to share them. That's the point of assimilating the data the agencies have already collected and not going back to the companies to ask the same questions."

## Extending the Study

James Gallup, SBIR program manager for the U.S. Environmental Protection Agency, referred to Mr. Turner's comment that it might be impractical for the study panel to evaluate all ten SBIR agencies. He said that he agreed with Ms. Goodnight's reason for trying to look at all of the ten. As the EPA SBIR program manager, he said, he could see "really significant" differences between the large and small agencies, and saw "some things the small agencies can do that will help us greatly." He called for clear guidance from the very beginning of the study about just how many agencies should be included.

Jim Turner of the House Science Committee responded that "we've thrown an impossible job at the committee, and I'm sure it will be sorted out in a wise way, probably through a compromise." He did point out that the largest programs are some 200 to 300 times the size of the smallest programs, and that it would be impractical to spend equal amounts of time on the smallest ones. He thanked the panel for taking on this challenge.

# SBIR at NASA

Moderator:
*Duncan T. Moore*
*University of Rochester*

Dr. Moore said that he was publicly known as a university professor, and also for his government service at the White House during the last years of the Clinton administration. Fewer people knew that he had started a small business using SBIR money, he said. Nonetheless, he suggested that his experience might illustrate a complexity that should be taken into account during the SBIR evaluation.

**Technology at the Mercy of the Market**

In 1970 he began doing research in the field of gradient index optics, or GRIN. The techniques of GRIN can make light travel by a curved path through optical materials, which reduces the number of lenses required in complicated optical systems. He said he had believed that "by 1975 everyone in the world would be using gradient index optics." The basis of that belief, and of others with whom he worked at Western Electric, in Princeton, New Jersey, was the then-rapid development of picture phones. It was widely accepted that picture phones would be in widespread use, and in order to make that possible, the industry was going to need more lenses than would be easily available.

However, picture phones did not emerge as anticipated, and the projected need for GRIN optics receded. In 1980, Dr. Moore started a company with the goal of commercializing some of the gradient index materials, and he received an SBIR award from the National Science Foundation. The objective of the company was to make axial gradients, and the theory, which had been proved in practice, was that the technology would halve the number of lenses needed for any complicated lens system, such as a camera or spotting scope.

The company had a contract with Olympus to start manufacturing, but a change in the market altered the plans. While it was true that the technology would reduce the lenses by a factor of two, the company still had to be able to make one GRIN lens for less than the cost of making two regular lenses. In the end, the economics of the technology fell short.

### Turning "Failure" into "Success"

An evaluation of the SBIR done in 1990 might have judged the company a failure. However, the story did not stop there. In 1992, Dr. Moore was asked to make a new type of disposable endoscope—a device to see inside the body, often for the purpose of performing minimally invasive surgery. This request, too, was accompanied by an unexpected economic context. In the economics of lens manufacture, the cost of large lenses is very high; as size diminishes, costs drop until they reach a minimum for lenses of around 5 millimeters in diameter. For lenses smaller than 5 mm, polishing became hard to control and costs began to rise again. The company developed a new technique, however, by which it was able to make smaller-diameter lenses more cheaply. By this method, a 1-mm GRIN optic, for example, was about eight times cheaper than a 2-mm optic. So in 1996 the company was able to introduce the first "borescope," which is today a commonly used device for seeing inside many materials and structures. The first such device was made to look not inside the body, but inside machines. Dr. Moore's company is now the largest manufacturer of borescopes in the United States.

### Finding Success Depends on When it is Measured

In terms of the SBIR program, he said, "if we hadn't done the earlier work that 'failed,' we couldn't have gone to the next step and 'succeeded'." He said that this is one of the reasons an assessment would be complex. "Innovation does not follow a linear model," he said. "It stops and starts." He judged that if his research project had been part of a large company, it would have been killed in 1990 and the technology abandoned. "But when you're a small company," he said, "you only have one technology. You figure out how to make it work or you go out of business." Since then, his company had gone up and down in terms of sales and people, but it was now very successful.

He concluded by saying that the story of his company should alert the study panel to the need to pay careful attention to the location of each company on its own particular "time line." He said that if a company could be evaluated more than once as it developed, the study panel might detect the kinds of fluctuations experienced by his own company.

## ACHIEVEMENTS, OPPORTUNITIES, AND CHALLENGES

*Robert L. Norwood*
*NASA*

Robert Norwood, Director of NASA's Commercial Technology Program, began by introducing the new mission and vision recently developed at NASA and the NASA SBIR program.

### NASA's Mission and Vision

The new vision is:

- To improve life here;
- To extend life to there;
- To find life beyond.

The new mission is:

- To understand and protect our home planet;
- To explore the universe and search for life;
- To inspire the next generation of explorers

…as only NASA can.

This mission and vision, he said, would be expressed shortly in the form of a new agency strategic plan.

Dr. Norwood offered a general introduction to the agency. NASA is organized under five "enterprises": Space science, earth science, biological and physical research, HEDS (human exploration and development of space), and aerospace technology. His own organization, the Commercial Technology Program, and the SBIR program are part of the Aerospace Technology Enterprise, which is charged not only with developing technology for the world of aeronautics, but also with providing most of the R&D for the other four enterprises.

The vision and mission of NASA, said Dr. Norwood, pervade many aspects of the SBIR program. One is investing in technology in collaboration with others—in this case, with small business. Another is to invest in new technologies that have the potential of bringing technical solutions to NASA. These objectives are part of a larger suite of R&D activities in which NASA seeks collaborations to make new technology more useful internally and to carry technology to commercial partnerships outside the agency.

He said that NASA had committed itself to a new emphasis on education, and was contemplating a new organization within the agency dedicated to education. NASA worked with many academic institutions, and the SBIR program was strengthened when NASA contributed to the nation's human resources in science and technology.

### Tying the SBIR to Enterprise Needs

NASA's technology strategy was closely coordinated in a "one-NASA framework" of strategic enterprises, and the SBIR and STTR activities were aligned with the technology needs of the enterprises. Several years ago NASA made a strategic change so that the content of each SBIR solicitation would be closely tied to enterprise needs. The enterprises and the respective offices at the ten NASA centers were responsible for writing the contents of the solicitation. This was to ensure that when responses came back from the small business community, the technologies they proposed would accurately reflect the interests of the enterprises. This would increase the likelihood that the technologies NASA supported would find internal applications.

Even though the agency had a one-source selection authority, a team had been formed so that all the enterprises and the centers contributed formal recommendations about which proposals to select. The work of this team tied the priorities of the enterprises more closely to the selection process.

### The Agency's Strategic Approach

Overall, the agency's strategic approach had several main elements:

- Cultivate innovative solutions: One objective of the Commercial Technology Program was to establish partnerships with all segments of industry, including large, medium, and small enterprises. The SBIR was the principal mechanism for linking with the small business community.
- Leverage existing commercial networks to assist small businesses: NASA maintains a network of commercialization offices throughout the United States and tries to leverage that network in support of the SBIR program. The offices include technology incubators and regional technology transfer centers, some of which were refocused last year specifically to help the SBIR program arrange business services and find partners in the investment community to help move companies into Phase III.
- Maximize the potential for commercial success: The commercial technology offices train NASA scientists and engineers to work with both the non-aerospace industry and small businesses. The agency also uses the benefits of partnerships, cooperative agreements, and other business assets in NASA.
- Communicate with the business community: NASA Tech Briefs reach well over 500,000 readers. The agency also communicates its needs to the

high-technology community through Innovation magazine, Spin-off magazine, and other publications.

### Narrowing the Time Gap

One complaint about the SBIR program is the long time gap between Phases I and II. In one innovation that has narrowed that gap, NASA had recently finished implementation of a paperless documentation system, spanning all activities from solicitation, development, and publication through the contracting process. The system, called Electronic Handbooks, was designed to speed data collection, improve management processes, and to make that data accessible to more people. Data could also be sent to and from reviewers more quickly through electronic means.

### Speeding Technology Toward the Marketplace

Another change, made in 1995, was intended to increase the rate at which SBIR research was translated into the marketplace. This was done primarily by two mechanisms to evaluate the commercialization potential of Phase I proposals: (1) through evaluation by an internal group of NASA experts who were asked to judge the technical merit of projects, and (2) through evaluation by an external group of business executives and university professors at business schools who were asked to judge commercial merit. For Phase II proposals, NASA added a request for applicants to draw up a business plan showing how the technology might succeed in the marketplace.

### Return on Investment

In 1996, a year after that change in emphasis, NASA surveyed all of its SBIR programs from 1983-1996. The survey included all 1,739 Phase II awards and the 800-900 firms that received them. The response rate was 84 percent; the assessment was conservative, making the assumption that non-respondents had achieved nothing. For commercial awards (no revenue from government sources), NASA received a minimum of $2.06 for every dollar it had invested in Phase II projects (see Figure 4).

Another finding was that a minimum of 31 percent of Phase II awards resulted in technology that was commercially applied in non-U.S. government markets (see Figure 5).

Dr. Norwood commented that while these figures sounded impressive, he had nothing to compare them to: “I don’t know if they are good or bad. Hopefully this study will lead us to an assessment at the national level about whether these are good numbers, because I don’t know what the rest of the industry does.”

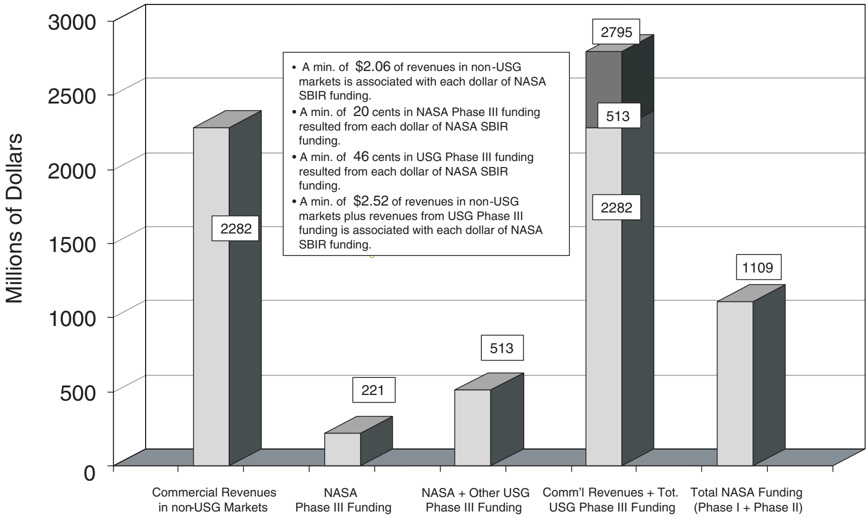


FIGURE 4 Minimum cumulative revenues generated by application of technology developed under NASA SBIR 1983–1996 Phase II Awards.

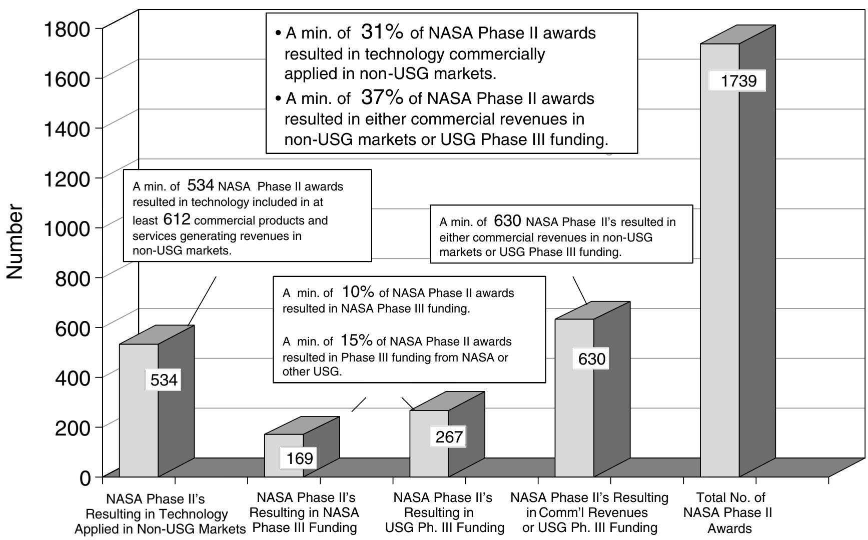


FIGURE 5 Application of NASA SBIR technology in non-USG and USG markets regarding: tracking of Phase II's for award years FY 1983-1996.

## Opportunities for the Study

He reviewed some of the opportunities presented by the study—a "unique opportunity for a national program assessment. This study can form a basis for assessing how we evaluate high-tech business and how it contributes to the nation."

For example, can the SBIR play a key role at the national level? Again, he said, this is not known. From the information heard so far from the Department of Defense and from the National Institutes of Health, however, he hoped that this study would "help us understand how to do a better job of integrating technologies into the national storehouse" of knowledge.

Dr. Norwood said he would like to know how SBIR companies compared with other companies in the same technology industries. He would also like to be able to identify themes for program improvements to help guide changes in the SBIR program. During the 20 years since the legislation was passed, he said, we have moved through a generation of new techniques; the economy is different, and the people running the economy are different. The challenge is to adapt the program to all these changes so it is more relevant today.

## Challenges for the Study

One challenge facing the study panel, he said, is the question of metrics. "I hope we don't throw up our hands and say it's too difficult to do." He said that he would like the panel to propose some national-level metrics and then to discuss them in light of each agency's mission and congressional guidelines.

He then listed other challenges for the study:

- SBIR and other industry sectors: We need to better understand how agencies can better integrate SBIR programs with companies of medium and large size and with industry at the national level. "It doesn't seem to make sense," he said, "to have a program of $1.3 billion working *ad hoc*. Are there techniques we're not seeing that might be helpful?"
- SBIR and other government programs: He suggested exploring new relationships between SBIR and other agencies, given the large number of federal and state efforts focused on R&D.
- SBIR and the academic community: The separate STTR program is focused on the academic and not-for-profit research community. Should this program be independent from SBIR, or might there be advantages to a merger?
- SBIR and the venture community: Can we take advantage of the presence of several representatives from the venture capital community on the committee to seek ways to collaborate? The investment community is expert at starting businesses and moving them into the market place; the SBIR

wants to do the same thing. Just from the "selfish viewpoint" of the agency, he said, NASA can benefit by buying technologies that advance the agency's mission. In some cases, the agency may be able to buy a technology from a company more cheaply in the marketplace than it could develop it internally. NASA would not be a major customer for these technologies, but if the agency worked more closely with the venture community, it might happen more often than it does at present.

- A collaborative model for SBIR: The program had worked for 20 years by funding individual companies. Industry was exploring more partnerships today between firms whose missions complemented one another. Could that work for the SBIR? Rather than limiting Phase II awards to single grants of $750,000, would it be more productive to support teams of firms with larger budgets?

Dr. Norwood closed by saying he hoped the study panel would have time to consider such possibilities, along with its more traditional evaluation activities.

## DISCUSSANTS

*David H. Finifter*
*The College of William and Mary*

Dr. Finifter, who had participated in the SBIR Fast Track evaluation and a study for NASA Langley Research Center, used the analogy of fruit to illustrate the many dynamic components of the SBIR program. He said that while fruit is good in general, it comes in many forms—apples, oranges, bananas, and strawberries. To understand how good fruit is, one has to understand the different kinds. The SBIR, he said, is a diverse and dynamic component of the R&D investment of the U.S. government and the U.S. economy.

### "High Time" for a Study

Because of the SBIR's importance, it is "high time, after about 20 years, to do a comprehensive evaluation of the SBIR system of programs," he said. It is important to examine and puzzle about its basic structure, program missions, and goals; it is also critical to understand the differences across agencies, and how programs are organized, targeted, and managed. One must understand programs at the agency level in order to understand the effects of the program at the national level.

Among the five major SBIR agencies, as well as the five smaller ones, he said, the issues that are critical will vary. In some agencies a major issue will be the comparison between grants and contracts. Other issues to examine will be who identifies the program targets; how much of target selection is mission driven as opposed to market driven; how effective is the agency in identifying and monitoring projects for its technical side versus the commercial side. For these reasons, he said, it is appropriate that the study panel was doing its work at the agency level. At the same time, it is critical to remember the national policy questions and "critical at the end of the day to come back to the question of how good is fruit for you."

### Talking to Program Managers

Dr. Finifter said that he had already seen, from DoD, NIH and NASA, that there are many differences within agencies—for example, in how they select, monitor, and "incentivize" contractors. The experience of the DoD Fast Track study, he said, would certainly help the current study panel review methodology and extrapolate it from the agency to the national policy level. In particular, he reported that the Fast Track team had discovered the great value of talking not only to firms but also to program managers and program points of contact in order to understand how the program was implemented. He said that he and a colleague, Robert Archibald, had done an email survey of the technical program points of contact and found that these people "have an understanding of the value of SBIR that others don't have."[16] The survey had asked the points of contact both to compare, both in an absolute sense and a relative sense, the SBIR with other R&D sponsored by their agency. The response, "somewhat to our surprise," had been that in both senses the SBIR "holds up pretty well." He and his colleague gained other insights by looking at firm-level data and case studies. He predicted that "all those things will come out in this study of the agencies," and could then be aggregated at the national level.

### Study the Program "Microscopically"

He said that NASA's SBIR program is an innovative one, and that he had been impressed while observing it for several years. Its mix of topics varied widely, compared with other agencies and with the overall range of R&D activity of the agency. This range was wide because of the five enterprise levels and the differences across the ten centers. But he said that studying the program "microscopically" before going to the macro level was important. "Decisions and feedback are built in terms of how the national program evolved, and it's important that we understand that as we study the program."

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[16]See Robert B. Archibald and David H. Finifter, "Evaluation of the Department of Defense Small Business Innovation Research Program and the Fast Track Initiative: A Balanced Approach," in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, Charles W. Wessner, ed., Washington, D.C.: National Academy Press, 2000.

He then turned to another joint study he had done with Dr. Archibald, this one for the NASA Langley Research Center in Virginia.[17] They looked at all of Langley's SBIR contracts from 1984 to 1995, both Phase I and II, by means of a mail survey. They received over 200 responses and developed the following conclusions:

- About 36 percent of the Phase II projects had developed a product and/or had sales;
- 28 percent had actual sales;
- 44 percent had some additional investment;
- 46 percent reported that the innovation would reduce costs to users;
- 45 percent had performed basic research leading to publication or technical reports;
- 34 percent had outcomes leading to intellectual property patents or copyrights.

## Allowing for Sufficient Risk

Like Dr. Norwood, he confessed to a lack of context for these results: Were they good or bad? A high success rate is gratifying, but a low success rate implies risk, and "we do want to be sure that it's a sufficiently risky portfolio." He said that if the program aims too low "we won't be doing our job as federal portfolio managers." The question of "how high is high," therefore, is important to the program and to the study.

He also noted that the measures of success varied by disciplinary area, such as aeronautics, computers, and space science, and by federal policy. He said that the study panel would be able to do some simulations of the effects of SBIR on federal policy, both before and after 1992. He and Dr. Archibald had already found a difference, because in 1992 a greater emphasis was placed on commercialization versus mission-driven research. They had written, for an article forthcoming in the journal *Research Policy,* that the change in the program in 1992 had come to some extent at the expense of basic research.[18] "This," he suggested, "should be debated in the policy arena."

[17]Robert B. Archibald and David H. Finifter, "Evaluating the Small Business Innovation Research Program: Evidence for NASA Langley Research Center," Thomas Jefferson Program in Public Policy, Center for Public Policy Research, The College of William and Mary, Policy Research Report, 1997.

[18]Robert B. Archibald and David H. Finifter, "Evaluating the NASA Small Business Innovation Research Program: Preliminary Evidence of a Trade-off Between Commercialization and Basic Research," *Research Policy*, 32(4):605-619.

### Start from the Agency Level

Returning to the analogy of fruit, he reminded his audience that the SBIR should be addressed as a national program, not merely as a collection of apples and oranges. He said that the panel should think of national policy goals as being implemented across multiple agencies and sub-agencies. The panel must produce a clear "bottom line" for Congress, he suggested, while being careful about how it arrives there. Starting from the agency level is the correct approach, he said, combined with sensitivity to the differences across agencies and sub-agencies, as well as differences in the perspective of firms, program managers, and technical points of contact at agencies. He also said that it was important to track variations among types of technologies that had different likelihood rates of commercialization, especially commercialization outside the funding agency. "We have our work cut out for us," he concluded, "and we look forward to your help."

*Charles Kolb*
*Aerodyne Research*

Dr. Kolb said he would first attempt to describe "what the ideal SBIR project would look like"—one that satisfied the goals of the government, private, and academic sectors—and then make a few "personal and biased" remarks on how to achieve this ideal in some of the NASA programs he had experienced.

### High Expectations for SBIR

He said that any SBIR project came with high expectations. "You start off with the fact that the 'I' stands for innovation, which means that it has to make a novel, unique, or at least potentially very significant contribution to our nation's science and technology knowledge base." For most research proposals to the government, he said, that was the only expectation, and a project that met this expectation was judged successful. The SBIR program, however, brought two additional expectations. The first was that it should generate commercial activity, such as job creation, export sales, and earnings for stockholders. It was expected to make a significant economic impact—something which was not usually expected of a research proposal from a university.

The second additional expectation, he said, was that it advance the mission of the sponsoring agency in some meaningful way—to help NASA or other agency do its job better. So an SBIR project must clear three significant hurdles to be successful, and it must do so for a total investment (Phase I plus Phase II) which is almost always less than a million dollars; in some of the smaller agencies, funding was about a third of a million dollars. This was not a large investment for such high expectations, he said, which presented a question for the study panel: how fair are these three expectations, and how often must any or all of them be met for the program to be judged a success?

## Tech Transfer as Part of NASA's Mission

At NASA, he said, after a proposal had been funded and presumably cleared the "innovative hurdle," the agency still had to evaluate the likelihood of commercialization and contribution to the agency mission. He referred to Dr. Norwood's description of the NASA Commercial Technology Program, and called it "one of the most energetic and comprehensive in the SBIR program." The CTP also went beyond the SBIR program, he said, in that NASA had for many years tried to stimulate its internal organization to develop technology and apply this development in ways that benefit the nation. Here he referred to the "folklore" about non-stick Teflon frying pans, Tang, and other NASA-generated products that have found wide usage. "In my own view, it's quite enough that NASA took us to the moon, and helped developed airplanes that are the envy of the world, communications satellites, meteorological satellites, and global change satellites, all of which are extremely important to the economic well-being and future of the country. But NASA also feels it's part of their mission to spin technology out into the commercial sector." He said that the SBIR program benefits from this objective, and from the Technology Commercialization Centers, as well as from NASA's publication of Tech Briefs, Aerospace Innovations, and other communications to the science and technology community.

Taking a slightly different view of what NASA was doing, he called attention to the inherent difficulty faced by a federal agency in guiding projects into the commercial arena. "It's a little like going to Jamaica to take snowboarding lessons," he said. "It's not really what they're good at." While the SBIR program is "thorough and energetic, I think most companies realize that it's up to them to commercialize their technology, not up to NASA."

## How SBIR can Help NASA

Then he focused on how a NASA SBIR award recipient can help NASA with its mission. This is difficult for a large agency, he said, especially one with NASA's breadth of mission. In NASA this is exacerbated by the relative independence of the ten field centers, or sub-organizations, which do not take naturally to collaboration. A small business applicant for an SBIR award has to sell its idea not only to NASA as a whole; it also has to direct its idea to a receptive center. Even if this happens, the "right" center may or may not be the entity that finally sponsors and monitors the work. "If I want my technology to go to NASA, I have to have a champion inside NASA who's going to push it," he said. "He goes to the NASA meeting I'm not invited to where he says, Look, this technology is a better way to do part of our mission." When things go well, a champion, which ideally is the program manager, can also make good suggestions about writing Phase II proposals so they are attractive to the center and to NASA in general. When the applicant cannot engage such a person, or the person moves elsewhere before completion of the project, progress may slow. Given the many uncertainties of this kind, he recommended that the study panel look for ways to better transfer technology to the mission agencies in ways that maximize its productivity.

## DISCUSSION

### Reconciling Differing Mission Orientations

Duncan Moore of the University of Rochester, pursuing a point made by the previous speaker, asked Dr. Norwood for advice on handling conflicts that emerge from the differing mission orientations of the 10 NASA centers.

Dr. Norwood offered an explanation of the SBIR selection process without emphasis on conflict. Once the missions are defined by each of the four enterprises, he said, they are further refined into the technical objectives needed to achieve each mission. Those technical needs are then related to the center(s) best positioned to execute them. For example, a new earth science mission would probably require a suite of technologies from the two centers that perform most of NASA's earth science, Goddard Space Flight Center and Jet Propulsion Laboratory. The enterprise manager would align the needed technologies with the appropriate center(s), and the technical manager at each center would write a solicitation explaining the technical needs. Once those needs were described, the solicitation would return to the enterprise level; the enterprises would review it and send it out as a request for proposals.

When the proposals returned to NASA, they would be evaluated, like every other program, against the mission's technical needs. The centers would make recommendations and order priorities; the enterprises would review the centers' response, which would return again to the selection authority. That authority would approve the suite of proposals based on the funding available. Dr. Norwood ended by saying he did not think that conflict was inherent to this process, other than normal collaborative tensions.

### Defining Success

Owen Moss of CIIT, Research Triangle Park, North Carolina, said that the symposium had heard good suggestions on how to refine what was already a successful program, and yet he felt that persuading Congress of its value would require more concrete evidence of success or metrics that could measure that success.

More generally, he said, SBIR is one of many agency programs that stimulates and harvests innovation in this country. He suggested that there are thousands of people involved in this process nationwide, at individual organizations and institutes and universities. These people are responsible for intellectual property programs in those places. He said it would be useful to know more about how programs other than SBIR are run and evaluated.

At each institution, for example, the person responsible for intellectual property has to report the number of inventions the program has produced. Out of that number, the program manager chooses a smaller number in which to invest money on patent applications. Of that smaller number, a still smaller number will actually receive patents over a 3- or 5-year period. Those three numbers can be used as concrete measures of annual achievement for the SBIR or any similar innovation program. All of them represent monetary output.

Yet another number could be used to represent intellectual property areas that were commercialized and that generated enough money to pay for the resources invested in them—in other words, those that broke even or better. A still smaller number would represent the quantity of projects that generated huge commercial success.

This process is general and nation-wide, he suggested, and such data are accessible because companies and organizations are proud of their successes, even if they produce just one successful project. In small companies, the rate of success is not high. An intellectual property manager at a company has to accept every project that is proposed and try to move it toward commercialization. He recalled that in the 1980s about one in a hundred patents would pay for themselves, and about one in a thousand would be "big hits."

The SBIR program, because of its more rigorous selection process and its ability to track projects and promote every innovation, would probably generate better rates of success than most small-business programs. He suggested that it should probably duplicate the success rate of a "reasonable-size company."

### Balancing Technical Merit and Commercial Potential

Charles Wessner thanked Dr. Norwood for his "engaging and open-ended presentation," and for the series of questions he posed to the study panel. He asked if Dr. Norwood had a suggestion about how NASA balances the number of SBIR projects that have a high apparent potential for product development and commercialization against the number projects that are clearly valuable research questions but which have less apparent potential for commercialization. He also asked whether some of the centers were more research-oriented than others, and whether that affected overall project selection.

Dr. Norwood answered that selection was a heuristic process in which "we try to evaluate on two axes, one on technical merit and another on commercial potential." He said that NASA tries to maximize both qualities, although the process is primarily a matter of judgment. He said that in all cases the primary objective is to meet NASA's technical missions. But there are also cases of projects that seem to have excellent commercial potential and also have the potential to help a NASA mission downstream by providing a commercial source of technology or service. Such a project may receive somewhat higher priority than a project that is purely technical. He repeated that the appropriate enterprise must first approve each project, and then the source selection authority examines the program *in toto* and asks probing questions about it "in a collaborative and ongoing process."

# SBIR at the Department of Energy

Moderator:
*Patricia R. Forbes*
*Senate Committee on Small Business and Entrepreneurship*

Ms. Forbes said that from the perspective of the Small Business Committee, the SBIR program is "very popular" and has a good deal of political support. Many programs are popular in the states where they do well, she pointed out, but not as popular in other states. This is not true for SBIR, where every state wants "a piece of the program. If they don't have a piece, they want to figure out how to get one."

She said that in her opinion, the study panel and its evaluation process were very important. As she introduced the first speaker, she added that her committee hoped to learn much from the panel's findings that could be applied to the program as best practices.

## ACHIEVEMENTS, OPPORTUNITIES, AND CHALLENGES

*Milton D. Johnson*
*Office of Science, Department of Energy*

Dr. Johnson said that he would provide an overview of the SBIR program at DoE and his relationship to it. He said that he was Deputy Director for Operations in the Office of Science (SC), "and that means I handle just about everything except the research programs." The Office had ten laboratories across the country, two operations offices, and a budget of about $3.5 billion.

SC was charged with managing SBIR for the department. In addition to the Office of Science, five other DoE programs received services from the SBIR office: Fossil Energy, Energy Efficiency and Renewable Energy, Nuclear Energy, Environmental Management, and Defense Nuclear Nonproliferation. SC was by far the largest program participating in SBIR, receiving 64 percent of the SBIR budget. Some areas of the department were exempt by law and did not contribute to SBIR, including the naval reactors and weapons programs.

## Importance of the DoE SBIR

He said that the SBIR program was important to him for two reasons. First, its annual budget was large—close to $100 million. Second, he served as the chairman of the SBIR Advisory Board, an oversight committee with policy-making authority. This board, which reported to the Director of the Office of Science, allowed all of the DoE program areas to have input into the management and direction of the SBIR program, and ensured that the program was responsive to department needs. He said that the program had proven to be responsive, bringing small businesses into partnership with the national laboratories, universities, and large companies as research and development performers that made important contributions to the department's mission.

## Goal 1: Utilizing Small Businesses in Federal R&D

Despite some early growing pains (i.e., the set-aside itself met with initial resistance), he said that the program had blended well with the rest of DoE's funding mechanisms (the other 97.5 percent of the budget). SBIR was regarded within the department like any other R&D program, namely, as a vehicle by which the department could accomplish its R&D objectives. The difference was simply that the work was performed by small businesses instead of national laboratories or universities.

This management "blending-in," he said, was critical for the SBIR office's ability to manage the program and to gain the cooperation of the technical programs. Without their cooperation, it would be impossible to evaluate the 1,200 grant applications (Phase I + Phase II) received each year. This cooperation was achieved through a balance of both centralized and decentralized management:

- The SBIR office was centralized in setting common schedules, procedures (for receipt and evaluation of grant applications), and scoring practices. The SBIR office also handled all logistics, such as dealing with thousands of outside peer reviewers.
- It was decentralized in that the programs were responsible for identifying technical topics, identifying peer reviewers, and selecting grant applications for funding.

### Gaining a Full Return on Investment

The best way to gain cooperation from the technical programs was to ensure that each program reaped a full return on its SBIR investment. The best way to achieve this was to approve only those grant applications that received scores above a high threshold.

In this way, the program benefited from a wide range of applicants. He described an example from an area that "might seem too esoteric"—the High-Energy Physics program, which supported complex science projects at accelerator facilities at Berkeley, Stanford, Fermi Lab, Brookhaven, and other locations throughout the world. Even these projects have found a place for small businesses to make a contribution—by developing technology and instrumentation needed to operate such facilities, such as detectors, particle sources, accelerating structures, and power supplies. Small businesses had responded not only by developing instrumentation but also by identifying commercial opportunities for the underlying technologies.

For example, one SBIR company developed a high-power modulator leading to a demonstration of the world's first high-voltage solid-state switch. In turn, this patented switching technology led to two R&D 100 awards, hundreds of delivered systems, and over $20 million in sales. He concluded that many kinds of SBIR projects were making important contributions to DoE missions, and encouraged the study panel to contact program managers throughout the department to gather views on SBIR quality.

### Goal 2: Increasing Commercialization from Federal R&D

Dr. Johnson said that the ability of small businesses to achieve excellent science was not the only measure of success. SBIR was a dual-purpose program, and in addition to increasing the involvement of small businesses in federal R&D, it sought to increase private-sector commercialization of innovations derived from federal R&D (i.e., SBIR Phase III). He said that the DoE had made significant progress with respect to this objective as well.

All DoE Phase II awardees were required to report on their Phase III activity as a condition of their grant. The department learned, through trial and error, an effective way to ask awardees about Phase III. The key, they found, was not to ask about individual projects. A project-by-project approach was tempting because (1) the agencies award and track individual projects and (2) the GAO, in its earlier studies of SBIR, also used this approach. However, it had proved to be imperfect because small businesses do not track their success in this way. Attempts to force them to do so resulted in distorted Phase III data.

### Tracking Success as Business Does

In reality, small companies track their success by the products and services derived from SBIR projects. Therefore, DoE learned to ask companies to (1) list all products and services that were derived from their DoE SBIR projects, (2) report on both sales and/or Phase III investment related to these products and services, and (3) identify which Phase II projects contributed to the development of the products and services.

Several years ago, when this type of information was last analyzed, the department learned that approximately 70 percent of its Phase II projects led to Phase III activity, with 50 percent leading to sales of products or services derived from SBIR research. It also learned that the companies achieved approximately $1 billion in Phase III funding (sales or further development funding), approximately three times the support that had been provided by the DoE SBIR program.

He suggested that the biggest contribution the study committee could make would be an independent assessment of Phase III activity in all the agencies. At the same time, he said, it was likely that any attempt to obtain this information by asking companies for Phase III funding data related to individual SBIR projects would produce misleading results.

### Help in Developing a Business Plan

In the Commercialization Assistance Program (CAP), Phase II companies were helped to develop a business plan by a contractor with experience in this field. The business planning process involved a "large dose of market research" in which the companies identified and contacted potential customers to learn of their needs. This allowed them to develop a focused business plan responsive to customers' needs. The contractor also coached the awardees in developing and making presentations to sources of capital. The CAP culminated in a Commercialization Forum in which the small businesses presented their business opportunities to a group of potential investors, including venture capitalists and representatives of large firms.

The program was intense, requiring a time investment by Phase II awardees of approximately 300 person-hours per company. However, it was judged to be very successful, because more than 50 percent of the small businesses participating in the CAP achieved Phase III funding of over $400 million.

The Department of Energy was the first agency to provide commercialization assistance to its SBIR awardees. Recognizing the value of this program, some agencies had "piggybacked" on the CAP while others were studying it as a model, with the assistance of DoE.

### Successes of the Program

Dr. Johnson expressed pride in the DoE SBIR program. Despite a small staff and limited financial resources, he said it had been able to provide:

- On-time service: The Small Business Administration's Policy Directive required that all Phase I grants begin within 6 months of the solicitation's closing date. DoE had achieved that requirement for 20 consecutive years.
- A modest lag time between Phase I and Phase II: The department kept this gap to no more than three months, providing continuity for awardees. When the lag time is longer, businesses have difficulty holding their teams together.

### Need for Additional Resources

He said that with additional resources, the department could do more, including:

- Outreach: Current resources limited the DoE's outreach staff to three people, who were able to make public presentations only at the two National SBIR conferences and a few regional conferences each year. They had to turn down invitations from many states to address potential applicants about the SBIR program. Additional resources would allow DoE to alert many more small businesses of the advantages of participating in SBIR, especially in rural areas and states of relatively little commercial activity.
- Phase III follow-up: The department's knowledge of Phase III success was limited. With more resources it could study more cases and share their stories with potential small business participants, potential investors, and members of Congress.
- Responsiveness: The DoE would have increased ability to respond to inquiries and problems from small business applicants and awardees.

Dr. Johnson concluded by recommending that the study panel examine the possible benefits of allowing agencies to use a fraction of the set-aside (he suggested 1 percent) for administrative expenses, thereby increasing the ability of the SBIR staffs to provide better service to small businesses.

## DISCUSSANTS

*Rosalie Ruegg*
*TIA Consulting*

Ms. Ruegg began by saying that she was "one of those rare people who thinks that evaluation is kind of nifty." As a member of the study panel, she said it would be a good idea if the study itself was evaluated.

### Thinking about How to Measure Success

She said the panel should think about how to measure "success" for the study, and how that measurement could best be used downstream. The evaluation would not be a success, she said, unless the panel could say that:

- The SBIR is working better than it was previously;
- It has overcome institutional barriers, to the extent they exist;
- Best practices are in place;
- SBIR projects were being tracked with respect to output measures;
- There were ways to measure long-term impact, including:
  - Direct effects, in terms of companies funded;
  - More indirect effects, such as others using the knowledge disseminated from the projects, the capacity that firms develop internally to do more, and beneficial networking effects.

"We the evaluators need to apply the same standard to ourselves that we apply to others," she said.

### Progress Through Conflict

Before starting her company, she had led the evaluation of the Advanced Technology Program during the period 1990 to 2000. The job was a "hot seat," she said, because of the pressures on the program and the demand from applicant companies, and yet it was "very good schooling at the intersection of science and technology, public policy, ideology, and empirical evaluation." These various forces, she said, "conflict, enrich each other, and bump off each other, and at the end of the day I think there's a lot of progress made."

### Evaluation as a Management Tool

She then said that evaluation has its limits. "I love it, but it can be misused, so a lot of care needs to be brought to the application of the evaluation." She said she felt optimistic about having this SBIR study done through the National Research Council, because it provided an excellent forum for organizing and implementing a "fair, balanced and constructive" evaluation. She said it was important in carrying out the evaluation to look not only at results but also at the process of the evaluation itself. She urged that during the study the panel members encourage organizations to make evaluation a "daily kind of process—not just to generate a report, but as a management tool, to improve operations."

### Assessing Both Direct and Indirect Effects

She said that the symposium had just heard that DoE had very rich databases, which meant it would be "a pleasure working with them." She urged that the study panel consider the "expectations of the study, which are downstream," and the assessment of both direct and indirect effects, "where we look beyond the companies to see how others are using the technology developed." It is useful to know as much as possible not only about the agency as it pursues its mission, she said, but also about others who are "out several steps" in the process of transferring technology to the marketplace. Too often, she said, an SBIR evaluation stops with the individual company. But it is also interesting to "look beyond that, to see who's using the processes or products that come out of it: who's using the journal articles that might be written, who's using the patents, who's citing the patents, how are the patents being used, how are the companies enriched in terms of doing other work."

### Attempts to Measure "Elusive Effects" of ATP

She said it was probably not possible to create a complete picture or measure of innovation in the SBIR program, but cited three previous attempts to describe some "elusive effects" of research for the Advanced Technology Program (ATP) in the Department of Commerce. She said that while these impacts appear "rather concrete" to most economists, they are viewed as abstract, if not esoteric, by many non-economists, who view only private returns as "real."

1. *The "halo effect*": Receiving a federal grant may increase the ability of a firm to attract additional funding—the so-called halo effect. Early attempts to quantify the halo effect consisted largely of crude efforts to ask ATP participants whether they experienced increased success in finding additional funding as a result of getting an ATP award; most said they had. A more recent study[19] approached this issue with more rigor, controlling for a number of other factors, and also using a control group of non-winners for comparison. Applying econometric techniques to survey data, the authors concluded that receipt of one ATP award indeed produced a halo effect.
2. *Knowledge spillovers*: Knowledge spillovers are an important social benefit of research, but they are indirect and difficult to observe or measure. One way early research addressed knowledge spillovers was to count patents and patent citations. Three researchers at the National Institute of

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[19]Maryann Feldman and Maryellen Kelley, "Winning an Award from the Advanced Technology Program: Pursuing R&D Strategies in the Public Interest and Benefiting from a Halo Effect," NISTIR 6577, National Institute of Standards and Technology, 2001.

Standards and Technology[20] developed a new model based on fuzzy logic and network analysis. This analysis took into account the extent to which those citing patents are connected to or embedded in the larger national innovation framework of universities, other companies, and national labs. With their technique, some citations were considered to have greater value than others. This work appeared to improve the ability to assess knowledge spillovers by using a given project's patent output.

3. *Market spillovers*: While the direct gains of innovating companies can be quantified, it has proven difficult to measure more general consumer welfare gains (also referred to as consumer surplus or market spillovers), another important social benefit. Molly Macauley and David Austin, economists at Resources for the Future (RFF), developed a new index method that built on previous work for estimating consumer welfare gains from new technologies with certain characteristics.[21] Their technique had the advantage of requiring less data than earlier methods.

Ms. Ruegg concluded that these three examples illustrated the progress being made in measuring effects which seem abstract and difficult to quantify. These effects are critically important components of social benefits because they underpin the rationale for public support of research. "We cannot hope to do a comprehensive measure of all of these effects," she said. "But I would be quite positive about capturing snapshots and indicators of the presence of elusive effects."

### *David B. Audretsch*
### *Indiana University*

Dr. Audretsch mused that this symposium was turning one of the old adages of science on its head. He had always heard that innovation is "all about standing on the shoulders of giants." Today, he said, he had heard that "innovation in the SBIR is all about standing on the shoulders of midgets." He said he had also learned that the SBIR had evolved from being largely ignored in the early 80s, both by academics and the media, to become the "sleeping giant of American economic policy."

[20]Michael Fogarty, Amit Sinha, and Adam Jaffe, "ATP and the U.S. Innovation System–A Methodology for Identifying Enabling R&D Spillover Networks with Applications to Microelectro-Mechanical Systems (MEMS) and Optical Recording," NIST GCR, National Institute of Standards and Technology, forthcoming.

[21]David Austin and Molly Macauley, "Estimating Future Consumer Benefits from ATP-funded Innovation: The Case of Digital Data Storage," NIST GCR 00-790, National Institute of Standards and Technology, 2000.

## The Evolution of Evaluation

Just as the SBIR had changed, so had the evaluation of the SBIR. He noted Dr. Johnson's insights into how evaluation had matured from some of the early studies by the General Accounting Office to the more complex and ambitious ideas expressed by DoE and by members of the study panel. For example, he said, the pioneer studies, when the SBIR was less well known, focused on the DoD, largely because it was the biggest SBIR agency and because it did extensive internal studies. Most of these exercises judged progress on the basis of only three somewhat restricted points: (1) had the program achieved certain straightforward benchmarks, (2) had the SBIR promoted the agency's mission, and (3) was the firm itself strengthened during its involvement with the program.

He noted that Dr. Johnson implied that these were good starting points, but that "it's clear from what we heard this morning that the mandate is to generate an innovative economy and innovative small firms." It was not as important that each firm receiving an SBIR award be innovative. He again cited a point by Dr. Johnson that an overly narrow focus on individual SBIR projects might miss larger benefits or effects that develop indirectly or emerge as some related product or service. "I think that's a very important insight for the evaluation team," he said. "If we make the metric too narrow, we'll miss some of the benefits."

## Searching for Spillover Effects

He noted a challenge for the study panel: that if some benefits spilled over from the SBIR project to other products and services of the firm, it might also be true that extra spillover value goes outside the firm. He told of interviewing an SBIR firm in Indianapolis, founded by a university medical researcher who had developed a technique to produce obese male rats for diabetes research. He asked the researcher about the impact of his first SBIR award. The researcher said that the program had been excellent, but the product had not been commercialized. However, he had then applied for a second SBIR award based on a new idea—producing aged rats for other kinds of research. That idea had come from another firm that had gone out of business when the founder accepted a position at another university. The colleague at Indianapolis had realized it was valuable, decided to pursue it, and advanced that new idea with the help of the SBIR program. Obviously, said Dr. Audretsch, evaluating the "success" of the original company would not have been easy using traditional metrics. "I had gone to talk to him about one SBIR award that had produced nothing, but he was actually building on another SBIR award that had originally gone to another firm."

## The Real Goal: An Innovative, Competitive Economy

He said that the concept of firm evaluation was evolving into something more sophisticated, "outside the narrow units of observation." It was important to know that firms actually receiving the SBIRs were successful, he said, but the real goal was to create an innovative, competitive economy. The challenge for the evaluators, he said, was to identify connections between cause and effect that are often elusive.

He suggested that this challenge was going to push the evaluation process into more areas than earlier evaluations. He seconded Dr. Feldman's plea for more data, and Dr. Johnson's suggestion that access to managers in the agencies would be invaluable, so that the study panel "can actually talk to the managers and learn from them what are their perceptions and how the SBIR program has been integrated into the creative goals of the agency's mission." The panel should also be aware, he said, of how the program can sometimes change the career trajectories of small-business scientists and engineers.

### Widening the Reach of SBIR

He noted that the goal of stimulating a more innovative economy was especially important in places like Indianapolis, where there was "a slight innovation deficit, a sense that people cannot or do not know how to" start their own companies. He recalled asking the medical researcher if he could have started his company without the SBIR. The man had said he had tried to secure a loan from a bank. This had failed because he had been unable to tell them exactly what he was going to produce, had no experience running a company, and had no assets other than the knowledge in his head. Fortunately he had heard about the SBIR from a colleague at the university, and, equally fortunately, the state of Indiana welcomed SBIR programs, even though it had few of them.

Dr. Audretsch described the job of a colleague whose job was talk to scientists about potential projects at federal agencies. He suggested that the study team might look at what were "the actual roles of states and local partners" and how such partnerships could be leveraged to make the programs more effective.

In conclusion, he said that the study panel might gain a fuller sense of the value of the SBIR by looking more broadly at its effects. "It's not just about the projects that get funded," he said, "or even the firms that get funded. It's about changing the American economy to make it more innovative than it would have been otherwise."

## DISCUSSION

### Technical Assistance to States

Patty Forbes of the Senate Committee on Small Business and Entrepreneurship said that reauthorization of SBIR in 2000 allowed the program to offer states and parts of states more technical assistance in applying. This effort was administered through the Small Business Administration, and she hoped that "by the time SBIR is reauthorized next time we'll have some sort of data on whether it helps."

### Gauging Program Success

David Finifter of the College of William and Mary asked two questions of Dr. Johnson: (1) What were the dates of the report he referred to, and is it available outside the agency; and (2) could he describe the elements of Phase III.

Robert Berger, SBIR Program Manager for the Department of Energy, answered these questions for Dr. Johnson. He said that DoE's definition of Phase III was "rather simple," with at least two indicators of success: one was sales, and the other was additional investment in the project. Within each of those, he said, DoE was interested in whether the money came from the private sector or from the federal government.

He added that he agreed with everything Dr. Audretsch had said about trying to find additional SBIR benefits beyond these two indicators, but cautioned that the task would be difficult. He said that DoE had tried to ask companies about individual projects, including the sales generated, but that the "company would make up numbers. They did not track things that way. They'd track sales by their own products and services." DoE then asked the companies what were the products and services derived from all their SBIR projects, and what sales and additional development funding could be attributed to those products and services. "They could at least measure that. Only then did we ask, which of our projects contributed to those products and services. We tried to get to it from the back door." He added that this information had not been issued publicly, but was internal DoE data last analyzed around 1998.

### The Role of the National Laboratories

Jacques Gansler asked about the role of the national labs in the overall DoE program. Robert Berger said that the labs had no role in the SBIR program, except as potential contractors of the DoE. The labs, he pointed out, are not part of the federal government, but may be subcontractors on SBIR grants if a small business wanted to use them. A small business might also use a university or a large business as a subcontractor. National labs were available as partners on projects of any agency, as far as the DoE is concerned.

### Use of Firm Data

Richard Coryell of the National Science Foundation, one of the innovators of the SBIR program, asked Dr. Berger about the availability of data from the agencies that had been obtained from private firms under conditions of confidentiality. Would such data be useable in the evaluation if the company was identified?

Robert Berger said that if he received a request for such data, he would ask the advice of their legal counsel.

### Balancing Technical Merit and Commercial Potential

Rosalie Ruegg asked Dr. Berger if he had noticed any difference in the way the agency weighed projects thought to have good commercialization potential versus those thought to have high research value for the lab. She said that in the research areas mentioned by Dr. Johnson, such as fossil fuel, energy efficiency, and renewable energy, emphasis was placed on whether topics furthered the research goals of DoE. Was there also emphasis on commercialization potential, she asked? And how did the emphasis vary within the agency?

Dr. Berger said that DoE used the same criteria across all its offices. In both Phases I and II, there were three criteria: (1) scientific and technical quality, (2) was the company qualified to do the work, and (3) what would be the likely impact of the project. Under (3), the agency might be interested in both technical benefits and economic benefits. In addition, in Phase II, the DoE took literally the contents of Public Law 102-564, which instructed SBIR agencies to consider certain factors related to commercialization: [22]

- The company's track record in commercializing previous SBIRs;
- Whether the company was willing to share costs during Phase II, which indicated a strong company belief in its project;
- Whether the company had commitments for funding at the conclusion of the SBIR grant.

DoE considered all of these factors, and also asked whether there was a difference among the programs, since some programs might relax one criterion or another for various reasons. "We demand very high scores," said Dr. Berger. "We don't want there to be doubt about any one of these three criteria. At the same time, one doesn't have to be fully excellent on all three." He noted that in some objectives of the department, such as the desire to move new hybrid electric vehicles into the private sector, SBIR might relax the research criteria. In a program in high-energy and nuclear physics, by contrast, the program might decide that the commercialization payoff is less important than the science.

He noted that companies themselves did not care whether the programs relaxed one or another selection criterion. The companies were more interested in obtaining rights to their technology in order to commercialize it. He said that DoE certainly saw the potential for high-energy physics companies to go to the private sector with products developed out of SBIR.

[22] Small Business Technology Transfer (STTR) Program 1992 Public Law 102-564, S.2941.

## Collaborating with National Laboratories

Charles Kolb of Aerodyne Research had two questions. First, he said that his company and companies he met with regularly felt the SBIR solicitation had begun to place stronger emphasis on the availability of the national laboratories as SBIR collaborators. He said that some people saw this as an opportunity for another strong private-public collaboration in science and technology, but that others saw it as a possibly cynical attempt to redirect some of the SBIR set-aside money back toward the national laboratories. He asked whether more Phase I and Phase II programs with national laboratory collaborators were being funded, and whether having a national laboratory as a collaborator gave a company a competitive advantage.

The second question regarded successful SBIR projects his company had had with national laboratory partners. He had found that the laboratories had different ways of interacting with small businesses. Some insisted on implementation of a full CRADA before they would agree to a partnership, as well as full payment in advance for their participation. Other laboratories behaved more like university or private-sector contractors. He asked whether the department had tried to set a framework of best practices for the labs in interacting with SBIR companies.

Robert Berger said that there had never been any attempt to coerce small companies to use the national laboratories as partners. In all the listings of available national laboratory facilities, only about 20 of the DoE SBIR projects had any collaboration with a national laboratory. He said there was more collaboration with universities than with national laboratories.

One of the reasons why national laboratories had been mentioned in the solicitations, he said, was that the program had begun to place solicitations for both SBIR and STTR projects in the same document. This was because the number of applications to STTR had fallen to a low level. Rather than fund poor-quality projects, the department decided to combine solicitations so that properly-positioned companies could apply to both programs at once, increasing their chances of winning an award.

In regard to the occasional difficulty experienced by small businesses in working with national laboratories, he said that his office was trying to respond to each complaint and had asked the national laboratories to “try to grease the skids. You do not want to have a small business in Phase I spend 3 months of the Phase I project trying to get their CRADA done with the national laboratory. This places the company at a disadvantage for Phase II, because Phase II is competitive, and the agency insists that all Phase II applications come in at the same time.”

## Opportunities and Challenges in SBIR

Charles Wessner asked the DoE representatives what they liked best about the SBIR program, and what they viewed as sources of difficulty from a management perspective. He also asked Ms. Ruegg if she thought it would be possible to capture the "elusive measures of outcomes" that Dr. Audretsch had proposed.

Dr. Johnson said it was easy for him to say what he liked most about the SBIR program. His father had come from a small business background and had encouraged him in many ways to experiment and design new equipment. But his father never went to the Small Business Administration for loans because the application process was too cumbersome. Instead, he simply used his own money to start his own company. Dr. Johnson said that the best part of the SBIR program was that it provided a simple way to encourage and fund the people who had good ideas. "Then it's up to them how far they can go." The same was true for the Office of Science, he said, which "lives and dies by the quality of the science we produce. If we produce lousy science, soon we won't get much money for it." He wanted to use part of the SBIR money to create more opportunities for people and to "reach out" in a way that raises interest in science. "Some day we may have a Nobel Prize winner who came from a background of a project like this."

As for what he liked least about the program, he said that he wished he had more money to put into it. With more resources, the staff could do better outreach with the states, work with more recipients, and help them benefit more from their SBIR funding.

Robert Berger added that as operations manager he had a slightly different perspective. Most of his job dealt with the logistics of evaluations and solicitations. But occasionally, he said, especially in the context of the Commercialization Assistance Program, he worked directly with the small businesses themselves. When he did that, he said that "it sometimes brings tears to your eyes—the enthusiasm of the people, and the difference they tell you this program makes in terms of where their company started and what it has grown to; what their vision is and what is possible; and just how good these people are at science and how well they understand the contribution they want to make to the economy."

He said that if he had to search for something he did not like about the program, it was having to rely on a small, overworked staff to produce the solicitations and evaluate the grants. "Most of them are very enthusiastic about SBIR and the companies they work with," he said. "It's those that are not that disappoint me."

Rosalie Ruegg, answering the second part of Dr. Wessner's question, addressed the difficulty of measuring the impact of research-based projects. She said that, to be sure, the study panel would look first at the easier, more quantitative kinds of metrics, such as sales, patents, publications, and commercialization of products. But she also repeated her earlier point that she was "pretty encouraged about addressing at least pieces of the more elusive effects."

## Administering SBIR

Robert Kispert of the Massachusetts Technology Collaborative asked why special administrative resources were required to support the program, and whether it was more expensive or difficult for agencies to administer than other R&D programs.

Robert Berger said that SBIR proposals were less efficient to review, per dollar of research funded, because of the large number of proposals received and the tightness of deadlines. While DoE had reduced the number of proposals by narrowing its topics, the proposal-to-award ratio was still considerably higher for SBIR than for other programs. Also, the performers were different, requiring more outreach than grantees at universities, for example, where the process of grant application is better understood. Finally, the agency's peer review system was labor-intensive; DoE had to convey information packages to at least three reviewers for every proposal and retrieve then on time, or find substitute reviewers.

Jim Turner concluded the discussion by noting that the initial SBIR legislation benefited from the combined perspectives of the House Science Committee, the Senate Committee on Small Business and Entrepreneurship, and other partners in Congress. He emphasized that having representation from both small and large states and from both major parties created "a much stronger product."

# SBIR at the National Science Foundation

Moderator:
*Jacques S. Gansler*
*University of Maryland*

At the outset of the session, Dr. Gansler introduced the first speaker, Dr. Joseph Bordogna.

## ACHIEVEMENTS, OPPORTUNITIES, AND CHALLENGES

*Joseph Bordogna*
*National Science Foundation*

Dr. Bordogna opened his talk with some frank praise for the SBIR: "We like being here because we like this program," he said. "It's an important program, because it's a collective investment in the nation's future, and it merits our most thoughtful attention and evaluation. The NSF welcomes the opportunity to join the other members of the SBIR team to provide an initial overview of the SBIR program."

### The SBIR as a Collaborative Process

He emphasized the importance of viewing the SBIR study as a collaborative exercise. Only as a team, he said, can "we do a really comprehensive evaluation of past achievements and future plans." By "we" he referred to all of the agencies that fund the SBIR. "We have all worked long and hard to develop a seamless program that integrates and amplifies common aims. The result is a nationally integrated federal program that gets the job done efficiently and effectively."

The job of the SBIR, he said, was to foster technological innovation across a wide range of research areas that were important priorities for the nation. What set the SBIR program apart from many others was its focus on particular talent and the capabilities of the small business community to take innovation to the market. Turning technological advances into commercial products, processes, and services was essential to the SBIR program, and continuously brought "a new set of players onto the field." The planned evaluation study was a splendid opportunity to look at the SBIR program in its full complexity, not just in its separate pieces. A comprehensive review, he said, would enable participants to make improvements in performance, fine-tune implementation, and help with planning.

He noted that the seeds of the SBIR program had been planted nearly 25 years before, when NSF initiated a small business innovation pilot program. He introduced two of the pioneers of that effort, Roland Tibbets and Richard Coryell, who were among the participants. He said that the program had started as an idea, in a natural way, when grantees asked to do something and an agency program officer had the alertness to respond to that request.

## A Common Focus on Innovation

He said that the goals of the SBIR program and the NSF dovetailed nicely, because both entities focused on innovation. He described the vision of the NSF as enabling the nation's future through discovery, learning, and innovation. Ten years ago, he said, that vision emphasized discovery. Since then, three objectives had become steadily more important: learning; the integration of research and education; and innovation.

The three strategic goals under this vision of research, education, and innovation were referred to simply as "people, ideas, and tools"—or, more fully expressed, to develop a world-class science and engineering workforce; to foster discovery at the frontiers of knowledge; and to develop the tools to get the job done. "People, ideas, and tools," he said. "It's as simple as that." To accomplish each of those missions, he said, involved three strategic thrusts: building intellectual capital, integrating research and education, and promoting partnerships.

## How SBIR Fits NSF's Strategic Vision

He characterized the SBIR as an important partnership. He said, "It isn't difficult to see that the SBIR fits NSF's strategic vision to a 'T'." NSF invested approximately $85 million in the program each year, and the SBIR portfolio spanned nearly every directorate: engineering, bioscience, the physical and mathematical sciences, information and communication science, and even research and education itself. Because the SBIR team planned and coordinated the program's investments, the majority of these NSF grants met the needs of other agencies as well as the goals of NSF.

He said that the SBIR filled a significant need that was not addressed by any other program. The NSF's primary mission was to support basic studies at the frontier of knowledge, but at the same time, the agency was responsible for producing results that are useful to the taxpayers. The SBIR produced many practical outcomes for the agency, helping to broaden its mission toward results that were clearly visible in the marketplace. It also addressed the Government Performance and Results Act, which required all federal agencies to describe the output and outcomes of their investments.

## Understanding SBIR in the Context of Innovation

He then said that while his colleagues had provided considerable detail, he now wanted to take a "long view of the SBIR program." He said this would be a collective view, because he talked frequently with colleagues in other agencies about the program. In many ways, he said, the program's distinctive role could be best understood in terms of large-scale transformations taking place in the nation's research and innovation enterprise. These transformations had opened new frontiers of knowledge, changed the process of research and innovation, and increased the complexity of science, engineering, and technological development. The "tools" issue for NSF was one example of rising complexity: who is going to build the cyber-infrastructure that will be needed in the future? Research is being done differently, he said, and new techniques had opened up new frontiers of knowledge and technological development, with a big impact on SBIR. The pace of discovery and innovation had accelerated and competition had expanded, and to evaluate SBIR properly required understanding this rapidly evolving context. "This is not the stream we were swimming in the past," he said. "It's a new stream. And we hope as it's being evaluated that we take this into account."

The SBIR study, he said, could be a "revolutionary chart of the new paths we will follow in the twenty-first century." Over the past decade, change had transformed institutions and forced business, research, and education into new directions. One source of this transformation had been the extraordinary outpouring of new knowledge. New knowledge was the result of advances in science and engineering, and was now a key force driving technological innovation. Innovation in turn created new jobs and wealth, spawned new industries, and grew economies.

## The Transition from Labor to Knowledge

He emphasized the importance of thinking about innovation during the study. The NSF distinguished between innovation and productivity, in the following sense. Productivity was using new knowledge and applying it to things we know how to do—i.e., doing more with less. Innovation was using new knowledge to do things that are new and different, and creating new enterprises. The SBIR was one mechanism to create new enterprises, new jobs, and new wealth, all of which help to expand the economy. We once thought of productivity in terms of work or labor, he said, but now we must think of it increasingly in terms of knowledge and the activities of knowledge workers. Economists were only beginning to learn how to measure productivity in the "knowledge era." Traditionally, we had used a 200-year-old construct to do this, and this was changing.

This transition from labor to knowledge, he said, is an important part of the SBIR program. The development from knowledge to innovation to commercialization is happening at increasing speeds. "It's no wonder," he said, "that the capacity to create and use new knowledge is seen in both the private and public sectors as the best path to economic prosperity and a higher quality of life." This process was once seen as a simple, though protracted, linear progression from research to development to market. That is no longer the case. Today, research and development can drive technological innovation, but it can also happen in the reverse direction. The high level of technological innovation under the SBIR program often drives research at the frontier. True innovation can spur the search for new knowledge, and create the context in which the next generation of research identifies new frontiers.

### Disciplinary Barriers Drop Away

A driving force in these transformations, he said, had been the revolution in information and communication technology. Genomics and the biotechnology industry were one example; the budding field of nanotechnology was likely to be another, where for the first time scientists had the ability to investigate highly complex phenomena. Several decades previously the frontier of science and engineering was divided into disciplines, because there were no tools capable of crossing disciplinary boundaries. Today, researchers could not choose to stay within a single discipline; they were more or less compelled to work in an interdisciplinary fashion. Nor could they choose to work only in basic research or applied research; practical improvements in technologies from drug delivery systems to renewable energy sources were driving the acquisition of new knowledge in new directions. "There's a new system evolving here," he said. "It's not theory versus practice, or basic versus applied. The government is spending an awful lot of money across a number of agencies, and we've got to do something big with it."

For example, new information and communication (ICT) tools had raised the bar of competition worldwide and accelerated the pace of change. The capacity to create and employ knowledge resided in an ever-growing, globally-linked community. New knowledge was accessible in more countries throughout the world, at nearly instantaneous speeds. The Massachusetts Institute of Technology, and other institutions, were making its courses available without cost on the Web. He described a conversation with the Minister of Science from New Zealand, who wanted to sell more products to the United States. His country was planning to do so by training excellent scientists and forming an SBIR-like program to move products more effectively into the United States, the world's largest market.

### The Need for Working in Partnership

Such changes, said Dr. Bordogna, had contributed to a blossoming of partnerships designed to facilitate the innovation process. Multidisciplinary research had brought together teams of researchers, and competition had spurred new alliances among business enterprises. Most important, collaboration among universities, businesses, and governments was thriving. The federal government, partly through the SBIR program, had provided strong leadership. For well over a decade, it had advocated public-private partnerships in federal R&D, and had begun to see genuine working arrangements with significant results. It was understood that discovery and innovation rarely happens without partnerships, because they bring to the table participants with diverse expertise, resources, and perspectives.

As products, processes, problems, and solutions increase in complexity, the need for a diversity of partners would grow as well. Partnerships would become more inclusive, as would the aims of the SBIR program. Collaboration among academia, business, labor, and industry is a powerful way to ensure a two-way road between the research laboratory, wherever it is located, and the world of commerce. Corporations and universities were having to reinvent themselves to remain innovative, and government partnerships had been reshaped as well.

### Reaping the Harvest of Technology

The SBIR program, and its close cousin the STTR program, had also evolved. The SBIR program arose from a need to allow small businesses to develop their own capabilities for innovation and to speed commercialization of new technologies. Reaping the harvest of innovation is central to our future and a revolutionary idea. It was well understood that universities and their scientists and engineers are critical resources for the country. They were poised to contribute to economic development in the twenty-first century much as agriculture and early industries did in the twentieth century. The same was true of entrepreneurs and small businesses, which make critical contributions to economic development by bringing technology from risky innovations to the commercial market.

The SBIR program had matured, he said, producing many successes and stimulating an unprecedented level of collaboration and important linkages. This maturation had required new levels of trust and collaboration between federal agencies and, in the end, led to a productive team that had turned the SBIR team into an integrated national program.

Whether we welcomed it or not, he concluded, the outpouring of new knowledge and the pace of technological change were unlikely to lessen soon. "We haven't seen the end of the information revolution," he said; "we are just beginning to feel the impact of the biological revolution. The biggest part of SBIR is to handle new technology yet unimagined. Part of building a continuum of success is to look at the SBIR comprehensively as a program that's going to do the nation's work."

## DISCUSSANTS

### *Gregory H. Olsen*
### *Sensors Unlimited*

Dr. Olsen opened his talk by saying he had been able to leverage SBIR awards into two successful companies, and had started a third SBIR company a week and a half previously. "The bottom line," he said, "is that the SBIR system really works. I know of four companies in the Princeton, New Jersey area that are highly successful and used SBIR to leverage themselves. I love it and think it works as a venture capital system."

### The Growth of an SBIR Company

He said that his small-business career had begun in late 1983, when he was a research scientist at RCA Laboratories. He had an idea for forming a new company making fiber optic detectors, and with several colleagues and some venture capital was able to start the firm EPITAXX. In the mid-1980s the company won its first SBIR contract, from the National Science Foundation. By 1989 it had grown to 55 employees and was earning a profit on $5 million in revenues. In 1990, the Japanese firm Nippon Sheet Glass bought his company for $12 million, and in 1999 it was acquired by JDS Uniphase for $400 million, near the height of the telecom boom.

In 1999 Dr. Olsen left EPITAXX and started Sensors Unlimited, which focused on infrared sensing (see Figure 6). The firm was self-financed and won several SBIR contracts, working closely with the Sarnoff laboratory and Princeton University. In the beginning, about 80 percent of the firm's revenues came from R&D contracts; as business grew, the proportion of R&D revenues decreased to 30 percent by 1999. In 1998, with the rapid growth of the Internet, Lucent and other companies discovered they could use infrared sensors in their optical networks and the company grew rapidly. By mid-2000 Sensors Unlimited was able to earn a $5 million profit on $25 million in revenue. It was then acquired by Finisar for the price of about $700 million, which, Dr. Olsen recalled, "was kind of like hitting the lottery." After that, the sales of Finisar, along with the rest of the telecom sector, plunged, and the employees bought back the original Sensors Unlimited company for $6.1 million in October 2002. "Now we have a company that is losing money," he said, "and we are trying to get it going again."

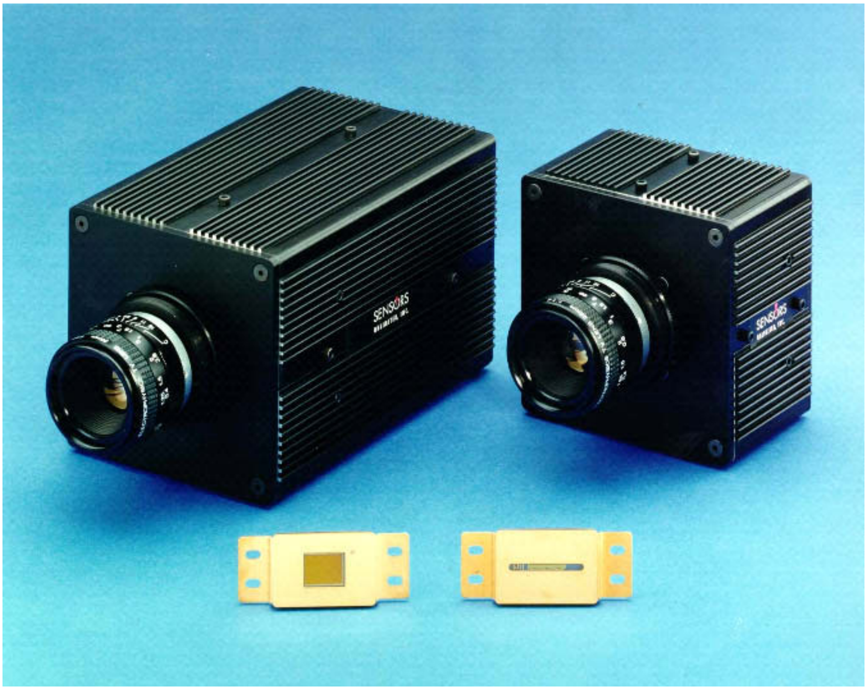


FIGURE 6 Sensors Unlimited, Inc.

### Paying Back the Investment

He said that in his opinion, both companies were success stories. Over 90 percent of the revenues of EPITAXX came from commercial sales at the time it was sold; when Sensors Unlimited was sold, about 85 percent of revenues were commercial. In the larger context of the value of the SBIR program, it was significant that the sale of both companies generated capital gains and state taxes of "many millions of dollars" that effectively paid back "many times over" what the companies had received from the government. "That is a very satisfying thing to us," said Dr. Olsen, "and a great sign to the SBIR system that it works extremely well."

He then offered a more detailed description of Sensors Unlimited, which started as an infrared camera company, using focal plane arrays. The camera can be used for such tasks as sensing ice on aircraft; NASA used it to monitor tanks of liquid oxygen, which tends to condense and freeze. The company was then attempting to shrink the sensor to a small enough size to fit directly on the wings of flight vehicles, and had applied for an SBIR grant to develop that ability. Motorola and Intel used the camera to locate defects on semiconductor wafers. It could also be used to locate minute changes in works of art. For example, it had detected changes made by Renoir on his famous painting "Luncheon of the Boating Party," now in the Phillips Collection in Washington. Finally, the camera had military applications, which was the company's primary market during the telecommunications slump. It could distinguish camouflage clothing from vegetation, and provided more sensitive detection at night than night-vision goggles.

## SBIR Fosters Partnerships

The SBIR system had also allowed the company to form partnerships with a variety of public and private entities, including Princeton University, Sarnoff Corporation, Rutgers University, New Jersey Institute of Technology, Rockwell International Science Center, and the New Jersey Technology Council (see Table 3). "I think one of the most valuable things you can do in this program is to network with other organizations," he said, "and SBIR allows you to do that."

From the point of view of a small company, he called the SBIR a "great source of venture capital," for several reasons. First, venture capital was much more difficult to find than it had been several years ago. Second, an SBIR grant allowed the company to preserve its capital instead of giving up equity. From the point of view of the nation, the tax revenues of a successful company pay the government back for its investment with a high return.

Dr. Olsen described some of the pre-commercial work Sensors Unlimited had done for its SBIR sponsors:

- For NASA, the company made photo arrays and solar cells;
- For DARPA, it produced semiconductor chips for its infrared camera;
- For NSF, it made an avalanche photo diode, which is a detector with an amplifier;
- For DoD, it produced technology for three-dimensional night-vision imaging.

The company had been able to take some of these technologies beyond the research stage and commercialize them. Some examples:

TABLE 3 Sensor Unlimited's Partnerships

| Partner |
|---|
| Princeton University (Steve Forrest) |
| Sarnoff Corporation |
| Rutgers University |
| New Jersey Institute of Technology (NJIT) |
| Rockwell International Science Center |
| New Jersey Technology Council (NJTC) |

- Research for NASA led to infrared sensing products for aerospace and defense companies.
- When the telecom boom gathered momentum in 1998, the company's infrared sensing products were sold to Lucent, Nortel, JDS Uniphase, and other companies. Sales quickly doubled, then redoubled by 2000.

**Benefits to Education and the Economy**

Dr. Olsen said that the SBIR program had produced results beyond forming companies and making sales. In this case, he said he believed that his company had produced "the best technology in the world," which would then be developed for additional uses of benefit to the country. In addition, the grant provided a good way to interact with universities. He was able to hire students from his alma mater, the University of Virginia, and share programs with the university. The acquisition by JDS Uniphase allowed him to donate money for a new materials science building on campus.

He said that the buyback of Sensors Unlimited from Finisar had been amiable, and beneficial for both parties. Finisar was able to shed expenses, reduce size, and work toward profitability, while his company was able to focus on aerospace and military markets and move toward profitability more quickly.

He concluded that "SBIR does work," and said he hoped that his own case was "just one of many examples that prove that." It is not just a one-way system, he said, but "a way to pay government back. It allows universities and companies to interact. It's a great thing for the country."

*Christina Gabriel*
*Carnegie Mellon University*

Dr. Gabriel said she had spent about 5 years at the National Science Foundation engineering directorate, where the SBIR program is located, where she worked with the founders of the program, including symposium attendees Roland Tibbets and Richard Coryell. Her current job as Vice Provost at Carnegie Mellon University, in Pittsburgh, includes research, technology transfer, and regional economic development, the last of which was "what our region wants from us as a university."

**Universities and Regional Development**

The city of Pittsburgh, she said, "was launched and built by the entrepreneurs of a hundred years ago, notably Andrew Carnegie." But the collapse of the U.S. steel industry several decades previously had removed much of the city's industrial base. Since then the city had become much more livable, with clean air and water, but people worried about the source of future jobs. The USX Tower, once filled with U.S. Steel employees, then held almost no U.S. Steel employees. Instead, she said, everyone was looking to CMU, the strong technical center, and the University of Pittsburgh, the strong medical center, and other schools in the region to produce new businesses. “And that’s a role universities haven’t been accustomed to playing.”

Nor, she said, was it a role anticipated when the SBIR program began. She referred to earlier discussions of disruptive technologies and creative destruction, and said that the SBIR program itself was a “disruptive innovation”—a different way of approaching program management. NSF had given Dr. Tibbets and others the flexibility to do this “relatively revolutionary thing.”

## Beyond the Linear Model

She also continued the discussion of the “linear model” of R&D, which assumed that innovation proceeded in one direction, from research to development to manufacturing. She said that when she worked at Bell Laboratories, the management of the company implicitly believed in the linear model. “It was never considered very important 20 years ago for the researchers to talk to the rest of the company,” she said. “My personal opinion is that that’s why we don’t have Bell Labs and the original research labs any more. Those big companies never understood how to connect their research to the rest of the company in a productive way. So small businesses and Japanese companies and others outside the labs were the ones who commercialized almost all the innovations that came out of our labs.”

However, she thought it was remarkable that the SBIR, even though it was founded on a faulty model of that era, continues to serve the nation in an effective way, “even though the entire world of technology has gone through six or seven revolutions since the program was started.” She suggested that even though the program was encumbered by many political and technical agendas, it was able to maintain “incredible flexibility.” Because it was a fairly small program, each agency could see how the SBIR promoted national objectives and, simultaneously, how the program could fit into the sponsoring agency’s particular mission.

## Questions for the Panel

She suggested that the members of the study panel listen carefully to what the agencies had learned in the past 20 years and use that history to create useful results. She acknowledged that the steering committee, on which she served, was “really struggling to figure out how this program can contribute even better to the national innovation system,” especially as a program that required teamwork among all the agencies.

She closed with a series of related questions:

- Should the panel search for some new "creatively destructive program innovations," or should they just seek to simplify the program operationally and leave as much of the original flexibility as possible in the system?
- How could the program be better linked to the national innovation system so as to help areas such as Pittsburgh promote regional economic development? Could regional clusters of small businesses, with particular technologies, be promoted by a federal program whose agenda concerned innovation in its broadest sense on a national scale?
- Finally, how could this program partner with other efforts so as to strengthen the country's overall innovation system?

*Robin Gaster*
*North Atlantic Research*

Dr. Gaster said that he had come to this meeting as a long-time researcher who had worked on many different projects, and yet he found this one "a difficult, complex, and intimidating one." It was as difficult as asking "what is success," he said, and how do you measure it. There were multiple dimensions to the answer that varied by agency, and measuring and finding the correct indicators "is a huge challenge." Dr. Gaster said that as a researcher he felt "a magnetic attraction to big-think issues" such as this one, but conceded that "you can end up with little to show for your work."

**Start by Talking to the Agencies**

The second alternative, he said, was to think about "how you can do the right research, and focus your project on the right level of analysis for the project." He said he had heard today that the evaluation project had to be focused on finding answers needed by program managers, by Congress, and by program participants. He advised starting the analysis from an empirical perspective by talking to the agencies and the participants, and learning what questions were most significant for them. "Then we will know which of the 'big-think' issues to focus on. Not all the micro issues require macro thinking."

As an example, he recounted a conversation with John Williams of the U.S. Navy SBIR program. He asked him whether he would want to improve his SBIR program through "more singles, more home runs, or fewer strikeouts." Mr. Williams had said he would want more "singles"—i.e., small successes. He said that another agency, perhaps the NSF, might want more "home runs"—big successes. Beyond this general impression, he said, was the desired frequency of success. An SBIR manager might decide that if 40 percent of the agency's Phase II projects were successful, the program was not taking enough risks. Another, with a longer time horizon like for NSF, might decide that a 10 percent success level was better. He said that the study panel should discuss such questions with the agencies.

He ended his comments by noting that the study panel would need a lot of help to address the "huge field of interesting problems ahead of us." He suggested that the place to start was "right at the bottom, with the people who are actually in the trenches."

*David Goldston*
*House Science Committee*

Dr. Goldston said that for the Congress, a fundamental question was whether the SBIR program could bring entities into the research program that would not otherwise be there.

### Two Fundamental Questions to Ask

He noted Dr. Olsen's comment that the SBIR has value as an alternative to a venture capital fund. But he said that "the basic question is how can we increase the pool we can draw from, and is that pool changing; are we getting different kinds of research as a result? If we are bringing in new entities, would their output be the same without the SBIR?"

Even if research output is the same with the SBIR as without it, one might still want to encourage small companies, for the jobs they generate and the regional economic development they promote, he said. There are also narrower questions about the program, he said, such as steps taken to discourage companies that are "SBIR mills" and the issue of geographic distribution of awards. He noted, however, that these narrower questions should not obscure the larger questions about the overall impact of the SBIR program. Acknowledging the difficulty of the assessment, he nonetheless stressed the need for the review, observing that "those are the questions that we who look at the program every few years have to grapple with."

## DISCUSSION

### Improving Program Administration

John Williams of the U.S. Navy said that his own evaluations had shown that the SBIR program is successful for the Navy. To spend additional time to quantify that success with metrics whose value is uncertain might not be cost-effective, he suggested. The measurements would likely repeat the conclusion that it is a good program.

However, he said, program managers such as himself did want to know many things that were not reflected in quantitative studies, such as the value of outreach to the states. Some states were good at using the SBIR program, while others needed assistance. "What we really want to find out is how we can make the companies better," he said. "What assistance do they need?"

For example, his office used a commercialization program borrowed from the Department of Energy that coached firms during Phase II on good business practices—an area where many of them were weak. He said he would like to know how much value the program has, how his office could use it better, and what steps could be taken on a national level. The Navy also worked hard to "have the acquisition program lead the projects," whereas the Army "does it more at the lab level. I'm not sure which one works better." He said that a major benefit of the study would be to evaluate such different kinds of management and determine the advantages of each.

## The Impact of SBIR

Richard Coryell noted that participants had named three overriding objectives of the SBIR program: (1) to serve agency missions, (2) to speed the commercialization of technology, and (3) to stimulate innovation and creativity. He asked Dr. Bordogna what the absence of the SBIR might mean for each of those three objectives.

Dr. Bordogna first said he agreed with Dr. Goldston's thesis that the study panel should first look at the "big picture." The NSF's thesis, he said, was that the panel's goal should be to anticipate how the SBIR could best function in the future, not today. The SBIR must change along with changes in technology, ways of doing business, and ways of doing research.

With regard to Mr. Coryell's question about the effect of the SBIR on the three objectives, he answered, "If there were no SBIR, these things would probably be going on, but not in as robust a way." He suggested that there was no "algorithmic way" of achieving all the objectives of SBIR and the NSF. But he said that the SBIR supported them all at the same time it built the science and technology capacity of the nation. He cited a Japanese philosophy of capacity building: "They don't worry too much about succeeding in every program. Their philosophy is that even if we fail at something, we've built up the workforce to do the next thing." The important task for the U.S. government, he said, was to invest in people's capacity to "do the next thing. And the endpoint is growing the capacity of the country—strengthening the workforce."

## SBIR and Venture Capital

Steven Wallach of Penney and Edmonds revisited Dr. Goldston's question about the extent to which the activities of the private sector could substitute for the SBIR program. He asked the panel members why venture capitalists were not doing what SBIR was doing to support startup companies.

David Goldston said that venture capital companies had both a positive and negative effect on startups. Three years ago, when the economy was booming, venture capitalists competed with one another to invest millions of dollars in high-technology businesses. Today, he said, the situation was reversed; venture capitalists felt saddled with once-booming small companies, and did not want to invest more money until the economy picked up. At such times, companies that needed financing were more likely to turn to the SBIR program.

Steven Wallach followed up by asking Dr. Olsen about his own case, in which the return on the government investment in Sensors Unlimited was very high. Why would the venture capitalist of today not think that the chance of a high return justified the risk of an investment in similar companies?

Gregory Olsen answered that one problem in matching small companies with venture capital funding is "deal size." The average deal size for venture capitalists, he said, was now more than $7 million and rising. The SBIR program made grants of less than one million dollars, so that most companies are "way below the radar" of the venture capital firms. He said he had recently found that to be true when trying to raise funds for his own company, despite his good record.

### The University as a Nexus of Economic Growth

Charles Wessner questioned Dr. Bordogna regarding Dr. Gabriel's comments about the importance of the university as a nexus of economic growth. "Do you think the current configuration of the SBIR is well suited for bringing ideas out of the universities and into the marketplace?" he asked. "Do you think we should make some changes in the NSF SBIR program that might make it better suited to your mission?"

Gregory Olsen answered first, saying that the SBIR had led him into intensive interaction with the university community. "I think that's one of the great things about SBIR." He said that he had often been asked for the names of people at a university to collaborate with. He had advised people not to "force it," but simply to get to know the professor or student working on equipment or an area of common interest, and get to know them. "I'm not sure there's anything more you need to do."

David Goldston pursued this topic further, asking Dr. Olsen how SBIR helped to facilitate interactions with university people. "Was it just in having money that you could bring to a professor's project," he asked, "or did the program bring a 'good housekeeping seal of approval'?"

Gregory Olsen said it had been "all of the above." He had worked with Dr. Steven Forrest at Princeton University, whose field is optoelectronics. Dr. Forrest had arrived at Princeton around the same time Dr. Olsen started Sensors Unlimited. Dr. Forrest had equipment useful to both efforts, but no engineers to install it or to train his students; Dr. Olsen had engineers but no equipment. So the two collaborated and "it was an opportunity made in heaven." The collaboration was fueled also by the strong desire in universities to transfer their technology to the commercial market. The SBIR provides a vehicle to do that.

Dr. Gabriel added the example of a CMU professor to whom the department gave a 49 percent leave of absence. The reason was that the professor had just won an SBIR grant that required him to spend at least 51 percent of his time at the company. He became the CEO of the company while holding a grant from a federal agency to continue working with his students, so he worked essentially half-time in both places. Dr. Bordogna agreed that any such arrangements that supported partnerships between academia, industry, and the federal government should be encouraged.

## Deal Size in Venture Capital Investments

Carl Ray of the NASA SBIR program asked about the "deal size" as the limiting factor for the involvement of venture capital. He wanted to know whether venture capital firms might fund SBIR-type companies on a pool basis to reduce the risk. Michael Borrus of the Petkevich Group said that it was difficult to answer any question about trends because the changes in venture capital activities over the past 5 to 7 years had been so dramatic.

*Panel VI* ——————————————————

# Roundtable Discussion

Moderator:
*Jacques S. Gansler*
*University of Maryland*

Dr. Gansler said that a great range of viewpoints had been expressed by symposium participants, which was to be expected. "This is the kickoff session, not the final session, and our challenge is to address all of these issues."

He highlighted several of those points, beginning with the need to link federal and state initiatives. He also expressed the desirability that some of the smaller SBIR agencies participate in the study, at least in terms of input and recommendations. "The very worst thing," he said, "would be to end up with recommendations that have an adverse effect on the smaller agencies." He said that the focus would necessarily be on the five largest agencies, which receive 96 percent of the SBIR dollars, but noted that the small ones may have some good practices to learn about "because they may be more nimble and faster to move."

He turned to the Department of Energy's discussion of proprietary data. Accessing this data, he said was "an issue we clearly need to address. We need to get that data from the agencies. I see no reason why we cannot protect it—either by not identifying the company or by dealing with aggregate data. In past studies that has not been a problem."

### Pay Attention to Agency Differences

He said that a number of people had asked why this study would focus on individual agencies. "It strikes me," he answered, "that each of the agency missions is so dramatically different that we have to be aiding the mission of each agency. If we don't pay attention to that, we are missing the number one priority, which is to be sure these resources are being spent with regard to mission needs."

To this end, he said, subcommittees of the steering group were planned for each agency. At the same time, it would be important for all members to have an overview of all the agencies. "The study panel and steering committee also need 'cross-pollination'," he said, "and in the overall activity we need to be able to see the big picture and its effectiveness and value to the nation." He said the panel would look for best practices to draw on, pointing at the effectiveness of DoE in doing "so much in three months."

He concluded that "this is going to require a great deal of input from a lot of people," and that it was a "challenging kind of mission, and always has been—how you demonstrate the value of an R&D project." He said that it was never possible to do so with precision, but it was possible at least to design better approaches.

*Jon Baron*
*Coalition for Evidence-Based Policy*

Mr. Baron noted that the symposium had heard examples of "the program at its best, of technology from companies whose SBIR-developed products have contributed to our lives in important ways." He referred to the cases of Martek Biosciences and Advanced Technology Materials. Technology developed by the latter company, he said, made it possible to transport toxic gases safely and avoid the need to evacuate whole communities should a transport truck crash.

**Needed: Help with Commercialization**

He said that a company needed to have two types of skills to develop such life-improving innovations. The first is technical expertise—that is, the ability to develop a sound technical idea and to carry out high-quality research. The other skill is entrepreneurship, the ability to translate a good idea into a prototype, to describe its commercial value in a compelling way to potential investors or customers, and ultimately to convert it into a commercially-successful product sold to commercial or military customers. These two steps required different skills, he said. Government, through the SBIR program, was good at evaluating the first skill—technical capability. But the government was not as good at identifying companies with the second skill—commercialization, and many agencies did not even attempt to find and fund true entrepreneurs who have that skill.

Addressing the importance of entrepreneurial talent, he said that a typical venture capital firm preferred to bet on first-rate management than on first-rate technology. This approach is substantially different from that of a government agency, he said. Instead of expecting this function from government, he suggested, it might be more effective to develop proxies or certain techniques that add this function. As examples he mentioned further investigation of the NSF

"Phase II-B" and the DoD Fast Track programs, which encourage independent third-party investors to contribute matching cash at the stage of commercialization. He suggested that the panel might investigate whether the presence of such outside support should be used as a criterion for choosing candidates for Phase II or for a larger Phase II award.

Another way to focus funding on entrepreneurs might be to weigh a company's commercialization track record; it might have won numerous SBIR awards, but what products or sales had come out of that? One important contribution of the study panel, he concluded, could be to suggest ways for government to improve the SBIR program and focus its funding more directly on companies most likely to make large contributions to the agency and the economy.

### *Paula E. Stephan*
### *Georgia State University*

Dr. Stephan said that her comments about the SBIR program stem from her interest in what leads scientists and engineers to be productive and the role that federal funding plays in fostering productivity.

First, she said, her work leads her to expect the benefits of the SBIR program to be highly skewed and distributed unevenly. When scientists and engineers are studied at the individual level, she said, productivity is highly skewed in terms of publications, citations to publications, patents, and citations to patents. This a well-known characteristic of discovery. We also find that productivity distributions are highly skewed at the institutional level, as well. The National Science Foundation's Science and Engineering Indicators show that a handful of universities hold the lion's share of patents and royalties and have a lion's share of R&D expenditures. ISI data indicate that publications are highly skewed across universities as well. In the for-profit sector, we know that many R&D projects are initiated, but few of them actually reach commercialization. The "extreme" case is seen in drug discovery, where the odds of a product reaching the market are exceptionally low. Thus, we would expect the distribution of discovery and innovation to be skewed in the SBIR program as well, and it is important to remember this during program evaluation.

A second point to remember during the study, she said, is that "today's dead end often can be a key to tomorrow's success, or what is seen as a failure today can be seen as a success tomorrow." She referred to the example given by Dr. Moore in his experience with optoelectronics, where a seeming dead end later opened up the way to producing a highly profitable technology.[23]

Finally, she reinforced the importance of a point made by several speakers—that human resources and training opportunities are critical outcomes of the SBIR program, just as they are of other federal investments in discovery.

[23]See opening comments by Duncan Moore in Panel III of the Proceedings.

*Michael Borrus*
*The Petkevich Group, LLC*

Mr. Borrus said he wanted to list three challenges that would be faced by the committee.

### Defining Meaningful Metrics

The first was the challenge of defining meaningful metrics for evaluating the SBIR program, especially metrics that allow comparative evaluation of different agencies and their programs. This, he suggested, would be difficult but not impossible. He said that the panel had heard useful suggestions for metrics that allow a fair evaluation of success. But he added that that the metrics used would depend on how the problem was defined. For example, the success of Martek Biosciences had stimulated the desire to find more entrepreneurs like Mr. Linsert, who were capable of creating and leading a successful company. While good leaders are one source of success, an alternative and equally valid route was to catalyze small businesses that are already successful at developing one product but lack the resources to enter a new market. "We need to be sensitive to what we are excluding by the measures we use," he said, "as well as to what we are including."

### Learning from other Agencies

A second challenge was to improve program performance as a whole. "There's a tremendous amount to be learned from what each agency has to teach the others, " he said, seconding Dr. Gansler's assertion. He said that NASA, for example, had done strong work with technical and commercial assistance; DoD with self-assessment; DoE with criteria to evaluate Phase III and to speed up the process as a whole; and NIH in using NIAID's infrastructure to support clinical outcomes. "I hold a somewhat heretical view," he said, "that the best ways to improve the program are more likely to come from what's already present and working in the program than from external benchmarks or insights we might bring from outside the program."

### Remaining Relevant

The third challenge, he said, was a contextual challenge: where and how does SBIR fit (1) in the context of federal technology programs overall, and (2) in the larger federal effort to have a significant impact on the long-run economic performance of the United States. He closed by listing a range of questions opened up by that contextual issue:

- In evaluating what the program is, are we missing opportunities for what it could be?
- Can there be partnerships or trans-agency collaboration in areas like biodefense?
- Are there opportunities for which SBIR is uniquely suited but under-exploited?
- In emphasizing SBIR, could we be unintentionally limiting small businesses' ability to make other positive impacts on federal agencies and their missions?

*Linda F. Powers*
*Toucan Capital Corporation*

Ms. Powers said that her perspective was a "pure, unadulterated, investor capitalist viewpoint." While that perspective was perhaps unusual, she said, it fit with the SBIR program.

### Concentrating on the "Valley of Death"

Her fund was one of the largest and only funds that invested in technology companies at the stage where research was coming out of the lab and into the beginnings of commercialization. That meant, she said, that her company concentrated on what was referred to as the "valley of death"—the stage between the development and marketing of a product. "It's a very fragile stage," she said, "where companies are going to be set on a path of success or non-success."

From the viewpoint of her firm, she said that the choice of metrics was crucial. She preferred to evaluate a program not by how many papers or patents emerged, but by true commercialization, which is indicated by sales. The reason for emphasizing sales, she said, was that it was a reliable measure of the utility of an innovation in meeting an unmet need. Sales were also simple and easy to measure.

### Sales as a Reliable Metric

Her next comment was about company reporting. She said it was appropriate to be sensitive about redundancy and work burdens, but that reporting was essential—knowing the outcome of a project and being able to measure it. Here again she advocated a simple approach: was the company still alive and making any sales, and was any portion of its product mix related to a product or process specified in the SBIR grant? This approach was not perfect or scientific, she said, but "sort of meets the 80 percent rule of significance" and indicated whether the SBIR had something to do with a company's success today.

She noted the comment that one size does not fit all, and that this study should appreciate and focus on the differences among agencies. The time frame for an NIH product was different from that of a DoD product, she said, and the posture of a small business in a defense contract was different from that of a small biotech firm vis-à-vis "big pharma." The defense contractor was expected to meet specifications, while the biotech firm was expected to innovate.

### Evaluating Disruptive Technologies

She turned to "what the program could be," and commended the earlier discussion about disruptive technologies. "But then we didn't talk much about that afterward," she said, adding that if the reviewers really wanted disruptive technologies, "we have to re-look at some operational aspects for at least a small slice of the program." She suggested that peer reviewers who were established, prominent people in a technical field might not be the best people to evaluate disruptive technologies or paradigm shifts.

Next she suggested that more interaction between the investor community and the SBIR program was "long overdue." The investor community, she said, attaches validation to programs that are selected for grants, but only a few parts of agency programs, such as DoD's Fast Track, attach validation to what private investors are funding. "I'd like to see more of that," she said. "I'd like to see business people on the review committees, more venture people on evaluation panels, and generally more direct contact and involvement with the investor community."

### Small Companies Need Consistent Funding

As her last observation, she encouraged the panel to look at ways to make the program more effective in regard to commercialization per se. Time cycles, she said, are vital. The example of the DoE evaluating its program in three months is excellent, she said, but the value of an annual evaluation to investors is limited. "It is much more important for grants to be done through the year on a rolling basis, rather than quickly on a far-apart basis," she said. "The reason so many companies die trying to get across the valley of death is that it is so wide and takes companies so long to cross it." A lot of that time is spent waiting for grant cycles and other agency procedures, she said. In the biotech world, each day that passes costs a company $3 to 5 million to develop a major product; for a small biotech firm, the product cost is about $1 million a day. Venture capital companies have to consider costs constantly. A Phase II SBIR award of $750 thousand is expected to last for 2 years, but such grants, she said, are too small to support a company during delays. "Even in an early stage," she said, "companies are burning that much per month."

Finally, she said, intellectual property is "absolutely key"—a fact that is not widely appreciated. She praised the recommendation by the Department of Commerce that universities should start receiving IP rights. That "would be best from an investor's perspective," she concluded, while representing the kinds of practicalities that investors need to see.

*James Turner*
*House Science Committee*

Mr. Turner said he had only a few points to add to what Ms. Powers had said. First, he urged the study panel to take full advantage of its opportunity to do a thorough evaluation of the SBIR program. It is a rare luxury, he said, to spend two-and-a-half or three years on a report, unrestrained "by quarterly reports, annual appropriations, or a two-year election cycle. You have time actually to think about something, and I hope you'll take the time to do it right." He urged the panel to come up with a metric that could be used both by agency managers as the basis for operational improvements and by the Congress for legislative improvements.

**Looking at all the Agencies**

Second, he reaffirmed the importance of looking at all of the agencies, including those with relatively small SBIR programs. He said he had learned from a representative of the Department of Agriculture, for example, that its distribution of grants should be different from those of the DoD or NIH; for agriculture, it is very important that the SBIR program has a strong rural component. He also reminded the panel members that measures to solve problems in the largest agencies might be effective there, but turn out to distort or harm the programs of smaller agencies. "A cold in the Department of Defense can be pneumonia for the Departments of Commerce and Education," he said. "So there is a reason to look at all of them in some way."

He concluded by pointing out that the symposium had drawn excellent attendance from representatives of every sector participating in the SBIR program, including congressional staff, agency representatives, and the small business community. "You're lucky to have a constituency that really cares," he told the panel. "I think you can count on them to be supportive of this study and to participate as it goes along."

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Dr. Gansler closed the symposium by thanking the panel members and participants for taking part, and by expressing optimism about the success of the meetings to come.

# III

# APPENDIXES

# Appendix A: Biographies of Speakers*

## DAVID B. AUDRETSCH

David B. Audretsch is the Ameritech Chair of Economic Development and Director of the Institute for Development Strategies at Indiana University. He is also a Research Fellow of the Centre for Economic Policy Research (London). He was at the Wissenschaftszentrum Berlin fuer Sozialforschung in Berlin, Germany, a government funded research think tank, between 1984 and 1997, serving as its Acting Director from 1989 to 1991. In 1991, he became the Research Professor.

Dr. Audretsch's research has focused on the links between entrepreneurship, government policy, innovation, economic development, and global competitiveness. He has consulted with the World Bank, National Academy of Sciences, U.S. State Department, United States Federal Trade Commission, General Accounting Office and International Trade Commission as well as the United Nations, Commission of the European Union, the European Parliament, the OECD, as well as numerous private corporations, state governments, and a number of European Governments. He is a member of the Advisory Board to a number of international research and policy institutes, including the Zentrum fuer Europaeisch Wirtschaftsforschung (ZEW, Centre for Economic Research), Mannheim, the Hamburgisches Welt-Wirtschafts-Archiv (HWWA, Hamburg Institute of International Economics), and the American Institute for Contemporary German Studies (AICGS), Washington, D.C.

His research has been published in over one hundred scholarly articles in the leading academic journals. He has published 25 books including, *Innovation and*

*As of October 2002.

*Industry Evolution*, with MIT Press. He is founder and editor of the premier journal on small business and economic development, *Small Business Economics: An International Journal*. He was awarded the 2001 International Award for Entrepreneurship and Small Business Research by the Swedish Foundation for Small Business Research.

## GENE BANUCCI

Gene Banucci, a founder of Advanced Technology Materials, Inc., has served as Chief Executive Officer, Chairman of the Board, and as Director since 1986. At its inception, ATMI focused its core expertise on materials for Chemical Vapor Deposition (CVD) technology and has since developed a unique portfolio of leading-edge materials technologies for innovative packaging, productive delivery systems, accurate solid-state sensors, low-impact environmental equipment, and engineered services that are combined into materials solutions.

Before co-founding ATMI in 1986, Gene Banucci served as a Director for American Cyanamid's Chemical Research Division, where he directed more than 400 scientists and engineers in new product research and development for this $1 billion unit. He also created and directed Cyanamid's Discovery Research Department where he managed the creation of new specialty chemical and materials technologies, leading to new business ventures.

Dr. Banucci holds 21 issued U.S. patents and is an author of numerous published scientific articles. He is a founding member of the Connecticut Technology Council, a member of the Board of Directors of Precision Combustion, Inc., and a member of the Board of Trustees of Beloit College. He received his Ph.D. in organic chemistry from Wayne State University, and his B.A. in chemistry from Beloit College.

## JON BARON

Jon Baron is the Director of the Coalition for Evidence-Based Policy, a project launched under the sponsorship of the Council for Excellence in Government in September 2001 to promote government policymaking based on rigorous evidence of program effectiveness.

Before joining the Council, he served as the Executive Director of the Presidential Commission on Offsets in International Trade (2000-2001). In that position, he developed and built consensus for a major Commission report to Congress that was approved by the Director of the Office of Management and Budget, with the concurrence of all Commission members.

From 1995-2000, he was the Program Manager for the Defense Department's Small Business Innovation Research (SBIR) program, which provides over a half-billion dollars each year to small technology companies to develop new commercial/military technologies. In that position, he initiated and led major program reforms that greatly increased the effectiveness of the program in spawning successful new companies and technologies, according to an independent evaluation by the National Academy of Sciences. The reforms received the Vice President's Hammer Award for reinventing government and were recognized by Harvard University's Innovations Awards Program as one of the top government innovations in the United States.

From May 1993 to May 1994, he was a special assistant for dual-use technology policy in the Office of the Secretary of Defense. From 1989-1994, he served as counsel to the House of Representatives Committee on Small Business, where among other activities he initiated, led, and worked successfully to secure enactment of legislation establishing the federal Small Business Technology Transfer (STTR) program. The program funds cooperative R&D projects involving universities and small technology companies, and was recently reauthorized by Congress and expanded to $130 million per year.

Mr. Baron holds a law degree from Yale Law School, a Master's degree in public affairs from Princeton University, and a Bachelor of Arts degree in economics from Rice University.

## ROSCOE G. BARTLETT

Roscoe G. Bartlett considers himself a citizen-legislator, not a politician. Prior to his election to Congress, he pursued successful careers as a professor, research scientist and inventor, small business owner, and farmer. Still an active farmer and retired from teaching and building homes, he was first elected in 1992 to represent Maryland's Sixth District in the United States Congress. He has been reelected to each succeeding Congress, most recently in 2000, and is currently serving his fifth term.

In the 107th Congress, Bartlett serves as Chairman of the Energy Subcommittee of the Science Committee. He has also been named to chair the Panel on Morale, Welfare, and Recreation (MWR) of the Armed Services Committee. Due to his extensive work experience, he also serves on the Small Business Committee as its Vice Chairman. In addition to his Energy Subcommittee and MWR Panel chairmanships, Congressman Bartlett serves on several subcommittees and panels as well.

Roscoe and his wife Ellen have been married for more than 30 years. They have 10 children and 12 grandchildren. Because of his commitment to philanthropy and the importance of education as a tool for success, Bartlett donates a significant portion of his Congressional salary to scholarships for undergraduate students at the 10 colleges in the district.

Bartlett attended Columbia Union College where he majored in theology and biology and minored in chemistry with the intention of becoming a minister. Considered too young for the ministry after receiving his bachelor's degree at age 21, Bartlett was encouraged to attend graduate school at the University of Maryland at College Park. He studied anatomy, physiology, and zoology earning a Master's degree in physiology. Bartlett was then hired as a U-MD faculty member and taught anatomy, physiology, and zoology while simultaneously earning a Ph.D. in physiology.

Bartlett engaged in research in addition to teaching first as an instructor, and later as an Assistant Professor at Loma Linda University School of Medicine in California. He relocated to Howard University in Washington, D.C. as a professor of physiology and endocrinology at its Medical School. Bartlett left to pursue research full-time first at the National Institutes of Health (NIH) and then at the U.S. Navy's School of Aviation Medicine (U.S. NAMI) in Pensacola, Florida. While at U.S. NAMI, Bartlett invented a series of break-through respiratory support equipment. He holds the basic patents for rebreathing equipment that recycle the oxygen from exhaled air in closed systems. This technological advance extends oxygen supplies and makes them portable. Bartlett's inventions are critical components of the equipment that supplies oxygen to astronauts, pilots, and fire/rescue personnel.

In 1961, Bartlett returned to Maryland and to farming after purchasing a 145-acre dairy farm on the Monocacy River in Frederick County. While running his farm, he worked at the Johns Hopkins Applied Physics Laboratory (APL) as director of a new 30-member research group in Space Life Sciences. The group designed and conducted a series of pioneering research experiments that contributed to NASA's successful Apollo missions to land men on the moon and bring them back safely to earth.

Dr. Bartlett later joined IBM and worked there on numerous biomedical engineering projects. With IBM's assistance, he formed his own research and development company, Roscoe Bartlett and Associates. He also taught anatomy and physiology to nursing students at Frederick Community College. His company later diversified into land development and home construction. Over 10 years, his firm built more than 100 homes in Frederick County, many of them solar powered.

In 1999, the American Institute of Aeronautics and Astronautics (AIAA) awarded Dr. Bartlett its Jeffries Aerospace Medicine and Life Sciences Research Award. Recognizing the importance of scientific aeronautics and space discoveries to the field of medicine, the award was established in 1940 in honor of Dr. John Jeffries, the American physician who made the earliest recorded scientific observations from the air. The association to recognize outstanding career research accomplishments in aerospace medicine and space life sciences presents it annually.

Bartlett continues to raise sheep and goats on his farm and commutes the 50 miles to Washington, D.C. when Congress is in session.

## WILLIAM B. BONVILLIAN

William Bonvillian is the Legislative Director and Chief Counsel to Senator Joseph I. Lieberman (D-CT). Prior to his work on Capitol Hill, he was a partner at both the law firms of Jenner & Block as well as Brown & Roady. Early in his career, he served as the Deputy Assistant Secretary and Director of Congressional Affairs at the Department of Transportation.

His recent articles include, "Organizing Science and Technology for Homeland Security," in *Issues in Science and Technology* and "Science at a Crossroads," published in *Technology in Society* this past February. His current legislative efforts at Senator Lieberman's office include science education, homeland research and development, and nanotechnology legislation.

Mr. Bonvillian is married to Janis Ann Sposato and has two children. He received his B.A. from Columbia University; his M.A.R. from Yale University; and his J.D. from Columbia Law School where he also served on the Board of Editors for the Columbia Law Review. He is a member of the Connecticut Bar, the District of Columbia Bar, and the U.S. Supreme Court Bar.

## JOSEPH BORDOGNA

Joseph Bordogna is Deputy Director and Chief Operating Officer of the National Science Foundation. Complementing his NSF duties, he is a member of the President's Management Council, has chaired Committees on Manufacturing, Environmental Technologies, and automotive technologies within the President's National Science and Technology Council; and was a member of the U.S.-Japan Joint Optoelectronics Project.

He received the B.S.E.E. and Ph.D. degrees from the University of Pennsylvania and the S.M. degree from the Massachusetts Institute of Technology. As well as his assignment at NSF, his career includes experience as a line officer in the U.S. Navy, a practicing engineer in industry, and a professor.

Prior to appointment at NSF, he served at the University of Pennsylvania as Alfred Fitler Moore Professor of Engineering, Director of The Moore School of Electrical Engineering, Dean of the School of Engineering and Applied Science, and Faculty Master of Stouffer College House, a living-learning student residence at the University.

He has made contributions to the engineering profession in a variety of areas including early laser communications systems, electro-optic recording materials, holographic television playback systems, and early space capsule recovery. He was a founder of PRIME (Philadelphia Regional Introduction for Minorities to Engineering) and served on the Board of The Philadelphia Partnership for Education, community coalitions providing, respectively, supportive academic programs for K-12 students and teachers.

He is a Fellow of the American Association for the Advancement of Science (AAAS), the American Society for Engineering Education (ASEE), the Institute of Electrical and Electronics Engineers (IEEE), and the International Engineering Consortium. He also served his profession globally as president of the IEEE.

## MICHAEL BORRUS

Michael Borrus is a Managing Director of Petkevich Group, which is an investment bank focused on the health-care and information technology industries. Before joining the Petkevich Group, Mr. Borrus was a Co-Director of the

Berkeley Roundtable on the International Economy (BRIE) at the University of California at Berkeley and Adjunct Professor in the College of Engineering, where he taught Management and Technology.

He is the author of two books and over 60 chapters, articles, and monographs on a variety of topics including high-technology competition, international trade and investment and the impact of new technologies on industry and society. For the last decade, he has served as consultant to a variety of governments and firms in the U.S., Asia, and Europe on policy and business strategy for international competition in high-technology industries. Mr. Borrus is a graduate of Harvard Law School and a member of the California State Bar.

## RICHARD CARROLL

Richard Carroll founded Digital System Resources, Inc., a computer hardware and software company specializing in technology critical to national security. The company was formed in 1982, incorporated in 1985, and has grown to 480 people with net revenues for 2001 of over $110 million. Richard Carroll has taken DSR from a fledgling defense-consulting firm into a major military hardware and software provider. DSR is in the top 100 largest prime Department of Defense contractors for Research, Development, Test, and Evaluation, and is a recognized leader in providing state-of-the-art high quality products.

DSR, under the leadership of Richard Carroll, has taken on the challenge of introducing a radically new software model to defense systems. DSR's products and services have been recognized with numerous awards and a continuum of competitive contract awards. DSR's experience includes the development and production of systems for passive and active sonar, electronic warfare, combat control, and computer-based training and simulation for these systems. DSR has an outstanding record of delivering these systems on time and within budget.

Richard Carroll has been called upon on several occasions to testify on the role of small high-tech business in providing innovation. He has become a recognized expert on the potential of small high-tech businesses to provide cost-effective solutions to complex problems. In particular, he has testified on the importance and limitations of the Small Business Innovation Research (SBIR) program in meeting the need for government innovation.

## GAIL CASSELL

Gail Cassell is currently Vice President of Infectious Diseases, Eli Lilly and Company. She was previously the Charles H. McCauley Professor and Chairman of the Department of Microbiology at the University of Alabama Schools of Medicine and Dentistry at Birmingham, a department that ranked first in research funding from the National Institutes of Health since 1989 during her leadership.

She is a current member of the Director's Advisory Committee of the National Centers of Disease Control and Prevention. She is a past President of the American Society for Microbiology, a former member of the National Institutes of Health Director's Advisory Committee, and a former member of the Advisory Council of the National Institute of Allergy and Infectious Diseases of NIH. Dr. Cassell served 8 years on the Bacteriology-Mycology 2 Study Section and as Chair for 3 years. She also was previously chair of the Board of Scientific Councilors of the Center for Infectious Diseases, Centers for Disease Control.

Dr. Cassell has been intimately involved in establishment of science policy and legislation related to biomedical research and public health. She is the Chairman of the Public and Scientific Affairs Board of the American Society for Microbiology; a member of the Institute of Medicine of the National Academy of Sciences; has served as an advisor on infectious diseases and indirect costs of research to the White House Office of Science and Technology Policy; and has been an invited participant in numerous Congressional hearings and briefings related to infectious diseases, antimicrobial resistance, and biomedical research. She has served on several editorial boards of scientific journals and has authored over 250 articles and book chapters. Dr. Cassell has received several national and international awards and an honorary degree for her research in infectious diseases.

## ELIZABETH DOWNING

Elizabeth Downing is President, CEO, and founder of 3D Technology Labs in Sunnyvale, California. She is a winner of Technology and Innovation awards from *Discover Magazine*, *Industry Week Magazine*, and Saatchi & Saatchi, and was recently featured, along with Hillary Rodham Clinton, Madeleine K. Albright, and Sandra Day O'Connor in *Feminine Fortunes—Women of the New Millennium.*

Dr. Downing is well known for her contributions to the field of volumetric visualization and display technology. She holds more than a dozen patents on optical and laser-based instrumentation, working not only to develop a paradigm shifting technology, but also to channel it into key initial markets where time-critical visualization of volumetric data can mean the difference between life and death. A mechanical engineer specializing in systems integration by training, Dr. Downing not only conceived of the basic concepts, but also has worked to develop the material processing capabilities and has integrated the optical systems to create the world's first 360-degree walk-around three-dimensional display. Founded in 1996 with the help of key technical and business experts, her company, 3D Technology Labs, has meticulously pushed the performance envelope of a challenging new visualization frontier.

In a business climate where IPO mania has often replaced common business sense, 3DTL has methodically used government funding (NIST-ATP, DARPA-BAA, SBIRs) to mitigate technical risk, ensuring that key technical barriers to commercialization could be successfully addressed. As a result, 3DTL is ready to embark on the next round of challenges, namely transition, to begin tailoring, testing, and evaluating crossed-beam volumetric displays for the Department of Defense.

Since 1996, Dr. Downing has been invited to speak as an expert in her field by the National Academy of Sciences, the Optical Society of America, SIGGRAPH, and the U.S. Display Consortium. In addition, she continues to push the boundaries of the field, and is the author of several innovative scientific publications relating to three-dimensional display, nonlinear optics, non-oxide glasses and their applications.

## MARYANN FELDMAN

Maryann Feldman is currently the Policy Director at the Johns Hopkins University Institute for Information Security (JHUISI) of the Whiting School of Engineering. In addition, she is a Research Scientist for the Program on Entrepreneurship and Management in the Department of Mathematical Sciences and adjunct Associate Professor in the Department of Economics at Johns Hopkins University. Before beginning her work as Policy Director, Dr. Feldman was Research Scientist for the Institute for Policy Studies at Johns Hopkins University. Prior to her work at John Hopkins, she was Visiting Assistant Professor at the H. J. Heinz III School of Public Policy and Management, Carnegie Mellon University, and Assistant Professor of Management and Economics at Goucher College in Baltimore, Maryland. As of January 2003, she will be Associate Professor of Business Economics at the Rotman School of Business at the University of Toronto.

Dr. Feldman is the author of over 40 referred articles on a variety of topics related to science and technology policy including the economics of science and technology, the location of innovative activity, and university technology transfer activities. Her research has been funded by the National Science Foundation, the Andrew W. Mellon Foundation, the Advanced Technology Program as well as her current work with the National Academy of Sciences' Board on Science, Technology and Economic Policy.

Throughout her career, Dr. Feldman has received numerous fellowships and professional awards. She received a B.A. in economics and geography from Ohio State University, a M.S. in management and policy analysis and a Ph.D. in economics and management from Carnegie Mellon University.

## DAVID H. FINIFTER

David H. Finifter is Dean of Research and Graduate Studies in Arts and Sciences and Professor of Economics and Public Policy at The College of William and Mary. He served as founding director of The Thomas Jefferson Program in Public Policy at William and Mary, a position he held from 1987 to 2000. He was also founding director of the Program's Center for Public Policy Research. His teaching and scholarly interests include the economics of higher education and public policy, human resource economics, science and technology policy, evaluation and benefit/cost analysis, labor economics, public health service delivery and finance, and microeconomics and econometrics applied to public policy analysis. Dr. Finifter has been on the faculty at The College of William and Mary since completing his Ph.D. in economics from the University of Pittsburgh. He also holds a B.S. degree from Loyola College of Maryland and an M.A. degree in economics from the University of Pittsburgh. He has published several articles and reports in the area of evaluation of human resources and public policy on issues including federally subsidized employment and training programs, and veterans' job training programs. He has also published research on workplace literacy and productivity. He has co-edited two books on higher education and public policy and a special edition of the *Quarterly Review of Economics and Business* on health care policy. He has served as a consultant to several federal government agencies, including the U.S. Department of Labor, the Veterans Administration, NASA, Sandia National Laboratories, and the Environmental Protection Agency. During 1978-79, he served as a Staff Associate in Employment Policy at the Brookings Institution and the U.S. Department of Labor. During the summer of 1995, he served as a faculty summer fellow, American Society for Engineering Education (ASEE) at NASA-Langley Research Center, and worked on technology transfer policy and performance measurement/metrics. His research over the past few years has emphasized work in collaboration with Dr. Robert B. Archibald on the Small Business Innovation Research (SBIR) program. They evaluated the SBIR program at NASA-Langley Research Center and for the U.S. Department of Defense as part of the National Academy of Sciences team working on the SBIR Fast Track Program. Dr. Finifter also has a research interest in the future of graduate and professional education and the linkages to research funding.

## KENNETH FLAMM

Kenneth Flamm is the Dean Rusk Professor of International Affairs at the LBJ School at the University of Texas–Austin. Before this, he worked at the Brookings Institution in Washington, where he served 11 years as a Senior Fellow in the Foreign Policy Studies Program. He is a 1973 honors graduate of Stanford University and received a Ph.D. in economics from MIT in 1979. From 1993 to 1995, Dr. Flamm served as Principal Deputy Assistant Secretary of Defense for Economic Security and Special Assistant to the Deputy Secretary of Defense for Dual Use Technology Policy. He was awarded the Department's Distinguished Public Service Medal by Defense Secretary William J. Perry in 1995 as well.

Dr. Flamm has been a professor of economics at the Instituto Tecnológico de México in Mexico City, the University of Massachusetts, and the George Washington University. He has also been an adviser to the Director General of Income Policy in the Mexican Ministry of Finance and a consultant to the Organization for Economic Cooperation and Development, the World Bank, the National Academy of Sciences, the Latin American Economic System, the U.S. Department of Defense, the U.S. Department of Justice, the U.S. Agency for International Development, and the Office of Technology Assessment of the U.S. Congress. He has played an active role in the National Academies of Sciences' Committee on Government-Industry Partnerships, under the direction of Gordon Moore, and he played a key role in that study's review of the SBIR program at the Department of Defense.

Dr. Flamm has made major contributions to our understanding of the growth of the electronics industry, with a particular focus on the development of the computer and the U.S. semiconductor industry. He is currently working on an analytical study of the post-Cold War defense industrial base and has expert knowledge of international trade and the high technology industry issues.

## PATRICIA R. FORBES

Shortly after Senator John Kerry (D-MA) became the senior Democrat of the Senate Committee on Small Business in 1997, Patty Forbes joined his Committee staff as his Staff Director and Chief Counsel. In her position, Ms. Forbes serves as Chairman Kerry's top advisor on the full range of small business issues and directs his Committee staff with respect to all aspects of Committee work, including preparing legislation, hearings, correspondence and speeches in the small business and entrepreneurship arena. She also represents Chairman Kerry and other Committee Democrats in negotiation and crafting legislation affecting SBA's programs and the nation's small businesses.

Ms. Forbes has 20 years of experience with small businesses, the Small Business Administration and its small business assistance programs. She has held several positions within the Small Business Administration and the Senate Committee on Small Business. Prior to joining Senator Kerry's staff, she worked as SBA's Acting Associate Deputy Administrator for Economic Development, providing overall leadership and direction for all nine of SBA's financing and entrepreneurial development programs. This followed a 4-year period when she worked for Chairman Dale Bumpers on the Senate Committee on Small Business; first, as his Majority Counsel and later as his Deputy Staff Director and Counsel. In those positions, she was responsible for implementing Senator Bumpers' legislative agenda and developing appropriations amendments relating to small business programs and initiatives. Prior to her service on Capitol Hill, Ms. Forbes spent 9 years in SBA's Office of General Counsel as Chief Counsel for Legislation and attorney advisor.

Ms. Forbes holds a B.A. from Middlebury College in Vermont and a J.D. from the University of Southern California.

## M. CHRISTINA GABRIEL

Christina Gabriel is Vice Provost for Corporate Partnerships and Technology Development at Carnegie Mellon University. Dr. Gabriel comes to Carnegie Mellon from CASurgica, Inc., a Carnegie Mellon spin-off company focusing on computer-assisted orthopedic surgery, where she was President and CEO. In earlier university positions, Dr. Gabriel has served as Director of Collaborative Initiatives at Carnegie Mellon as well as Vice President for Research and Technology Transfer at Case Western Reserve University in Cleveland, Ohio.

Dr. Gabriel spent 5 years with the National Science Foundation in Washington, D.C., and Arlington, VA, most recently serving as Deputy Assistant Director for Engineering, which is the chief operating officer of the Engineering Directorate, an organization of 140 staff members (half Ph.D.-level) which awards over $300 million to universities and small businesses for engineering research and education. In earlier assignments at NSF, Dr. Gabriel served as program director within several engineering research programs, as well as Coordinator for the $50 million university-industry collaborative Engineering Research Centers program.

Dr. Gabriel spent most of the year 1994 at the United States Senate Appropriations Committee, working as one of three majority professional staff members for the Subcommittee on VA, HUD and Independent Agencies, chaired by Senator Barbara Mikulski. This subcommittee was responsible for appropriating about $90 billion annually among 25 federal organizations. Dr. Gabriel was also a researcher for six years at AT&T Bell Laboratories in New Jersey and spent six months in 1990 as a visiting professor at the University of Tokyo in Japan. She received her masters and doctorate degrees in electrical engineering and computer science from the Massachusetts Institute of Technology and her undergraduate electrical engineering degree from the University of Pittsburgh. She was an AT&T Bell Laboratories GRPW Fellow and a National Merit Scholar (Richard King Mellon Foundation). Her research publications focus on digital optical switching devices and systems exploiting ultra fast optical non-linearities in fibers and wave guides of glasses, polymers and semiconductors, and she holds three patents.

## JACQUES S. GANSLER

Jacques Gansler, former Under Secretary of Defense for Acquisition, Technology, and Logistics, is the first to hold the University of Maryland's Roger C. Lipitz Chair in Public Policy and Private Enterprise. As the third ranking civilian at the Pentagon from 1997 to 2001, Dr. Gansler was responsible for all research and development activities, acquisition reform, logistics, advanced technology, environmental security, defense industry, and other programs. Before joining the Clinton Administration, Dr. Gansler held a variety of positions in government and the private sector, including those of Deputy Assistant Secretary of Defense (Material Acquisition), Assistant Director of Defense Research and Engineering (Electronics), Vice President of ITT, and engineering and management positions with Singer and Raytheon Corporations.

Throughout his career, Dr. Gansler has written, published, and taught on subjects related to his work. He is the author of *Defense Conversion: Transforming the Arsenal of Democracy*, MIT Press, 1995; *Affording Defense*, MIT Press, 1989, and *The Defense Industry*, MIT Press, 1990. He has published numerous articles in *Foreign Affairs*, *Harvard Business Review*, *International Security, Public Affairs*, and other journals as well as newspapers and Congressional hearings.

## ROBIN GASTER

Dr. Robin Gaster has been President of North Atlantic Research Inc., a Washington, D.C. consulting company, since 1989. Over that period, NAR has completed research and assessment projects for a wide range of corporate, nonprofit, and government clients.

Major research projects include an analysis of the future of the telecommunications industry, strategic assessment of prospects for online textbook sales, several projects covering transatlantic trade and technology issues (including a book on transatlantic telecommunications issues), and many assignments covering various aspects of e-commerce and online development.

Most recently, Dr. Gaster has been deeply involved in several entrepreneurial projects aiming to address failures in the economic information flow which have badly affected inner city markets, including a current assignment for the (nonprofit) "Living Cities" initiative, as well as several partnership efforts focused on creating sustainable online communities.

## DAVID GOLDSTON

David Goldston was appointed to run the House Committee on Science in January 2001. As Staff Director, he oversees a committee with jurisdiction over most of the federal civilian research and development budget, including programs run by NASA, the National Science Foundation, the Department of Energy, the Department of Commerce and the Environmental Protection Agency.

Prior to becoming Staff Director, Goldston was Legislative Director for Congressman Sherwood Boehlert (R-NY), who became Chairman of the Science Committee in January 2001. Boehlert is a leading moderate Republican and has led Republican efforts to protect the environment. As Legislative Director, Goldston was Boehlert's top environmental aide and also oversaw the legislative and press operations of the office.

Goldston came to Capitol Hill in 1983 as Boehlert's press secretary. From 1985 to 1994, he served on the Science Committee as the Special Assistant on the Subcommittee on Science, Research and Technology. In that role, Goldston oversaw the programs of the National Science Foundation and the National Institute of Standards and Technology and also directed Boehlert's efforts to shut down the Superconducting Super Collider (SSC).

In 1994 and 1995, Goldston was Project Director at the Council on Competitiveness, a private sector group with members from industry, labor and academia. Goldston directed work on the report, *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness.*

Goldston was graduated magna cum laude with a B.A. in American history from Cornell University in 1978. He has completed the course work for a Ph.D. in American history at the University of Pennsylvania.

## JO ANNE GOODNIGHT

Ms. Goodnight currently holds the position as the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program Coordinator of the National Institutes of Health (NIH) and the Department of Health and Human Services (DHHS) Public Health Service. She has held this position, which is located in the NIH Office of Extramural Research (OER), Office of the Director, since March 1999. Prior to joining OER, she served in positions encompassing research, program administration and program management. During nearly 20 years of Government service she has held positions in the U.S. Department of Agriculture (USDA), the Food and Drug Administration, and now the NIH. As part of her undergraduate education (1978-1983), she spent four years as a Cooperative Education student conducting research at the USDA's Animal Parasitology Institute. While at NIH, she has been a part of the National Cancer Institute's (NCI) Intramural Research Program (1989-1994) and the NCI's Extramural Research Program (1994-1999). As an intramural scientist, she published over 20 studies about the selective involvement of Protein Kinase C in differentiation and neoplastic transformation. She joined the NCI's Extramural Research Program in 1994 where she served as a Special Assistant to the Director in the Division of Cancer Biology and Program Director for SBIR/STTR grants that supported studies in the field of cancer biology, cancer genetics, and cancer immunology as well as the SBIR/STTR Program Policy Coordinator for the entire NCI. She was appointed as the NIH SBIR/STTR Program Coordinator in 1999 where she continues today.

She was intimately involved in the development and implementation of the NIH SBIR/STTR Fast Track Program and continues to develop other programs that assist the small business community in commercialization of their technologies. She has been an invited participant in numerous SBIR/STTR conferences to discuss funding opportunities for small businesses through the NIH. She also has provided written and oral testimony at Congressional hearings related to the reauthorization of the SBIR and STTR programs.

Ms. Goodnight has received several national awards including an NIH Merit Award (1998) for her "exemplary contributions in the administration and coordination of the extramural research programs of the Division of Cancer Biology" and a Tibbetts award from the Small Business Administration for her "leadership role in making the SBIR and STTR programs more accessible, more relevant, and more effective."

Ms. Goodnight received a Bachelor of Science degree in microbiology from Virginia Tech in 1983.

## CAROLE A. HEILMAN

Dr. Carole Heilman is the Director of the Division of Microbiology and Infectious Diseases (DMID), NIAID, NIH. Previously, Dr. Heilman served as Deputy Director of the Division of AIDS, NIAID, NIH for 3 years. As Director of DMID she has the responsibility for scientific direction, oversight, and management of all infectious diseases, except AIDS, within the NIH. Dr. Heilman has a Ph.D. in microbiology from Rutgers University. She did her post-doctoral work in molecular virology at the National Cancer Institute and continued on at the NCI as a senior staff fellow in molecular oncology. She moved into the health science administration area in 1986 where she focused on respiratory pathogens, in particular vaccine development. She has received numerous awards for scientific management and leadership, including two DHHS Secretary Awards for Distinguished Service for her efforts on pertussis vaccine and AIDS vaccine development.

## CHARLES J. HOLLAND

Dr. Holland is the Deputy Under Secretary of Defense (Science and Technology). He is responsible for Defense Science and Technology strategic planning, budget allocation, and program review and execution. He ensures that the National Defense objectives are met by the $9 billion per year DoD Science and Technology program. Dr. Holland is the Principal U.S. representative to the Technical Cooperation Program between Australia, Canada, New Zealand, the United Kingdom, and the U.S. He is also responsible for the DoD High Performance Computing Modernization Program, the Defense Modeling and Simulation Office, and management oversight of the Software Engineering Institute.

Previously, he was Director for Information Systems within the ODUSD (S&T). He formulated guidance, developed the strategic plans, and provided the technical leadership for the entire DoD information technologies R&D effort, with an annual budget of approximately $1.8 billion. Technology programs under his purview included: decision making; modeling and simulation; high performance computing; information management, distribution and security; seamless communications; and computing and software technology. He served as the DoD representative to the interagency Critical Infrastructure Protection R&D group responding to Presidential Decision Directive 63.

Prior to being appointed the Director for Information Technologies in March 1998, Dr. Holland was the Director of the DoD High Performance Computing Modernization Program Office reporting to DUSD(S&T). A substantial portion of Dr. Holland's government career involved the direction of basic research programs in applied mathematics and information technology at the Air Force Office of Scientific Research (1988-1997) and at the Office of Naval Research (1981-1988). He served as a liaison scientist at the European Office of Naval Research in London from 1984-1985.

Prior to joining government service, Dr. Holland was a faculty member and researcher at Purdue University and the Courant Institute of Mathematical Sciences at New York University. He has authored more than 20 research publications on control and systems theory, probabilistic methods in partial differential equations, and in reaction-diffusion phenomena. He is professionally recognized, along with his co-author, Dr. Jim Berryman, for the analysis of fast diffusion phenomena.

Dr. Holland was an Army ROTC graduate in 1968. Following an education delay for graduate school, he served as a 1st Lt. in the U.S. Army, Military Intelligence, in 1972. Dr. Holland received the Presidential Rank Award, Meritorious Executive (2000) and the Society for Industrial and Applied Mathematics Commendation for Public Service Award (1999). He is a recipient of the Meritorious Civilian Service Award from the Secretary of Defense (2001), Air Force (1998), and the Navy (1984).

Dr. Holland received a B.S. (1968) and M.S. (1969) in applied mathematics from the Georgia Institute of Technology and a Ph.D. (1972) in applied mathematics from Brown University.

## MILTON D. JOHNSON

Dr. Milton D. Johnson is the Deputy Director for Operations for the Office of Science (SC) in the Department of Energy (DoE). SC, formerly the Office of Energy Research, is the third largest federal sponsor of basic research in the United States and is viewed as one of the premier science organizations in the world. Its fiscal year 2002 budget of $3.3 billion funds programs in high energy and nuclear physics, basic energy sciences, magnetic fusion energy, biological and environmental research, and computational science.

Dr. Johnson became the Deputy Director for Operations in January 2000. In this position, he is the focal point within the SC Director's Office for field and laboratory management issues and concerns. His responsibilities include management oversight of the DoE Chicago and Oak Ridge Operations Offices, the Berkeley and Stanford Site Offices, their 10 associated research laboratories, and their other facilities and operational activities.

Dr. Johnson directed the day-to-day technical and management activities for all SC headquarters and field components when he served as the Acting Principal Deputy Director between January 2001 and March 2002. Dr. Johnson has also held several other positions within the Department. He joined the Office of Fusion Energy, Office of Energy Research, in 1975 as a program manager. He left Washington in 1980 to become Chief of the Engineering Branch at the DoE Princeton Area Office (PAO) and was promoted to the position of PAO Manager in 1987. His responsibilities included operational and contractual oversight of the Princeton Plasma Physics Laboratory. Dr. Johnson returned to DoE headquarters in July 1996 as the Deputy Associate Director of the Office of Fusion Energy Sciences.

In August 1997, Dr. Johnson became the Associate Director of the newly-created SC Office of Laboratory Operations and Environment, Safety, and Health. Dr. Johnson's responsibilities included providing leadership and corporate focus within SC headquarters for operations-related activities including construction and infrastructure management, integrated safety management, environmental management, and security.

Dr. Johnson has also served as the Acting Assistant Manager for Laboratory Operations in the Chicago Operations Office and as the Source Selection Official for the management contract that went into effect in April 2000 at the Oak Ridge National Laboratory. Before joining DoE, Dr. Johnson was employed as an engineer in the electronics industry, at universities, and at the Lawrence Livermore National Laboratory. His research interests included laser diagnostics and wave propagation in the ionosphere.

Dr. Johnson received his B.S. and M.S. degrees in electrical engineering from the University of Arizona (1962 and 1966, respectively), and a Ph.D. from Cornell University in 1975. His field of research was experimental plasma physics. Dr. Johnson has received numerous awards from DoE including a Presidential Meritorious Rank Award. An avid runner, Dr. Johnson completed the Marine Corps Marathon in 2000. Dr. Johnson was born in Jamestown, New York, and was raised in Arizona. He is married and has two adult children.

## CHARLES KOLB

Charles Kolb is the President and Chief Executive Officer of Aerodyne Research, Inc., (ARI) a position he has held since 1984. Since 1970, ARI has provided research and development services requiring expertise in the physical and engineering sciences to commercial and government clients working to solve national and international environmental problems. These include a wide range of topics such as global and regional environmental quality and the development of clean and efficient energy and new propulsion technologies.

Dr. Kolb has received numerous professional honors and has served in a broad range of professional and Academy related positions. He is currently a member of the Advisory Council for the Department of Civil and Environmental Engineering at Princeton University and the Science Advisory Committee of the Radcliffe Institute for Advanced Study at Harvard University. He has contributed to a variety of National Academies of Sciences studies including: the Board on Atmospheric Sciences and Climate, Committee to Assess the North American Research Strategy for Tropospheric Ozone, the Committee to Review NARSTO's Assessment of Airborne Particulate Matter and served as Chairman on the National Research Council's Committee on Review and Evaluation of Chemical Events at Army Chemical Disposal Facilities.

Dr. Kolb holds an S.B. in chemistry (chemical physics option) from Massachusetts Institute of Technology, an M.S. in physical chemistry from Princeton University and a Ph.D. in physical chemistry from Princeton University. His research interests include: atmospheric, combustion and materials chemistry as well as physics and chemistry of aircraft and rocket exhaust plumes. In addition to over 250 reports, non-refereed symposia papers, patents, book reviews, and policy papers, Dr. Kolb has published over 160 archival journal articles and book chapters.

## HENRY LINSERT, JR.

Henry Linsert joined Martek as Chairman of the Board in 1988 and became its Chief Executive Officer in 1989. From 1987 to 1988, he was primarily engaged as President of American Technology Investments Corp. ("ATI"), a consulting company specializing in the development and financing of early-stage companies in the Mid-Atlantic area. He was President and Chief Executive Officer of Suburban Capital Corporation, a venture capital subsidiary of Sovran Financial Corporation (now part of Bank of America), from 1983 to 1987. Before 1983, Mr. Linsert was Vice President of Inverness Capital Corporation, a small business investment company, and Vice President of First Virginia Bank. He also served as a Captain in the U.S. Marine Corps and as an artillery officer in Vietnam.

Mr. Linsert received an M.A. in economics from George Washington University and a B.A. from Duke University.

## DUNCAN T. MOORE

Duncan Moore is the Rudolf and Hilda Kingslake Professor of Optical Engineering and Professor of Biomedical Engineering at the University of Rochester. He is also Special Assistant to the University President and Executive Director of the University, Industry and Government Partnership for Advanced Photonics.

Previously, from 1995 until the end of 1997, he served as Dean of Engineering and Applied Sciences at the University.

In 1996, Dr. Moore also served as President of the Optical Society of America (OSA), a professional organization of 12,000 members worldwide. From January 2001 to the present, he has served as Senior Science Advisor at OSA.

The U.S. Senate confirmed Dr. Moore in the fall of 1997 for the position of Associate Director for Technology in The White House Office of Science and Technology Policy (OSTP). In this position, which ended December 2000, he worked with Dr. Neal Lane, President Clinton's Science Advisor, to advise the President on U.S. technology policy, including the Next Generation Internet, Clean Car Initiative, elder tech, crime tech, and NASA. From January through May 2001, Dr. Moore served as Special Advisor to the Acting Director of OSTP.

Dr. Moore has extensive experience in the academic, research, business, and governmental arenas of science and technology. He is an expert in gradient-index optics, computer-aided design, and the manufacture of optical systems. He has advised nearly 50 graduate thesis students. In addition, Dr. Moore began a one-year appointment as Science Advisor to Senator John D. Rockefeller IV of West Virginia in 1993. He also chaired the successful Hubble Independent Optical Review Panel organized in 1990 to determine the correct prescription of the Hubble Space Telescope. Dr. Moore is also the founder and former president of Gradient Lens Corporation of Rochester, New York, a company that manufactures the high-quality, low-cost Hawkeye boroscope.

Dr. Moore was elected to the National Academy of Engineering in February 1998. He has been the recipient of the Science and Technology Award of the Greater Rochester Metro Chamber of Commerce (1992), Distinguished Inventor of the Year Award of the Rochester Intellectual Property Law Association (1993), Gradient-Index Award of the Japanese Applied Physics Society (1993), and an Honorary Doctor of Science degree from the University of Maine (1995). In 1999, he received the National Engineering Award of the American Association of Engineering Societies and was recognized as the Engineer of the Year by the Rochester Engineering Society. Most recently, he was the recipient of the 2001 OSA Leadership Award.

Dr. Moore holds a Ph.D. in optics (1974) from the University of Rochester. He had previously earned a master's degree in optics at Rochester and a bachelor's degree in physics from the University of Maine.

## ROBERT L. NORWOOD

Dr. Robert L. Norwood currently serves as Director for Commercial Technology in the Office of Aerospace Technology (OAT). The position is responsible for overall strategy and management of NASA's Commercial Technology program within NASA and the Strategic leadership of the NASA SBIR program.

Dr. Norwood has previously served as Deputy Director for Space Technology in the Office of Aeronautics and Space Technology since January 1991. In this position, he assisted the Director for Space Technology in the overall direction, advocacy, and budgeting for NASA Space Research and Technology Program.

Dr. Norwood comes to NASA from the Department of Defense where he held the position of Deputy for Space and Strategic Systems in the Office of the Assistant Secretary of the Army (Research, Development, and Acquisition) since 1979. Prior to that, Dr. Norwood held operations research and engineering positions with the Center for Naval Analyses and McDonnell Douglas Astronautics Corporation, respectively.

Dr. Norwood received a B.S. in engineering mechanics from the University of Illinois in 1964, a M.S. in mechanical engineering from the University of Southern California in 1969, and a Ph.D. in theoretical and applied mechanics from the University of Illinois in 1980. His professional activities have spanned several organizations including the American Institute of Aeronautics and Astronautics, the American Society of Mechanical Engineers, the National Space Club, Board of Directors, and the Board of Technical Advisors for the National Technical Association.

In addition to the above, Dr. Norwood has served on Fairfax County Education Advocacy Councils and serves on the Fairfax County Engineering Standards Review Board, and the College of Engineering Advisory Board, University of Illinois, from 2001-2004.

## GREGORY H. OLSEN

Gregory H. Olsen received his B.S. in physics in 1966, a BSEE and M.S. physics (magna cum laude) in 1968 from Fairleigh Dickenson University, and a Ph.D. in material science in 1971 from the University of Virginia. From 1971 to 1972, he was a visiting scientist at the University of Port Elizabeth (South Africa), Physics Department. In 1972, Dr. Olsen joined RCA Laboratories at Princeton, NJ as a Member of the Technical Staff. He brought major innovations to the hydride vapor phase crystal growth of InGaAsP alloys and developed long-wavelength lasers and detectors. His background covers vapor phase epitaxy crystal growth, crystal defects, characterization of III-V compounds, and optoelectronic devices for fiber optics, near-infrared instrumentation, and imaging applications. Dr. Olsen is a Fellow of the IEEE, has been active in many technical societies and has ten patents and over 100 publications. He was a 1992 IEEE/LEOS Distinguished Lecturer and a member of the LEOS Board of Governors and CLEO Steering Committee. In 1984, he founded EPITAXX Inc., a high-technology company in Princeton, NJ, which manufactured fiber optic detectors and emitters. Nippon Sheet Glass acquired it in 1990. Dr. Olsen founded Sensors Unlimited in 1991 for the development and manufacture of optoelectronic devices for dense wavelength division multiplexing fiber optic systems, spectroscopy, photonic and near infrared imaging devices. Finisar Corporation acquired this in 2000. He has also been a board member of a number of high-tech firms including QED, ASIP, and Finisar. Dr. Olsen remains as president, and is active in the NJ Tech Council Venture Fund. In October 2002 he led the employee "buy back" of Sensors Unlimited from Finisar Corp., which had acquired it for $700 million in October 2000.

## LINDA F. POWERS

Linda Powers has more than fifteen years of experience in the fields of corporate mergers and acquisitions (both hostile and friendly), restructurings, and highly leveraged, structured and specialty finance transactions. She is a co-founder and Managing Director of Toucan Capital Corporation.

Before co-founding Toucan Capital, Ms. Powers was Senior Vice President, Global Finance, at Enron Corporation. Before joining Enron, Ms. Powers served as Deputy Assistant Secretary of Commerce in the Bush Administration. In that capacity, she was responsible for a number of small business programs, mainly concerned with access to capital. She also assisted financial services, information services and related businesses in entering foreign markets, and was responsible for government-to-government negotiations to remove foreign market entry restrictions for U.S. firms. She was co-lead negotiator for the U.S. on the North American Free Trade Agreement, financial sector agreement, which opened banking, securities, insurance, pension fund and related opportunities in Canada and Mexico.

During the 1980s, Ms. Powers practiced law, specializing in corporate mergers, acquisitions and financings, and certain kinds of intellectual property transactions. While working for the headquarters of the European Union in Brussels, she was responsible for drafting the initial intellectual property rules that now govern know-how licensing in the European Union.

Ms. Powers has also taught International Business Transactions and European Business Law at Georgetown Law School for 8 years, as an adjunct professor. She is a graduate, magna cum laude, of both Princeton University and Harvard Law School.

## ROSALIE RUEGG

Rosalie Ruegg has more than 30 years experience in economic impact assessment of advanced technologies. Her current projects include preparing a cross-cutting retrospective analysis of methodologies and findings from a large number of evaluation studies; organizing a workshop on best practices in evaluating federal technology programs; and developing, documenting, and applying a project performance scoring system for a multi-objective technology program.

Prior to founding TIA Consulting, Ms. Ruegg was Director of the Advanced

Technology Program's Economic Assessment Office. In this capacity, she developed and implemented a comprehensive evaluation program, and led and served on boards responsible for selecting R&D projects for more than $1 billion of federal awards. She also formed and convened panels of industry executives, business specialists, and senior economists who provided advice to the government on the business and economic merit of industry proposals. Before joining ATP, Ms. Ruegg was a senior economist in NIST's Center for Applied Mathematics, where she led an award-winning, multi-sector economic impact study for Congress. Earlier, she was a financial economist for the Federal Reserve System's Board of Governors.

She has more than 60 publications, among them a case-study guide for science managers and an economics textbook. As a member of the Federal Senior Executive Service, she received DOC's Gold Medal for excellence. A member of Phi Beta Kappa and a Woodrow Wilson Fellow, she received degrees in economics from the Universities of North Carolina and Maryland, an M.B.A from The American University, and has extensive executive training from the Federal Executive Institute and Harvard University. In 2001, she was the recipient of the Institute of Industrial Engineers' Wellington Award, for outstanding contributions in the field of engineering economics.

## PAULA E. STEPHAN

Paula Stephan is Professor of Economics, Andrew Young School of Policy Studies, Georgia State University. Her research interests focus on the careers of scientists and engineers and the process by which knowledge moves across institutional boundaries in the economy. Stephan's research has been supported by the Alfred P. Sloan Foundation, the Andrew Mellon Foundation, the Exxon Education Foundation, the National Science Foundation, the North Atlantic Treaty Organization, and the U.S. Department of Labor. She has served on several National Research Council committees including the Committee on Dimensions, Causes, and Implications of Recent Trends in the Careers of Life Scientists, Committee on Methods of Forecasting Demand and Supply of Doctoral Scientists and Engineers, and the Committee to Assess the Portfolio of the Science Resources Studies Division of NSF. She is a regular participant in the National Bureau of Economic Research's meetings in Higher Education and has testified before the U.S. House Subcommittee on Basic Science. She currently is serving a 3-year term as a member of CEOSE, the National Science Foundation's Committee on Equal Opportunity in Science and Engineering and is a member of the SBE Advisory Committee, National Science Foundation.

Dr. Stephan graduated from Grinnell College (Phi Beta Kappa) with a B.A. in economics and earned both her M.A. and Ph.D. in economics from the University of Michigan. She has published numerous articles in journals such as *The American Economic Review, Science, The Journal of Economic Literature, Eco-*

*nomic Inquiry* and *Social Studies of Science*. Stephan coauthored with Sharon Levin Striking the *Mother Lode in Science*, published by Oxford University Press, 1992. The book was reviewed in *Science, Chemical and Engineering News, Journal of Economic Literature, The Southern Economic Journal* and *The Journal of Higher Education*. Her research on the careers of scientists has been the focus of articles in *The Economist, Science,* and *The Scientist*. Stephan is a frequent presenter at meetings such as The American Economic Association, the American Association for the Advancement of Science, and the Society for the Social Studies of Science. Stephan reviews regularly for the National Science Foundation and a number of academic journals including *The American Economic Review, The American Sociological Review, Economic Inquiry, The Journal of Political Economy*, and *The Journal of Human Resources*.

## JAMES TURNER

Jim Turner has served on the professional staff of the Committee on Science in the U.S. House of Representatives for approximately 20 years. He currently serves as the Full Committee Chief Democratic Counsel where he works across the board on the Committee's legislative agenda.

For the 10 years prior to the Republican takeover of Congress, Mr. Turner was the Committee's senior staff member for technology policy including four years as technology subcommittee staff director. He also served as a subcommittee legal counsel. During the late 1970s and early 1980s, Mr. Turner worked on the Committee's Republican staff as Minority Energy Counsel.

During his years on the Committee, Mr. Turner has worked on numerous bills, reports, and hearings on a wide variety of topics. These include the international competitiveness of U.S. industry, environmental and energy research and development, trade and technology policy, intellectual property, standards, and technology transfer.

Mr. Turner also spent 3 years working for Wheelabrator-Frye, 2 years for Congressman Gary Myers, 2 years for the State of Connecticut, and shorter periods with NASA and FAA. He holds degrees from Georgetown and Yale Universities and from Westminster College and attended the Senior Managers in Government Program at Harvard.

## CHARLES W. WESSNER

Dr. Charles Wessner is widely recognized as a national and international expert on public-private partnerships, early-stage financing for new firms, and the special needs and benefits of high-technology industry. He regularly testifies to the U.S. Congress and major national commissions, acts as an advisor to agencies of the Executive Branch of the U.S. government, and lectures at major universities in the U.S. and abroad. He is frequently asked to address policy issues of shared policy interest with foreign governments, universities, and research institutes. In this capacity, he serves as an advisor to the 30-nation OECD Committee on Science and Technology Policy and as a member of the Norwegian Technology Forum.

Dr. Wessner's work focuses on the linkages between science-based economic growth, new technology development, university-industry clusters, regional development, small-firm finance and public-private partnerships. His program at the Academies also addresses policy issues associated with international technology cooperation, investment and trade in high-technology industries. Dr. Wessner's portfolio at the National Academies has included a White House-initiated study on U.S. aerospace competitiveness and a major cooperative review, with Hamburg's HWWA, of international competition and cooperation in high-technology industry. Currently, he directs a series of studies centered on government measures to support the development of new technologies and the policies that may be required to continue the productivity gains characteristic of the New Economy. Since joining the National Research Council, Dr. Wessner has directed several major studies, generating more than 15 reports.

# Appendix B:
# Participants List
# 24 October 2002 Symposium

Zoltan Acs
University of Baltimore

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*David B. Audretsch*
*Indiana University*

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*Jon Baron*
*Coalition for Evidence-Based Policy*

*Roscoe G. Bartlett*
*U.S. House of Representatives*

Tabitha Benney
The National Academies

Robert Berger
Department of Energy

Richard Bissell
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Grant Black
Georgia State University

*William B. Bonvillian*
*Office of Senator Lieberman*

*Joseph Bordogna*
*National Science Foundation*

*Michael Borrus*
*The Petkevich Group, LLC*

Peter Cahill
BRTRC, Inc.

Speakers are in italics

Joseph Capuano
Department of Transportation

Robert Carpenter
University of Maryland, Baltimore County

*Richard W. Carroll*
*Digital System Resources, Inc.*

*Gail Cassell*
*Eli Lilly and Company*

Victor Chavez
Sandia National Laboratories

Major L. Clarke, III
Small Business Administration

Charles Cleland
Department of Agriculture

Ritchie Coryell
National Science Foundation

K.C. Das
Commonwealth of Virginia

Gregory J. Dean
Senate Committee on Small Business and Entrepreneurship

LeAnn Delaney
House Committee on Small Business

David Dierksheide
The National Academies

Lee Eiden
Department of Education

Julie Ann Elston
University of Central Florida

*Maryann Feldman*
*Johns Hopkins University*

*David H. Finifter*
*The College of William and Mary*

Ivory Fisher
Department of Defense

*Kenneth Flamm*
*University of Texas at Austin*

*Patricia R. Forbes*
*Senate Committee on Small Business and Entreprenuership*

R.H. Forrester
Aston Business School

*M. Christina Gabriel*
*Carnegie Mellon University*

James Gallup
Environmental Protection Agency

*Jacques S. Gansler*
*University of Maryland*

*Robin Gaster*
*North Atlantic Research*

Jere Glover
Small Business and Technology Coalition

*David Goldston*
*House Science Committee*

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Speakers are in italics

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*National Institutes of Health*

Gina Harrison
Office of Congresswoman Jane Harman

Chris Hayter
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National Institutes of Health

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Department of Transportation

Chip Highsmith
Digital System Resources

*Charles J. Holland*
*Department of Defense*

Jim Jensen
National Academy of Sciences

*Milton D. Johnson*
*Department of Energy*

Michael-David Kerns
National Institute on Aging

Robert Kispert
Massachusetts Technology Collaborative

*Charles Kolb*
*Aerodyne Research, Inc.*

Adam Korobow
The National Academies

Bernd Kramer
German Embassy

David Kramer
Science and Government Report

Thomas Liljemark
VINNOVA

*Henry (Pete) Linsert, Jr.*
*Martek Biosciences Corporation*

Terry Lynch
National Institute of Standards and Technology

Clark McFadden
Dewey Ballantine

Michael McGeary
McGeary and Smith

*Duncan T. Moore*
*Rochester University*

Francisco Moris
National Science Foundation

Owen Moss
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Russell Moy
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Speakers are in italics

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Royal Norwegian Embassy

Kesh S. Narayanan
National Science Foundation

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*NASA*

Markku Oikarainen
Tekes

*Gregory H. Olsen*
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Teresa Puretz
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Amy Ryan
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Jack Yadvish
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Speakers are in italics

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