An Assessment of the Small Business Innovation Research Program at the National Aeronautics and Space Administration

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AN ASSESSMENT OF THE SBIR PROGRAM AT THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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

Policy and Global Affairs

Charles W. Wessner, Editor

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Preface

Today's knowledge economy is driven in large part by the nation's entrepreneurs who 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 research and development (R&D) effort, SBIR grants are intended to stimulate innovative new technologies that help agencies meet the specific R&D needs of the nation in many areas, including health, the environment, and national defense.

[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, DC: 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*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2002.

SBIR REAUTHORIZATION AND CONGRESSIONAL REQUEST FOR REVIEW

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.[3] The five agencies meeting this criterion, by size of program, are the Department of Defense (DoD), The National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DoE), and the National Science Foundation (NSF).

Statement of Task: Congress directed the National Research Council (NRC), via HR 5667, to evaluate the quality of SBIR research and evaluate the SBIR program's value to the agency mission. It called 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 noneconomic benefits. It also called 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.[4]

Responding to congressional request for 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 still further improvements to the program, this study by the NRC represents the first, systematic external analysis of the program's operations, challenges, and accomplishments over the 20 years of its history. It provides an empirical analysis of the operations of the program and assesses the quality of research projects conducted under SBIR, the commercialization of research, and the program's contribution to accomplishing agency missions.

To guide this study, the NRC drew together an expert committee that included eminent economists, small businessmen and women, and venture capitalists. The membership of this committee is listed in the front matter of this volume. Given the extent of "green-field research" required for this study, the Steering Committee in turn drew on a distinguished team of researchers to, among other tasks, administer surveys and case studies, and to develop statistical information about the program. The membership of this research team is also listed in the front matter to this volume.

This report is one of a series published by the National Academies in response to the congressional request. The series includes reports on the Small

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

[4]Chapter 3 of the Committee's Methodology Report describes how this legislative guidance was drawn out in operational terms. National Research Council, *An Assessment of the Small Business Innovation Research Program—Project Methodology*, Washington, DC: The National Academies Press, 2004. Access this report at <*http://www7.nationalacademies.org/sbir/SBIR_Methodology_Report.pdf*>.

Business Innovation Research Program at the Department of Defense, the Department of Energy, the National Institutes of Health, and the National Science Foundation as well as an Overview Report that provides assessment of the program's operations across the federal government. Other reports in the series include a summary of the 2002 conference that launched the study and that documented for the first time the enormous diversity in the SBIR program, and a summary of the 2005 conference on *SBIR and the Phase III Challenge of Commercialization* that focused on the DoD and NASA.[5]

PROJECT ANTECEDENTS

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). Under the direction of Gordon Moore, Chairman Emeritus of Intel, the NRC Committee on Government Industry Partnerships prepared 11 volumes reviewing 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.[6]

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, *The Small Business Innovation Research Program: Challenges and Opportunities*, examined the origins of the program and identified some operational challenges critical to the program's future effectiveness.[7] The report also highlighted the relative paucity of research on this program.

Following this initial report, the DoD asked the NRC to assess the Department's Fast Track Initiative in comparison with the operation of its regular SBIR program. The resulting report, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, was the first comprehensive, external assessment of the DoD's program. The study, which involved substantial case study and survey research, found that the

[5]See National Research Council, *SBIR: Program Diversity and Assessment Challenges*, Charles W. Wessner, ed., Washington, DC: The National Academies Press 2004; and National Research Council, *SBIR and the Phase III Challenge of Commercialization*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007.

[6]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.

[7]See National Research Council, *The Small Business Innovation Research Program: Challenges and Opportunities*, Charles W. Wessner, ed., Washington, DC: National Academy Press, 1999.

SBIR program was achieving its legislated goals. It also found that DoD's Fast Track Initiative was achieving its objective of greater commercialization and recommended that the program be continued and expanded where appropriate.[8] The report also recommended that the SBIR program overall would benefit from further research and analysis, a perspective adopted by the U.S. Congress in requesting this assessment.

ACKNOWLEDGMENTS

On behalf of the National Academies, we express our appreciation and recognition for the insights, experiences, and perspectives made available by the participants of the conferences and meetings, as well as survey respondents and case study interviewees who participated over the course of this study. We are also very much in debt to officials from NASA, especially Carl Ray and Paul Mexcur, for their cooperation and assistance.

The committee's research team deserves major recognition for their instrumental role in the preparation of this report. Thanks are due to David Finifter of the College of William and Mary, Michael Fogerty of Portland State University, and Julie Elston of Oregon State University. Robin Gaster of North Atlantic Research also deserves special recognition for the skills and insights he brought to the completion of the study. 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 National Academies' 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, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Robert Barnhill, Arizona State University; Bruce Marcus, TRW (Retired); Jeanne Powell, National Institute of Standards and Technology (Retired); and Robert Weiss, Physical Sciences, Inc.

Although the reviewers listed above have provided many constructive com-

[8]See National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, Charles W. Wessner, ed., Washington, DC: National Academy Press, 2000. 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.

ments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Robert Frosch, Harvard University, and Robert White, Carnegie Mellon University. Appointed by the National Academies, they were 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

Summary

I. INTRODUCTION

The Small Business Innovation Research (SBIR) program was created in 1982 through the Small Business Innovation Development Act. As the SBIR program approached its twentieth year of operation, the U.S. Congress requested the National Research Council (NRC) of the National Academies 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 to make recommendations with respect to the SBIR program. Mandated as a part of SBIR's reauthorization in late 2000, the NRC study has assessed the SBIR program as administered at the five federal agencies that together make up some 96 percent of SBIR program expenditures. The agencies, in order of program size are the Department of Defense (DoD), the National Institutes of Health (NIH), the Department of Energy (DoE), the National Aeronautics and Space Administration (NASA), and the National Science Foundation (NSF).

Based on that legislation, and after extensive consultations with both Congress and agency officials, the NRC focused its study on two overarching questions. First, how well do the agency SBIR programs meet four societal objectives of interest to Congress:

- To stimulate technological innovation;
- To increase private-sector commercialization of innovations;
- To use small business to meet federal research and development needs;

and

- To foster and encourage participation by minority and disadvantaged persons in technological innovation.

Second, can the management of agency SBIR programs be made more effective? Are there best practices in agency SBIR programs that may be extended to other agencies' SBIR programs?

To satisfy the congressional request for an external assessment of the program, the NRC conducted empirical analyses of the operations of SBIR based on commissioned surveys and case studies. Agency-compiled program data, program documents, and the existing literature were reviewed. In addition, extensive interviews and discussions were conducted with project managers, program participants, agency 'users' of the program, as well as program stakeholders.

The study as a whole sought to answer questions of program operation and effectiveness, including the quality of the research projects being conducted under the SBIR program, the commercialization of the research, and the program's contribution to accomplishing agency missions. To the extent possible, the evaluation included estimates of the benefits (both economic and noneconomic) achieved by the SBIR program, as well as broader policy issues associated with public-private collaborations for technology development and government support for high technology innovation.

Taken together, this study is the most comprehensive assessment of SBIR to date. Its empirical, multifaceted approach to evaluation sheds new light on the operation of the SBIR program in the challenging area of early stage finance. As with any assessment, particularly one across five quite different agencies and departments, there are methodological challenges. These are identified and discussed at several points in the text. This important caveat notwithstanding, the scope and diversity of the report's research should contribute significantly to the understanding of the SBIR program's multiple objectives, measurement issues, operational challenges, and achievements. This volume presents the committee's assessment of the SBIR program at the National Aeronautics and Space Administration.

This study analyzes program data from the period before the 2006 NASA reorganization, which also altered the management of the SBIR program. Nonetheless, the results of this study are valuable, not least as a point of reference to see whether the organizational changes make recently have enhanced the effectiveness of the NASA SBIR program.

II. SBIR AT NASA

Program Size

With $103 million in annual awards in 2005, NASA operates the fourth largest SBIR program in the federal government.

A NASA SBIR Phase I award is currently set at a maximum of $100,000 and lasts for six months. A Phase II award is set at a maximum of $600,000 and

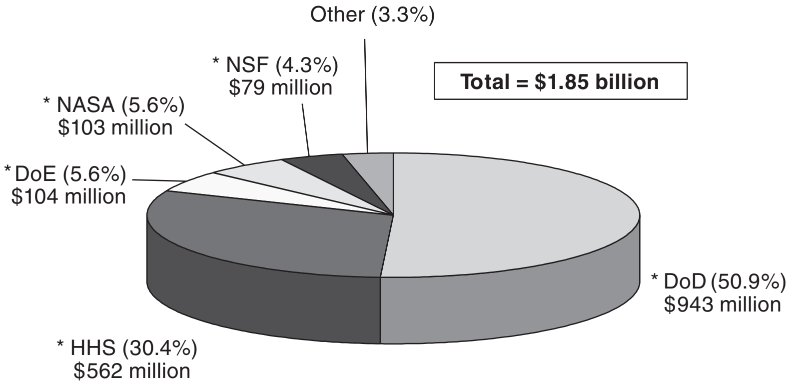

FIGURE S-1 Dimensions of the SBIR program in 2005.
SOURCE: U.S. Small Business Administration. Accessed at <*http://tech-net.sba.gov/*>.

lasts for a period of up to two years. NASA has not yet adopted the Phase IIB or Phase II Plus or Fast Track option that exists at some other agencies.

Program Management

The NASA SBIR program has varied over the years in terms of how centralized it is. Until recently, program operations were run at each of the 10 NASA field centers with NASA Headquarters, supported by a national office located at Goddard, focusing on the overall administration of the program. Following NASA's recent reorganization, the program will be less decentralized. It will run through only four field centers (Ames, JPL, Glenn, and Langley) with Ames replacing Goddard as the national office.

Each NASA center has an SBIR Field Center Program Manager who administers the program at the respective center. Contracts are managed by NASA's Contracting Officer at each center with support from the Contract Officer Technical Representative (COTR). The COTR serves as the primary contact within NASA on a contract's technology focus and objectives. Overall program policy, effectiveness, and assessment are the responsibility of the Headquarters Program Executive.

It should be noted that the NRC assessment of SBIR program management at NASA has dealt with a moving target. Because management structures at NASA have changed so extensively, data from past projects are of limited relevance in guiding current management (because structures have already changed since the relevant projects were funded.)

BOX S-1
The Challenge of Assessing SBIR in a Restructuring NASA

As with other parts of NASA, the NASA SBIR program has, experienced sequential waves of reorientation and restructuring. Mission objectives have changed very substantially, far more than at other SBIR agencies.

During NASA's reorganization of 2003-2004, the agency's SBIR program became a component of the Advanced Space Technology Program within the Exploration Systems Mission Directorate (ESMD), which is charged with implementing NASA's planned exploration of Mars and other space exploration projects. In 2006, further reorganization led a change in the balance of management power between the Mission Directorates and the Centers, with the former assuming much more direct authority over SBIR topic and award selection.

Because of this churn, any assessment of program management at NASA must deal with a moving target. Extensive changes in management structures mean that data regarding past activities is of limited relevance in directly guiding current management. However, it provides a basis for NASA to judge if its organizational changes have improved the effectiveness of its SBIR program.

Acquisition and Commercialization

With the appointment of NASA Administrator Michael D. Griffin in 2005, NASA made "spin-in"—the use of SBIR technology by NASA for mission needs—the SBIR program's main priority. The shift to mission-purpose uses is accompanied by other fundamental changes underway at NASA:

- A new Moon-Mars mission, which is altering the relative position of NASA's 10 centers;
- A redesign of NASA's Innovation Partnership Program to reduce fragmentation and to emphasize spin-in[1];
- A new budget model that employs full-cost accounting and incorporates competition for funding among NASA centers; and
- Movement of the Innovation Partnership Program to NASA Headquarters, giving it higher priority status within the agency.

Like DoD (and unlike NSF and NIH) NASA is a procurement agency. However, NASA's SBIR program has not relied solely on procuring the technologies it funds as the only means of fostering commercialization. It has emphasized marketplace commercialization as well as infusion for mission use. Recent changes in NASA have led to a greater emphasis on infusion for mission use or spin-in outcomes. Furthermore, NASA funds companies from diverse industries across

[1]As noted above, the SBIR program is now part of the Innovative Partnership Program (IPP).

BOX S-2
Some Special Features of the NASA SBIR Program

Research Topics. NASA's Mission Directorates conceive and describe the topics each year. Subtopic conception, composition, and development are done by project managers and researchers at the various NASA installations.

Acquisition. Unlike some major participants in the program (e.g. NIH & NSF), NASA seeks to acquire and use many of the technologies and products developed through the program. NASA intends to use SBIR funding increasingly for spin-in and less for spin-out.

Electronic Handbook. Small businesses submit their proposals to NASA through a sophisticated multipurpose online system called *Electronic Handbooks and E-Submission (EHB)*. NASA's Electronic Handbook is a "set of Internet-based tools that support the paperless documentation and management of complex distributed processes," including the SBIR program. EHB helps guide users through the program and provides real-time, online, paperless documentation and process management.

a fairly broad spectrum of technologies presenting a challenge to NASA's SBIR program in achieving its commercialization goals.

Evaluation Culture

NASA has initiated program analysis, experimentation, and evaluation, but a successful effort requires funding and management support over the long term. In 2002, NASA published the results of its Commercial Metrics project, which surveyed all Phase II firms and gathered the commercialization results of NASA SBIR projects. However, this project has been halted pending further funding.

NASA posts numerous "success stories" on its Web site.[2] NASA also develops "quad charts" that describe the technology of an SBIR project and its potential uses.

I. KEY PROGRAM FINDINGS

A. **The NASA SBIR program is making significant progress in achieving the congressional goals for the program.**[3] Keeping in mind NASA's unique mission and the recent significant changes to the program, the SBIR program

[2]Access at <*http://sbir.nasa.gov/SBIR/success.htm*>.
[3]See the Committee's Finding A in Chapter 2.

is sound in concept and effective in practice at NASA.[4] With the programmatic changes recommended here, the SBIR program should be even more effective in achieving its legislative goals.[5]

B. The NASA SBIR program helps its award recipients achieve significant levels of commercialization.[6]

- According to the NRC Phase II Survey, nearly half (some 46 percent) of NASA Phase II projects reach the marketplace and generate revenue.[7] 17.7 percent of those projects with revenues generate revenues greater than $1 million.[8]
- From 1983 to 1996, NASA SBIR projects created goods and services that generated over $2.3 billion in revenues in the private economy.[9]
- A notable feature of NASA commercialization is that 46 percent of all sales resulting from Phase II awards went to markets other than the federal government.[10]

C. SBIR Phase II projects result in substantially useful results for NASA, comparable to other NASA R&D.[11]

- According to a survey of NASA Contracting Officer's Technical Representatives (COTRs):[12]
  - Nearly two-thirds (63 percent) deemed SBIR projects to have significant research value.[13]
  - Over a third (34.6 percent) of surveyed projects resulted were deemed by NASA COTRs to have resulted in a product or service of commercial value.
  - More than two-thirds (68 percent) of COTRs reported that SBIR spending gave the same or more benefits to the agency mission as other NASA R&D projects.

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[4]These changes create discontinuities in program goals that complicate assessment. These important changes are described in the Chapter 5 on Program Management.

[5]These objectives are set out in the Small Business Innovation Development Act (PL 97-219). In reauthorizing the program in 1992, (PL 102-564) Congress expanded the purposes to "emphasize the program's goal of increasing private-sector commercialization developed through federal research and development and to improve the federal government's dissemination of information concerning small business innovation, particularly with regard to woman-owned business concerns and by socially and economically disadvantaged small business concerns."

[6]See the Committee's Finding B in Chapter 2.

[7]See Figure 4-1, which is based on the NRC Phase II Survey.

[8]See Figure 4-2.

[9]See NASA *Commercial Metrics Survey*, October 2002, page 1. Access at <*http://www.sbir.nasa.gov/SBIR/survey.html*>.

[10]See Table 4-1.

[11]See the Committee's Finding C in Chapter 2.

[12]See the NRC Project Manager Survey in Appendix D of this volume.

[13]NRC Project Manager Survey, Table App-D-20.

D. The NASA SBIR program stimulates collaboration, technological innovation and generates new knowledge.[14]

- About a quarter of projects responding to the NRC Phase II Survey reported filing at least one related patent; and a fifth received at least one patent.[15]
- The NASA SBIR program has stimulated links among NASA, small businesses, and universities. Nearly a third (29 percent) of the NRC Phase II Survey respondents reported having university participation in their projects.

E. NASA SBIR provides substantial, frequently decisive, support for small businesses.[16]

- **Firm Initiation.** From the NRC Firm Survey, 20 percent of the NASA respondents stated that they were founded at least in part due to SBIR.[17]
- **Project Initiation.** Over two-thirds (68 percent) of SBIR Phase II award recipients say that they definitely or probably would not have undertaken the funded research project without the SBIR funding.[18]
- **Developmental funding.** Just under half of the respondents (44 percent) received additional funding for their project subsequent to the receipt of the Phase II award.[19]

F. NASA's SBIR program supports the participation of minority- and woman-owned small businesses in innovation research.[20]

- During the 1997-2004 period, minority-owned firms received 12.18 percent of Phase II awards and woman-owned firms received 9.94 percent of Phase II awards (see Figure S-2).
- Participation by minority- and woman-owned firms in the SBIR program did not appear to greatly increase or diminish with time (see Figure S-2).

G. NASA's technology transfer program has shifted recently from a focus on commercialization ("spin-out") to a focus on supplying mission needs ("spin-in" or "infusion.")[21]

- This shift has created significant challenges for the SBIR program.
- The new emphasis on spin-in requires the creation of a new regional in-

[14]See the Committee's Finding D in Chapter 2.
[15]See Table 4-18.
[16]See the Committee's Finding E in Chapter 2.
[17]See NRC Phase II Firm Survey, Question 1.
[18]See Figure 4-8.
[19]See NRC Phase II Survey, Question 22.
[20]See the Committee's Finding F in Chapter 2.
[21]See the Committee's Finding G in Chapter 2.

FIGURE S-2 NASA SBIR Phase II awards, by demographic group, 1997-2004.
SOURCE: National Aeronautics and Space Administration.

frastructure focused on technology acquisition, not technology generation and diffusion.

H. NASA does not provide an appropriate level of resources for assessing the program's performance. Consequently, NASA SBIR program management is not sufficiently data-driven.[22]

- Given the size and scope of its SBIR program, NASA does not provide an appropriate level of resources for monitoring and assessing the program's performance.
- Partly because of lack of sufficient funding, the program is not sufficiently evidence-based. It lacks clear benchmarks and metrics for success. Program evaluation—while recently improved—needs to be enhanced further.

II. KEY PROGRAM RECOMMENDATIONS

A. Additional management resources are needed.[23]

- Effective management and evaluation requires adequate funding. An

[22]See the Committee's Finding I in Chapter 2.
[23]See the Committee's Recommendation D in Chapter 2.

evidence-based program requires high quality data and systematic assessment.

- To enhance program utilization, management, and evaluation, the NASA SBIR program should be provided with additional funding for management and evaluation.

B. NASA should evaluate the impact of NASA's reorganization on SBIR.[24]

- Following the recent agency restructuring, NASA seeks to make "spin-in" the main priority for the SBIR program.
- NASA should study how the new agency orientation towards spin-in will impact SBIR program outcomes.
- The new NASA structure and the Innovative Partnership Program (IPP) should be evaluated in terms of its technology transfer management goals.

C. NASA should develop data for evaluation, conduct regular assessments, and report to Congress.[25]

- The NASA SBIR program should develop a series of specific data objectives—identifying both the data needed to run the program well and the means of acquiring those data.
- Each year, NASA should provide Congress with a summary report on the SBIR program. This annual report should include descriptive statistics for applications, awards, and outcomes along the dimensions identified in this report, including knowledge creation, technology innovation, and impact on agency mission, as well as commercialization.
- NASA should also commission regular external arms-length evaluations to assess the program progress and the impact of new initiative.

D. NASA should consider the creation of an independent Advisory Board.[26]

- This Advisory Board would draw together senior agency management, SBIR managers, and other stakeholders as well as outside experts to review current operations and achievements and recommend changes to the SBIR program.
- The Advisory Board could be assembled on the model of the Defense Science Board (DSB) or perhaps the National Science Foundation's SBIR Advisory Board.[27]

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[24] See the Committee's Recommendation G in Chapter 2.

[25] See the Committee's Recommendation E in Chapter 2.

[26] See the Committee's Recommendation F in Chapter 2.

[27] The intent here is to use the DSB or the NSF SBIR Board as a model, not something necessarily to be copied exactly.

E. NASA should continue to encourage program flexibility and experimentation, followed by evaluation of outcomes.[28]

- NASA should develop an effective program for developing, deploying, and evaluating pilot initiatives.
- NASA should explore how to increase the flexibility of projects, given changes in technology and information.
- Guided by regular assessments of outcomes, NASA should expand the NASA Alliance for Small Business Opportunities (NASBO).
- NASA should evaluate other agencies' approaches to commercialization assistance and adopt the best approaches where applicable.

[28]For the Committee's formal recommendation, see Recommendation C in Chapter 2.

1

Introduction

1.1 SBIR CREATION AND ASSESSMENT

Created in 1982 by the Small Business Innovation Development Act, the Small Business Innovation Research (SBIR) program was designed to stimulate technological innovation among small private-sector businesses while providing the government cost-effective new technical and scientific solutions to challenging mission problems. SBIR was also designed to help to stimulate the U.S. economy by encouraging small businesses to market innovative technologies in the private sector.[1]

As the SBIR program approached its twentieth year of existence, the U.S. Congress requested that the National Research Council (NRC) of the National Academies 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.[2] Mandated as a part of SBIR's renewal in late 2000, the NRC study has assessed the SBIR program as administered at the five federal agencies that together make up 96 percent of SBIR program expenditures. The agencies are, in decreasing order of program size: the Department of Defense (DoD), the

[1]The SBIR legislation drew from a growing body of evidence, starting in the late 1970s and accelerating in the 1980s, which indicated that small businesses were assuming an increasingly important role in both innovation and job creation. This evidence gained new credibility with empirical analysis by Zoltan Acs and David Audretsch of the U.S. Small Business Innovation Data Base, which confirmed the increased importance of small firms in generating technological innovations and their growing contribution to the U.S. economy. See Zoltan Acs and David Audretsch, *Innovation and Small Firms*, Cambridge MA: MIT Press, 1990.

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

National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DoE), and the National Science Foundation (NSF).

The NRC Committee assessing the SBIR program was not asked to consider if SBIR should exist or not—Congress has affirmatively decided this question on three occasions.[3] Rather, the Committee was charged with providing assessment-based findings to improve public understanding of the operations, achievements, and challenges of the program as well as recommendations to improve the program's effectiveness.

1.2 SBIR PROGRAM STRUCTURE

Eleven federal agencies are currently required to set aside 2.5 percent of their extramural research and development budget exclusively for SBIR contracts. Each year these agencies identify various R&D topics, representing scientific and technical problems requiring innovative solutions, for pursuit by small businesses under the SBIR program. These topics are bundled together into individual agency "solicitations"—publicly announced requests for SBIR proposals from interested small businesses. A small business can identify an appropriate topic it wants to pursue from these solicitations and, in response, propose a project for an SBIR grant. The required format for submitting a proposal is different for each agency. Proposal selection also varies, though peer review of proposals on a competitive basis by experts in the field is typical. Each agency then selects the proposals that are found best to meet program selection criteria, and awards contracts or grants to the proposing small businesses.

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

- Phase I grants essentially fund feasibility studies in which award winners undertake a limited amount of research aimed at establishing an idea's scientific and commercial promise. Today, the legislative guidance anticipates normal Phase I grants around $100,000.[4]
- Phase II grants are larger—typically about $750,000—and fund more extensive R&D to develop the scientific and commercial promise of research ideas.
- Phase III. During this phase, companies do not receive additional funding from the SBIR program. Instead, grant recipients should be obtaining additional funds from a procurement program at the agency that made the award, from pri-

[3]These are the 1982 Small Business Development Act, and the subsequent multiyear reauthorizations of the SBIR program in 1992 and 2000.

[4]With the agreement of the Small Business Administration, which plays an oversight role for the program, this amount can be substantially 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.

vate investors, or from the capital markets. The objective of this phase is to move the technology from the prototype stage to acquisition or the marketplace.

Obtaining Phase III support is often the most difficult challenge for new firms to overcome. In practice, agencies have developed different approaches to facilitate SBIR grantees' transition to commercial viability; not least among them are encouraging applications for additional competitively awarded SBIR grants.

Previous NRC research has shown that firms have different objectives in applying to the program. Some want to demonstrate the potential of promising research but may not seek to commercialize it themselves. Others think they can fulfill agency research requirements more cost-effectively through the SBIR program than through the traditional procurement process. Still others seek a certification of quality (and the private investments that can come from such recognition) as they push science-based products towards commercialization.[5]

1.3 SBIR REAUTHORIZATIONS

The SBIR program approached reauthorization in 1992 amidst continued concerns 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.[6]

Following this report, the Small Business Research and Development Enhancement Act (P.L. 102-564), which reauthorized the SBIR program until September 30, 2000, doubled the set-aside rate to 2.5 percent.[7] 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 tech-

[5]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*, Charles W. Wessner, ed., Washington, DC: National Academy Press, 2000.

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

[7]For fiscal year 2005, this has resulted in a program budget of approximately $1.85 billion across all federal agencies, with the Department of Defense (DoD) having the largest SBIR program at $943 million, followed by the National Institutes of Health (NIH) at $562 million. The DoD SBIR program, is made up of ten participating components: 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 separate institutes and agencies making SBIR awards, many with multiple programs.

nologies.[8] 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.

The 1992 legislation mandated that program administrators consider the existence of second-phase funding commitments from the private sector or other non-SBIR sources when judging Phase II applications. Evidence of third-phase follow-on commitments, along with other indicators of commercial potential, was also to be sought. Moreover, the 1992 reauthorization directed that a small business' record of commercialization be taken into account when evaluating its Phase II application.[9]

The Small Business Reauthorization Act of 2000 (P.L. 106-554) extended SBIR until September 30, 2008. It called for this assessment by the National Research Council of the broader impacts of the program, including those on employment, health, national security, and national competitiveness.[10]

1.4 STRUCTURE OF THE NRC STUDY

This NRC assessment of SBIR has been conducted in two phases. In the first phase, at the request of the agencies, a formal report on research methodology was to be developed by the NRC. Once developed, this methodology was then reviewed and approved by an independent National Academies panel of experts.[11] Information about the program was also gathered through interviews with SBIR program administrators and during four major conferences where SBIR officials

[8]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," in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*, op. cit. pp. 211-250.

[9]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, *Federal Research: Evaluations of Small Business Innovation Research Can Be Strengthened*, AO/RCED-99-114, Washington, DC: U.S. General Accounting Office, 1999.

[10]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*>.

[11]The SBIR methodology report is available on the Web. Access at <*http://www7.nationalacademies.org/sbir/SBIR_Methodology_Report.pdf*>.

were invited to describe program operations, challenges, and accomplishments.[12] These conferences highlighted the important differences in each agency's SBIR program's goals, practices, and evaluations. The conferences also explored the challenges of assessing such a diverse range of program objectives and practices using common metrics.

The second phase of the NRC study implemented the approved research methodology. The Committee deployed multiple survey instruments and its researchers conducted case studies of a wide profile of SBIR firms. The Committee then evaluated the results and developed both agency-specific and overall findings and recommendations for improving the effectiveness of the SBIR program. The final report includes complete assessments for each of the five agencies and an overview of the program as a whole.

1.5 SBIR ASSESSMENT CHALLENGES

At its outset, the NRC's SBIR study identified a series of assessment challenges that must be addressed. As discussed at the October 2002 conference that launched the study, the administrative flexibility found in the SBIR program makes it difficult to make cross-agency comparisons. Although each agency's SBIR program shares the common three-phase structure, the SBIR concept is interpreted uniquely at each agency. This flexibility is a positive attribute in that it permits each agency to adapt its SBIR program to the agency's particular mission, scale, and working culture. For example, NSF operates its SBIR program differently than DoD because "research" is often coupled with procurement of goods and services at DoD but rarely at NSF. Programmatic diversity means that each agency's SBIR activities must be understood in terms of its separate missions and operating procedures. This diversity is commendable but, operationally, makes the task of assessing the program more challenging.

A second challenge concerns the linear process of commercialization implied by the design of SBIR's three-phase structure.[13] In the linear model, illustrated in Figure 1-1, innovation begins with basic research supplying a steady stream

[12]The opening conference on October 24, 2002, examined the program's diversity and assessment challenges. For a published report of this conference, see National Research Council, *SBIR: Program Diversity and Assessment Challenges*, Charles W. Wessner ed., Washington, DC: The National Academies Press, 2004. A second conference, held on March 28, 2003, was titled, "Identifying Best Practice." The conference provided a forum for the SBIR Program Managers from each of the five agencies in the study's purview to describe their administrative innovations and best practices. A conference on June 14, 2005, focused on the commercialization of SBIR-funded innovations at DoD and NASA. See National Research Council, *SBIR and the Phase III Challenge of Commercialization*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007. A final conference, held on April 7, 2006, examined role of the state programs in leveraging SBIR to advance local and regional economic growth.

[13]This view was echoed by Duncan Moore: "Innovation does not follow a linear model. It stops and starts." National Research Council, *SBIR: Program Diversity and Assessment Challenges*, op. cit.

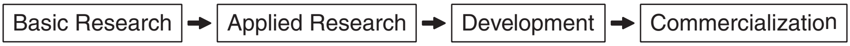

FIGURE 1-1 The linear model of innovation.

of fresh and new ideas. Among these ideas, those that show technical feasibility become innovations. Such innovations, when further developed by firms, become marketable products driving economic growth.

As NSF's Joseph Bordogna observed at the launch conference, innovation almost never takes place through a protracted linear progression from research to development to market.[14] Research and development drives technological innovation, which, in turn, opens up new frontiers in R&D.[15] True innovation, Bordogna noted, can spur the search for new knowledge and create the context in which the next generation of research identifies new frontiers. This nonlinearity, illustrated in Figure 1-2, makes it difficult to rate the efficiency of SBIR program. Inputs do not match up with outputs according to a simple function. Figure 1-2, while more complex than Figure 1-1 is itself a highly simplified model. For example, feedback loops can stretch backwards or forwards by more than one level.

A third assessment challenge relates to the measurement of outputs and outcomes. Program realities can and often do complicate the task of data gathering. In some cases, for example, SBIR recipients receive a Phase I award from one agency and a Phase II award from another. In other cases, multiple SBIR awards may have been used to help a particular technology become sufficiently mature to reach the market. Also complicating matters is the possibility that for any particular grantee, an SBIR award may be only one among other federal and non-federal sources of funding. Causality can thus be difficult, if not impossible, to establish.

The task of measuring outcomes is made harder because companies that have garnered SBIR awards can also merge, fail, or change their names before a product reaches the market. In addition, principal investigators or other key individuals can change firms, carrying their knowledge of an SBIR project with them. A technology developed using SBIR funds may eventually achieve commercial success at an entirely different company than that which received the initial SBIR award.

Complications plague even the apparently straightforward task of assessing commercial success. For example, research enabled by a particular SBIR award may take on commercial relevance in new unanticipated contexts. At the launch conference, Duncan Moore, former Associate Director of Technology at the

[14] While few hold this process of linear innovation to be literally true, the concept nonetheless survives—for example, in retrospective accounts of the path taken by a particular innovation.

[15] See Donald E. Stokes, *Pasteur's Quadrant, Basic Science and Technological Innovation*, Washington, DC: The Brookings Institution, 1997. Stokes' analysis challenges the artificial separation between basic and applied research underpinning the myth of linear innovation.

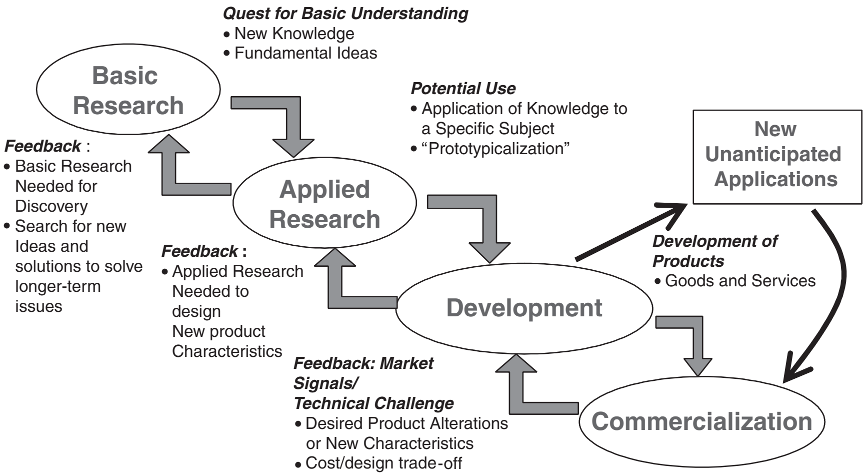

FIGURE 1-2 A feedback model of innovation.

BOX 1-1
SBIR and the Luna Innovation Model

Developed by Kent Murphy who founded Luna in rural southern Virginia, the Luna model uses multiple flexible funding instruments, both public and private including SBIR, the Advanced Technology Program (ATP), venture capital, corporate partners, and internal funding to develop and commercialize ideas that were originally generated at universities or with commercial partners.

Securing venture capital funding can be difficult even in the best of times; Luna received only two small investments during the late 1990s bubble. Venture capital firms tend to be highly specialized geographically, and Luna's southern Virginia location has minimal local venture funding.[a] The path to technical and financial success is often complex for new technologies, especially those located in more rural areas distant from high-tech clusters.

In one example, Luna Energies built its basic technology with funding from prime contractors and then used SBIR funding to develop applications for NASA and the Air Force. Eventually, it developed civilian applications for the energy industry, leading to its purchase by an energy company. According to Murphy, innovation awards from both SBIR and ATP were "critical" to Luna's success.[b]

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[a]See John Freear, Jeffrey Sohl, and William Wetzel, "Angles on Angels: Financing Technology-based Ventures—A Historical Perspective, *Venture Capital*, 4(4):275-287, 2002.

[b]Luna Innovations is now a public company, following an IPO on June 9, 2006.

White House Office of Science and Technology Policy (OSTP), cited the case of SBIR-funded research in gradient index optics that was initially considered a commercial failure when an anticipated market for its application did not emerge. Years later, however, products derived from the research turned out to be a major commercial success.[16] Today's apparent dead end can be a lead to a major achievement tomorrow. Lacking clairvoyance, analysts cannot anticipate or measure such potential SBIR benefits.

Gauging commercialization is also difficult when the product in question is destined for public procurement. The challenge is to develop a satisfactory measure of how useful an SBIR-funded innovation has been to an agency mission. A related challenge is determining how central (or even useful) SBIR awards have proved in developing a particular technology or product. In some cases, the Phase I award can meet the agency's need—completing the research with no further action required. In other cases, surrogate measures are often required. For example, one way of measuring commercialization success is to count the products developed using SBIR funds that are procured by an agency such as DoD. In practice, however, large procurements from major suppliers are typically easier to track than products from small suppliers such as SBIR firms. Moreover, successful development of a technology or product does not always translate into successful "uptake" by the procuring agency. Often, the absence of procurement may have little to do with the product's quality or the potential contribution of SBIR.

Understanding failure is equally challenging. By its very nature, an early-stage program such as SBIR should anticipate a high failure rate. The causes of failure are many. The most straightforward, of course, is *technical failure*, where the research objectives of the award are not achieved. In some cases, the project can be a technically successful but a commercial failure. This can occur when a procuring agency changes its mission objectives and hence its procurement priorities. NASA's new Mars Mission is one example of a *mission shift* that may result in the cancellation of programs involving SBIR awards to make room for new agency priorities. Cancelled weapons system programs at the Department of Defense can have similar effects. Technologies procured through SBIR may also *fail in the transition to acquisition*. Some technology developments by small businesses do not survive the long lead times created by complex testing and certification procedures required by the Department of Defense. Indeed, small firms encounter considerable difficulty in penetrating the "procurement thicket" that characterizes defense acquisition.[17] In addition to complex federal acquisi-

[16]Duncan Moore, "Turning Failure into Success," in National Research Council, *SBIR: Program Diversity and Assessment Challenges*, op. cit., p. 94.

[17]For a description of the challenges small businesses face in defense procurement, the subject of a June 14, 2005, NRC conference and one element of the congressionally requested assessment of SBIR, see National Research Council, *SBIR and the Phase III Challenge of Commercialization*, op. cit. Relatedly, see remarks by Kenneth Flamm on procurement barriers, including contracting

tion procedures, there are strong disincentives for high-profile projects to adopt untried technologies. Technology transfer in commercial markets can be equally difficult. A *failure to transfer to commercial markets* can occur even when a technology is technically successful if the market is smaller than anticipated, competing technologies emerge or are more competitive than expected, if the technology is not cost-competitive, or if the product is not adequately marketed. Understanding and accepting the varied sources of project failure in the high-risk, high-reward environment of cutting-edge R&D is a challenge for analysts and policymakers alike.

This raises the issue concerning the standard on which SBIR programs should be evaluated. An assessment of SBIR must take into account the expected distribution of successes and failures in early-stage finance. As a point of comparison, Gail Cassell, Vice President for Scientific Affairs at Eli Lilly, has noted that only one in ten innovative products in the biotechnology industry will turn out to be a commercial success.[18] Similarly, venture capital funds often achieve considerable commercial success on only two or three out of twenty or more investments.[19]

In setting metrics for SBIR projects, therefore, it is important to have a realistic expectation of the success rate for competitive awards to small firms investing in promising but unproven technologies. Similarly, it is important to have some understanding of what can be reasonably expected—that is, what constitutes "success" for an SBIR award, and some understanding of the constraints and opportunities successful SBIR awardees face in bringing new products to market. From the management perspective, the rate of success also raises the question of appropriate expectations and desired levels of risk taking. A portfolio that always succeeds would not be investing in high risk, high pay-off projects that push the technology envelope. A very high rate of "success" would, thus, paradoxically suggest an inappropriate use of the program. Understanding the nature of success and the appropriate benchmarks for a program with this focus is therefore important to understanding the SBIR program and the approach of this study.

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overhead and small firm disadvantages in lobbying in National Research Council, *SBIR: Program Diversity and Assessment Challenges*, op. cit., pp. 63-67.

[18]Gail Cassell, "Setting Realistic Expectations for Success." Ibid, p. 86.

[19]See John H. Cochrane, "The Risk and Return of Venture Capital," *Journal of Financial Economics*, 75(1):3-52, 2005. Drawing on the VentureOne database Cochrane plots a histogram of net venture capital returns on investments that "shows an extraordinary skewness of returns. Most returns are modest, but there is a long right tail of extraordinary good returns. Fifteen percent of the firms that go public or are acquired give a return greater than 1,000 percent! It is also interesting how many modest returns there are. About 15 percent of returns are less than 0, and 35 percent are less than 100 percent. An IPO or acquisition is not a guarantee of a huge return. In fact, the modal or "most probable" outcome is about a 25 percent return." See also Paul A. Gompers and Josh Lerner, "Risk and Reward in Private Equity Investments: The Challenge of Performance Assessment," *Journal of Private Equity*, 1 (Winter 1977):5-12. Steven D. Carden and Olive Darragh, "A Halo for Angel Investors" *The McKinsey Quarterly*, 1, 2004, also show a similar skew in the distribution of returns for venture capital portfolios.

1.6 SBIR AT NASA

With $103 million in annual awards in 2005, NASA operates the fourth largest SBIR program in the federal government. Currently, NASA SBIR Phase I award is set at a maximum of $100,000 and lasts for six months. A Phase II award is set at a maximum of $600,000 and lasts for a period of up to two years. NASA has not yet adopted the Phase IIB or Phase II Plus or Fast Track option that exists at some other agencies.

The NASA SBIR program has varied over the years in terms of how centralized it is. Until recently, program operations were run at each of the ten NASA field centers with NASA Headquarters, supported by a national office located at Goddard, focusing on the overall administration of the program. Following NASA's recent reorganization, the program will be less decentralized. It will run through only four field centers (Ames, JPL, Glenn, and Langley) with Ames replacing Goddard as the national office.

Each NASA center has an SBIR Field Center Program Manager who administers the program at the respective center. Contracts are managed by NASA's Contracting Officer at each center with support from the Contract Officer Technical Representative (COTR). The COTR serves as the primary contact within NASA on a contract's technology focus and objectives. Overall program policy, effectiveness, and assessment are the responsibility of the Headquarters Program Executive.

The impetus of the 2006 reorganization is to refocus SBIR on the NASA's core mission objective, deemphasizing the commercialization outside of NASA. Interviews with Mission Directorate liaisons indicate that, because of the reorganization, the balance of power between the Centers and Headquarters changed substantially in FY2005-2006.

The reorganization is intended to address dissatisfaction with the outcomes of the previous approach. For example, the 2002 *Commercial Metrics* report (covering 1983-1996) found that only about six percent of NASA's 1,739 SBIR Phase II awards during this period supported technologies that were eventually infused into NASA or other federal programs *via* Phase III funding.[20]

The reorganization also reflects changing needs and priorities within NASA. The addition of new missions and the expansion of existing ones have placed additional demands on Mission Directorates, squeezing funding for basic research.

As a result of the reorganization, Mission Directorates are now focusing on aligning research funded through SBIR with specific technologies that can be taken up (or in NASA-speak "infused") into the their own technology development programs. Whereas commercialization was the primary priority of NASA's SBIR program (or, at least, a priority equal to the support for the agency's mission), the focus of the program since the 2006 reorganization is

[20]"Phase III funding" comprises contractual or other monies awarded to a SBIR project for federal agency use of the subject technology after expiration of a SBIR Phase II award.

squarely on support for the NASA mission. For SBIR, this involves finding and developing technologies that can help NASA meet its very specific needs and requirements.

Overall, this new clarity of focus appears to be a positive development. As described in some detail in Chapter 4 (Outcomes), the low volume and high degree of specificity (e.g., space-hardiness) required to meet NASA's needs makes it less likely that SBIR funded technologies can spin off into commercial sales.[21]

1.7 ASSESSING SBIR AT NASA

In gathering and analyzing the data to assess the SBIR program at NASA, the Committee drew on the following set of research questions:

- How successful has NASA SBIR program been in *commercializing technologies* supported by Phase I and Phase II awards (and what are the factors that have contributed to or inhibited this level of commercialization)?
- To what extent has NASA SBIR program supported NASA's *mission* (and what are the factors that have contributed to or inhibited this level of support)?
- To what extent has NASA SBIR program *stimulated innovation*.
- How well has the NASA SBIR program encouraged *small firms* and supported the growth and development of woman- and minority-owned businesses?
- How effective has NASA's *management* of the SBIR program been (and how might this management be improved)?

1.7.1 Surveys of NASA SBIR Award-recipient Companies

Original data gathered by the research team in support of the NRC study of NASA SBIR program included a survey of NASA Phase II award-recipient firms; a survey NASA Phase I award-recipient firms that did not also receive a Phase II award; a survey of NASA technical staff involved in the SBIR program; numerous interviews with NASA personnel directly involved in administering the SBIR program; the assessment and analysis of data provided by NASA's SBIR staff; and company case studies.

[21]Of course, some companies have made its transition successfully, but overall, there are significant structural impediments standing against successful commercialization from NASA SBIR project—as opposed for example to DoD, where there may be a huge potential market within the agency, or NIH where the private-sector market for SBIR-funded technologies is also potentially enormous.

BOX 1-2
A Moving Target: The Challenge of Assessing SBIR in a Restructuring NASA

As with other parts of NASA, the NASA SBIR program has, experienced sequential waves of reorientation and restructuring. Mission objectives have changed very substantially, far more than at other SBIR agencies.

During NASA's reorganization of 2003-2004, the agency's SBIR program became a component of the Advanced Space Technology Program within the Exploration Systems Mission Directorate (ESMD), which is charged with implementing NASA's planned exploration of Mars and other space exploration projects. In 2006, further reorganization led a change in the balance of management power between the Mission Directorates and the centers, with the former assuming much more direct authority over SBIR topic and award selection.

Because of this churn, any assessment of program management at NASA must deal with a moving target. Extensive changes in management structures mean that data regarding past activities is of limited relevance in guiding current management.

The NRC Phase II Survey (Appendix B)

In Spring 2005, the National Research Council administered a survey of Phase II SBIR projects across agencies as part of its congressionally mandated evaluation of the SBIR program. The survey targeted a sample of Phase II awards that were awarded through 2001. A large majority of Phase II awards would have been completed by the 2005 survey date, and at least some commercialization efforts could have been initiated.

There may be some biases in these data. Projects from firms with multiple awards were underrepresented in the sample, because they could not be expected to complete a questionnaire for each of possibly numerous awards received; but they may have been overrepresented in the responses because they might be more committed to the SBIR program. Nearly 40 percent of respondents began Phase I efforts after 1998, partly because the number of Phase I awards increased, starting in the late 1990s, and partly because winners from more distant years are harder to reach, as small businesses regularly cease operations, staff with knowledge of SBIR awards leave, and institutional knowledge erodes.

The NRC Phase I Survey (Appendix C)

The Committee conducted a second recipient survey, in an attempt to determine the impact of Phase I awards that did not go on to Phase II. The original sample for this Phase I study was the 3,363 NASA Phase I awards from 1992-2001 inclusive. Valid responses were received from 303 NASA Phase I projects that did not advance to Phase II.

Survey of NASA Project Managers (Appendix D)

The technical project managers of individual SBIR projects can provide unique perspectives on the SBIR program. The project managers were surveyed electronically in three agencies—DoD, DoE, and NASA.

The NRC Project Manager Survey was based on Phase II projects awarded during the study period (1992-2001 inclusive). Project managers for these projects were identified with the help of the agencies. As expected, there was significant attrition (due to absence of email addresses, inability to identify the project manager, the project manager having left the agency or deceased, etc.). The three agencies were able to locate the names and email addresses of project managers for 2,584 projects. Of these, responses were received for 513 projects (a 20 percent response rate), of which 82 were for NASA projects (a 30 percent response rate). It should be noted that the number of individuals responding was fewer than the number of projects because some project managers had oversight for multiple projects. The NASA sample was based on projects since 1997 only.

1.7.2 Case Studies (Appendix E)

Case studies can provide valuable insights concerning the viewpoints and concerns of the small businesses that participate in SBIR, insights that cannot be derived from statistical analysis. While all of the companies selected for case study won SBIR awards from NASA, most also won awards from other agencies as well. The interviews concerned their SBIR experience as a whole, and were not limited to NASA program.

Candidate case study firms were selected from four lists: top recipients of SBIR awards from NASA; NASA SBIR awardees who received R&D 100 awards; NASA identified "success stories"; and firms with large commercial sales as reported as reported to NASA SBIR program. The selected case studies include firms from a variety of locations, across a range of founding dates, having received different numbers of SBIR awards received, and representing a variety of technological domains.

The case studies highlight the ways companies use the SBIR program: the extent to which SBIR is important to their company's survival and growth, whether and how they intend to commercialize SBIR technology, whether and how the receipt of multiple awards influence their ability to commercialize, what challenges they have faced in the commercialization process, in what way they see the SBIR program serving the needs of technology entrepreneurs and how they believe the program can be improved. In addition, the cases provide insight

BOX 1-3
Three Company Profiles from the Case Studies

The case studies reported in Appendix E highlight the variety of technologies, businesses and uses for SBIR awards. As the cases highlighted in this box show, they improve our understanding of how firms view the SBIR program in practice and what role it plays in meeting the diverse missions of the federal government.

Creare, Inc. This privately held engineering services company located in Hanover NH was founded with a focus on engineering problem-solving. To date Creare has spawned a dozen spin-offs that employ over 1,500 people in the Hanover region and that generate revenues in excess of $250 million.

Creare specializes in solving agency-initiated problems. For example, when the Hubble space telescope failed due to an unexpectedly rapid depletion of solid nitrogen used to cool it, Creare was able to solve this problem for NASA by drawing on its knowledge of cryogenic refrigeration technologies developed through SBIR funded research.

Technology Management, Inc. The case study of this Cleveland firm illustrates the significance of SBIR as a source of early-stage funding. TMI used SBIR to support the basic and applied research necessary to prove its Solid Oxide Fuel Cell (SOFC) technology. The case also draws attention to the potential impact on the SBIR program of NASA's new emphasis on spinning-in technologies from outside. By focusing on harvesting technologies with a higher readiness level for NASA's near-term use, TMI's CEO argues that spin-in erodes support for seeding technology development with a focus on long-term private-sector commercialization.

ARACOR. ARACOR's mobile x-ray inspection system (Eagle) is now being used to inspect containers and trucks at the nation's ports and borders for contraband. In less than 30 seconds, the Eagle can scan a densely loaded 20-foot container using full penetration and resolution. ARACOR has over $25 million in sales.

According to the firm's founder, SBIR awards (78 Phase I and 42 Phase II awards from NSF, DoD, and NASA) played a very important role in developing the Eagle's computed tomography (CT) technology. He pointed out that "SBIR is a brick, not a building." A combination of SBIR awards were used to build the CT industrial inspection technology. ARACOR was purchased in 2004 by OSI Systems, Inc. (a NASDAQ company) and is now known as Rapiscan Systems High Energy Inspection Corporation.

as to how the NASA's administration of the SBIR impacts on the program's outcomes.

1.8 OUTLINE OF THE REMAINDER OF THE REPORT

This report sets out the Committee's assessment of the SBIR program at the National Aeronautics and Space Administration. The Committee's detailed findings and recommendations are presented in the next chapter. The Committee finds that the NASA SBIR program largely meets it legislative objectives and makes recommendations to improve program outcomes. Chapter 3 reviews awards made by NASA. Chapter 4 looks at the outcomes of the NASA SBIR program, including commercial sales and employment effects. Chapter 5 examines how the SBIR program at NASA is managed. Appendix A presents program data collected by NASA. Appendix B and C provide the template and results of the NRC Firm Survey and the NRC surveys of SBIR Phase I and Phase II projects. Appendix D provides the results of the survey of agency project managers. Appendix E presents illustrative case studies of firms participating in the NASA SBIR program. Finally, Appendix F provides a reference bibliography.

2

Findings and Recommendations

I. NATIONAL RESEARCH COUNCIL STUDY FINDINGS

The NASA SBIR program is making significant progress in achieving the congressional goals for the program. Keeping in mind NASA's unique mission and the recent significant changes to the program, the SBIR program is sound in concept and effective in practice at NASA.[1] With the programmatic changes recommended here, the SBIR program should be even more effective in achieving its legislative goals.[2]

A. Overall, the program has made significant progress in achieving its congressional objectives by:

- Increasing private-sector commercialization of innovations derived from federal research and development. (See Finding B.)
- Using small business to meet federal research and development needs. (See Finding C.)
- Stimulating technological innovation. (See Finding D.)

[1]These changes create discontinuities in program goals that complicate assessment. These important changes are described in Chapter 5 on Program Management.

[2]These objectives are set out in the Small Business Innovation Development Act (PL 97-219). In reauthorizing the program in 1992, (PL 102-564) Congress expanded the purposes to "emphasize the program's goal of increasing private-sector commercialization developed through federal research and development and to improve the Federal government's dissemination of information concerning small business innovation, particularly with regard to woman-owned business concerns and by socially and economically disadvantaged small business concerns."

- Fostering and encouraging participation by minority and disadvantaged persons in technological innovation. (See Finding E.)

B. The NASA SBIR program helps its award recipients achieve significant levels of commercialization, as shown by the following metrics:

- **Market sales.**
  - According to the NRC Phase II Survey, nearly half (46 percent) of NASA Phase II projects reach the marketplace and generate revenue.[3]
  - 17.7 percent of projects generate revenues greater than $1 million.[4]
- **Substantial revenues.**
  - According to the NASA Commercial Metrics Survey, from 1983 to 1996, NASA SBIR projects created goods and services that generated over $2.3 billion in revenues in the private economy.[5]
  - Nearly half (46 percent) of all sales resulting from Phase II awards went to markets other than the federal government.[6]
- **Commercial success is concentrated.**
  - For the NASA SBIR Phase II projects reporting sales greater than $0, average sales per project were $1,154,156. Commercial success is highly concentrated with about 40 percent of the total sales dollars resulting from two NASA projects that had $5,000,000 or more in sales. The highest cumulative sales figure reported was $15,000,000.[7]
  - This skewed pattern is also evident in private-sector early-stage finance.[8]
- **Balanced sales.**
  - Phase III sales by NASA SBIR recipients appear to be roughly balanced between the private sector (47 percent) and the federal government (53 percent). (See Figure 2-1.)

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[3]See Figure 4-1.

[4]See Figure 4-2.

[5]See *NASA Commercial Metrics Survey*, October 2002, p. 8. Accessed at <*http://www.sbir.nasa.gov/SBIR/survey.html*>.

[6]See Table 4-1 on Percentage of Sales by Type of Customer.

[7]See Figure 4-2 for the distribution of projects with sales greater than zero dollars.

[8]See John H. Cochrane, "The Risk and Return of Venture Capital," *Journal of Financial Economics*, 75(1):3-52, 2005. Drawing on the VentureOne database Cochrane plots a histogram of net venture capital returns on investments that "shows an extraordinary skewness of returns. Most returns are modest, but there is a long right tail of extraordinary good returns. Fifteen percent of the firms that go public or are acquired give a return greater than 1,000 percent! It is also interesting how many modest returns there are. About 15 percent of returns are less than 0, and 35 percent are less than 100 percent. An IPO or acquisition is not a guarantee of a huge return. In fact, the modal or "most probable" outcome is about a 25 percent return." See also Paul A. Gompers and Josh Lerner, "Risk and Reward in Private Equity Investments: The Challenge of Performance Assessment," *Journal of Private Equity*, 1 (Winter 1977):5-12. Steven D. Carden and Olive Darragh, "A Halo for Angel Investors" *The McKinsey Quarterly*, 1, 2004, also show a similar skew in the distribution of returns for venture capital portfolios.

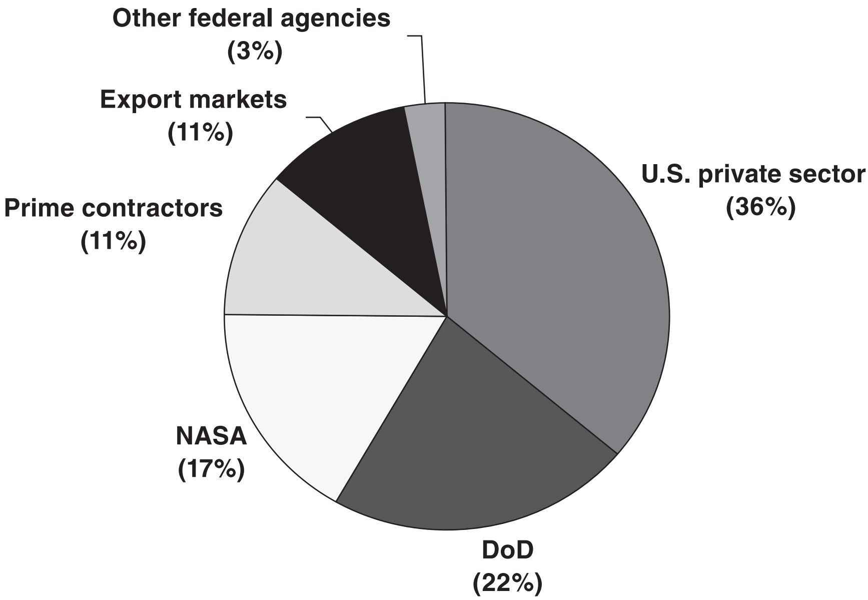

FIGURE 2-1 Distribution of NASA SBIR Phase III sales by customer.
SOURCE: NRC Phase II Survey.

C. SBIR Phase II projects result in substantially useful results for NASA.

1. SBIR projects create valuable commercial and research outcomes.

- According to the NRC Project Manager Survey:[9]
  - Sixty-three percent of surveyed projects were deemed by NASA's Contracting Officer's Technical Representatives (COTR) to have significant noncommercial, intrinsic research value.[10]
  - 34.6 percent of surveyed projects resulted were deemed by NASA COTRs to have resulted in a product or service of commercial value.[11]

2. SBIR Phase II projects are linked to NASA missions.

- According to the NRC Project Manager Survey:[12]
  - About a quarter (26 percent) of NASA project managers who responded to the survey reported that the SBIR-funded project "produced results that have been useful to us, and we have tried to

[9]See Project Manager Survey, Appendix D.
[10]See Question 14 and Table App-D-20 of the Project Manager Survey.
[11]See Table App-D-24 of the Project Manager Survey.
[12]See Table App-D-12 of the Project Manager Survey.

follow up on the ideas initiated in this SBIR contract by encouraging the firm to apply for additional SBIR awards."

- ◦ Another third of NASA project managers responding to the NRC Program Manager Survey noted that the SBIR project "produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract in other research we conduct or sponsor."

3. NASA's SBIR research is ranked less favorably than traditional NASA research.

- According to the NRC Project Manager Survey:[13]
    - ◦ COTRs were asked to rank their SBIR projects in terms of quality on a scale of 1 to 10. The mean score for SBIR is 6.98 (with a standard deviation of 1.846) and the mean score for non-SBIR is 7.45 (with a standard deviation of 1.268).[14]
    - ◦ In all, 57 percent of those surveyed said that SBIR Phase II project produced useful results for the agency.[15]

4. SBIR projects give NASA value for money:

- According to the NRC Project Manager Survey:
    - ◦ A little more than two-thirds of COTRs (68 percent) saw that SBIR spending gave the same or more benefits to the agency mission as other NASA R&D projects.[16]
    - ◦ A majority of COTRs (56 percent) received more quality Phase II proposals than they could fund.[17]
    - ◦ Another fifth of COTRs (23 percent) thought that the balance of funding available and good applications is about right.[18]

D. The NASA SBIR program stimulates collaboration, technological innovation and generates new knowledge.

1. The NASA SBIR program has successfully supported the creation and diffusion of knowledge by small companies:

- **Patents.** A quarter of projects responding to the NRC Phase II Survey reported filing at least one related patent; a fifth received at least one patent.[19]

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[13] See Tables 4-7, 4-8, 4-9 and 4-10.

[14] While these data indicate that project managers viewed the quality of non-SBIR research more favorably, this result is driven by outliers: 6.1 percent of the respondents rank SBIR projects at a score of three or below compared to 0.0 percent for non-SBIR projects.

[15] See Table App-D-12 of the Project Manager Survey.

[16] See Table App-D-13 of the Project Manager Survey.

[17] See Table App-D-14 of the Project Manager Survey.

[18] Ibid.

[19] See Table 4-18.

- **Publications.** Respondents to the relevant question in the NRC Phase II Survey reported that peer-reviewed articles were published because of the SBIR-supported work.[20]

2. **The NASA SBIR program has stimulated links among NASA, small businesses, and universities.**
   - Just under a third of NRC Phase II Survey respondents (29 percent) reported having university participation in their projects had the following interactions with universities.[21]
     - PI was faculty/adjunct (3 percent).
     - Faculty participated as consultants (17 percent).
     - Graduate students participated (15 percent).
     - University facilities/equipment used (13 percent).
     - Technology licensed from university (2 percent).
     - Technology developed at university by participant (4 percent).
     - University was subcontractor on Phase II (16 percent).

E. **NASA SBIR provides substantial support for small businesses, stimulating entrepreneurship, new business formation and employment.**

1. **Awards stimulate significant small businesses formation.**
   - From the NRC Firm Survey, 20 percent of the respondents stated that they were founded at least in part due to SBIR.[22]
   - Firsthand accounts of this can be seen in several of the NASA-related firms interviewed for case studies. They noted that their firm was founded either because of SBIR and/or attribute significant growth of the firm to the impact of the SBIR award.[23]

2. **Employment growth is positively correlated with SBIR.**[24]
   - From the NRC Phase II Survey, half of the responding firms reported that they were in the smallest size group (one to five employees) at the time of their first Phase II award.
   - Only 22 percent remained at that size at the time of the survey. All other (larger) size groups have increased in percent of reporting firms.

3. **The NASA SBIR program supports both seasoned entrepreneurs and academic researchers with little experience in the commercial world.**

[20] See Table 4-19. Some 161 respondents reported 220 articles.

[21] See NRC Phase II Survey, Question 31 and Table 4-22.

[22] See NRC Firm Survey, Question 1.

[23] See, for example, the case studies of AeroSoft, Inc., and Deformation Technology Control, Inc., in Appendix E.

[24] See Table 4-5.

- Based on results from the NRC Firm Survey, over a quarter (28 percent) of the respondent firms had no founders with a business background.
- For 26 percent of the firms, at least one founder had an academic background.[25]
- Private companies (65 percent) and universities or colleges (36 percent) are the source of the most recent employment for most of the firm founders.[26]
- Several of the NASA-related firm case studies are consistent with these survey findings.[27]

4. **SBIR prompts the project initiation decision.**
   - Over two-thirds (68 percent) of SBIR Phase II award recipients say that they definitely or probably would *not* have undertaken the funded research project without the SBIR funding.[28]
   - While the impact of the award is significant, just under a fifth of the respondents to the NRC Phase II Survey (18 percent) said that the project probably or definitely would have occurred even without the SBIR award.[29]

5. **SBIR enhances the scope and progress of projects.**
   - Forty-three percent of respondents stated that the project would have been narrower in scope without the SBIR award.[30]
   - Over half responded that the project would have been behind the current schedule in the absence of SBIR funding.[31]

6. **SBIR may also help small businesses obtain additional developmental funding for their projects.**
   - A significant percent of the survey respondents (44 percent) received additional funding for their project subsequent to the receipt of the Phase II award.[32]
   - Non-SBIR federal funds (average of $133,829) and intrafirm funds (average of $100,450) made up the majority of the development funding for the respondents.[33]
   - Further federal non-SBIR funding for NASA amounted to 48 percent of all additional funding for development.[34]

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[25]NRC Firm Survey, Question 2.
[26]NRC Firm Survey, Question 3.
[27]See, for example, the case study of Mainstream Engineering Corporation in Appendix E.
[28]See NRC Phase II Survey, Question 13.
[29]Ibid.
[30]See NRC Phase II Survey, Question 14.
[31]See NRC Phase II Survey, Question 15c.
[32]See NRC Phase II Survey, Question 22.
[33]See NRC Phase II Survey, Question 23.
[34]See NRC Phase II Survey, Question 23.

- This feature is also documented in the case studies where several firms indicated that SBIR had a positive effect on securing other federal financing.[35]

F. NASA's SBIR program supports the participation of minority- and woman-owned small businesses in innovation research.

- During the 1997-2004 period, minority-owned firms received 12.18 percent of Phase II awards and woman-owned firms received 9.94 percent of Phase II awards.[36]
- Participation by minority- and woman-owned firms in the SBIR program did not appear to greatly increase or diminish with time (see Figure 2-2).

G. The recent shift in NASA's technology transfer program from a focus on commercialization ("spin-out") to a focus on supplying mission needs ("spin-in" or "infusion") will create significant challenges for the SBIR program.

1. The new emphasis on spin-in requires the creation of a new regional infrastructure focused on technology acquisition, not technology generation and diffusion.

2. This infrastructure:
   - Needs both advanced knowledge of specific technologies and extensive knowledge of NASA's needs.
   - Must account for a shift in responsibility for achieving mission-purpose use from SBIR to NASA centers and NASA's scientists and engineers.
   - Requires that each NASA center have the capacity for identifying and support the SBIR projects best matched to the center's high priority technology needs, regardless of where in the country those projects are.
   - Must have more coordinated and effective NASA oversight of projects from solicitation through Phase III to ensure that the research done aligns with agency needs.

H. Notwithstanding the change in NASA organization and mission, NASA's solicitation of SBIR proposals is run efficiently and effectively. NASA's SBIR proposal review process can be improved further.

1. **Electronic Handbook.** Proposals are submitted electronically, using the

[35]See, for example, case study of Space Photonics, Inc., in Appendix E.
[36]See NASA awards database.

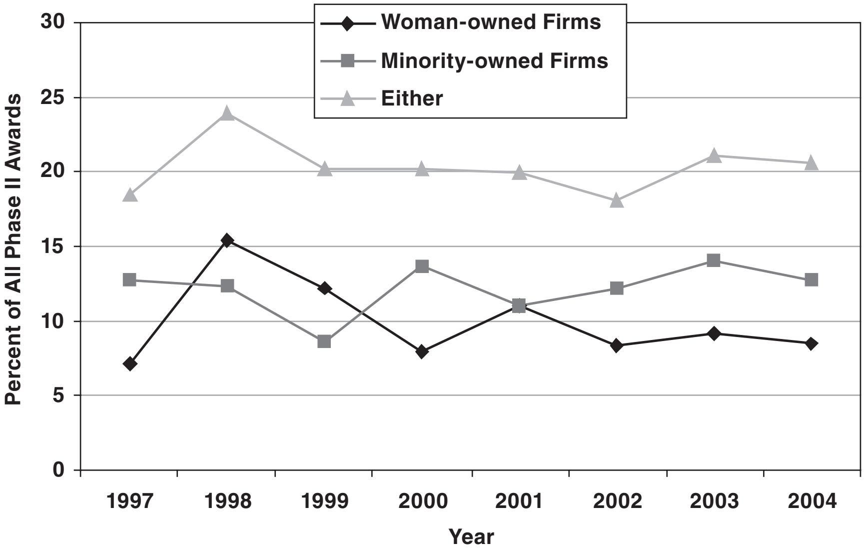

FIGURE 2-2 NASA SBIR Phase II awards, by demographic group, 1997-2004.
SOURCE: National Aeronautics and Space Administration.

NASA-developed Electronic Handbook. NASA has been an early leader in this regard.

2. **Technical review.** This takes place at each NASA center based on evaluation criteria that considers:
   - Scientific/Technical Merit and Feasibility.
   - Experience, Qualifications and Facilities.
   - Effectiveness of the Proposed Work Plan.
   - Commercial Merit and Feasibility.
   - Alignment with the NASA mission, most recently with the emphasis on "spin-in."

3. **Selection.** NASA centers provide a ranked listing to the Program Management Office, which prepares a selection of options for the Source Selection Official, who make the final decisions.

4. **Improving the review process.** Several of the companies interviewed for the NASA-related case studies held that NASA's review process is in need of improvement. This would include improvement in communication between potential applicants and NASA to ensure that it is worthwhile

for firms to submit proposals and better debriefing process for rejected applications to give a firm a better idea of whether or not to reapply.[37]

I. Monitoring and assessment of the program needs improvement. NASA does not provide an appropriate level of resources for assessing the program's performance and, as a result, SBIR management is not sufficiently evidence-based.

1. Given the size and scope of its SBIR program, NASA does not provide an appropriate level of resources for assessing the program's performance.
2. Partly because of lack of sufficient funding, the program is not sufficiently evidence-based. It lacks clear benchmarks and metrics for success. Program evaluation—while recently improved—needs to be enhanced further.

J. Understanding multiple-award winners: The path to successful SBIR award outcomes is non-linear and technologies often require multiple awards to reach fruition.

1. **Firms receiving more NASA Phase II awards appear to produce better commercial outcomes.**
   - The *Commercial Metrics survey* suggests that either companies improve their commercialization capabilities with practice or certain entrepreneurs have an inherent knack for business (and others do not). It is also consistent with the nonlinear and cumulative influence of technological change and its relation to economic growth.[38]
   - Evidence from the NASA-related firm case studies supports the notion that multiple awards contribute to the development of a given technology. The companies interviewed indicated that they made sustained, strategic use of a number of SBIR awards over time.[39]
2. **Innovative new technologies often take more time and money to develop than a single set of Phase I and Phase II awards provides.**
   - Not every project leads immediately to a market-ready product. Some small businesses have difficulty raising money from private sources for early-stage technologies, especially for NASA's limited niche market. The firms, therefore, often rely on multiple SBIR awards to get to the point where they can provide the product to NASA and/or sell it in the commercial market and thus fund their own research.

[37] See, for example, the case studies of AeroSoft, Inc., and Luna Innovations, Inc., in Appendix E.
[38] See *NASA Commercial Metrics Survey*, October 2002, op. cit.
[39] See the case studies in Appendix E.

II. NATIONAL RESEARCH COUNCIL STUDY RECOMMENDATIONS

The recommendations in this section are designed to improve the operation of the SBIR program at NASA. They complement the core findings that the program is addressing its legislative goals—that significant commercialization is occurring, that the awards are making valuable additions to nation's stock of scientific and technical knowledge, and that SBIR is developing products that apply this knowledge to NASA's missions.

A. Improve program processes.

1. **NASA should explore how to increase the flexibility of projects, given changes in technology and information.**
    - Address Time Lags: Some of the firms interviewed for this study noted that the period from writing a proposal to completing a Phase II is often too long, compared to the pace of change in the technology.[40]
- Increase Contract Flexibility: It would be helpful if firms could change direction of the contract as information changes. Means of increasing flexibility should be examined by NASA.

2. **Create a sense of ownership, including career and financial incentives for project managers to promote increased technology infusion.**
    - "Program offices should own SBIR." This is a quote from Wayne Schober, SBIR program director at JPL. This is a necessary condition to increase infusion or mission use of the technologies developed through the SBIR program.

3. **Study the funding gap problem and propose and implement a solution.**
    - The funding gap between Phase I and Phase II is a major concern, especially for the smaller firms. While larger and more diversified firms can often cope, smaller and newly founded firms often have to scale back significantly or go into debt. A phased approach, such as that adopted by the Navy and NSF, may be applicable here.

4. **Develop program synergies and complementarities.**
    - Complementarities between the NASA and DoD SBIR projects should be encouraged. NASA SBIR projects often find homes in DoD during Phase III. Encouraging such complementarities can promote efficient use of technology for society as a whole.

5. **Study the feasibility of yearly technical conferences to help define NASA's technical needs.**

[40] See, for example, the case study of AeroSoft, Inc., in Appendix E.

- A yearly technical conference can help NASA generate more appropriate proposals by more clearly defining its technical needs to prospective applicants.

B. NASA should reexamine the size of its Phase II awards.

1. NASA Phase I and II awards are smaller than those of other major SBIR funding agencies, and had not increased for several years.
   - Recently, the maximum Phase I award size was increased from \$70,000 to \$100,000, but the maximum level of Phase II award remains \$600,000.
   - Award size affects the portfolio of projects and Technology Readiness Levels that can be supported.
2. There is a trade-off between award size and the number of awards that can be funded.
   - Case study evidence suggests that while firms generally want larger size awards, many are not willing to accept the smaller number of awards implied by larger awards.[41]
   - COTRs and Project Managers also both indicated that NASA received more good proposals than it could fund.[42]
3. NASA should consider whether pilot programs offering larger (or indeed smaller) Phase II awards might be useful in some cases.
   - The key test will be whether there is an adequate flow of good proposals that are substantial enough to meet the agency's technology needs.

C. Encourage program experimentation, followed by evaluation of outcomes.

1. **Develop and evaluate pilot programs.**
   - NASA should develop an effective program for developing, deploying, and evaluating pilot initiatives. Pilot programs underway include:
     - A Langley Research Center program to provide matching non-SBIR money to proposals. This approach could be very helpful in promoting spin-in/infusion efforts.
     - The Director's Fund to provide greater Phase II funding for worthy projects.
     - A Langley Research Center program that helps link SBIR projects to NASA prime contractors that could become potential customers.

[41] For example, see the case of ARACOR in Appendix E.
[42] See Table App-D-14 of the Project Manager Survey.

2. **Expand and assess the NASA Alliance for Small Business Opportunities (NASBO).**
   - NASBO's regional dimension has the potential to encourage spin-out, spin-in, and dual use outcomes.
   - To realize this potential, NASBO should be increased in scale and evaluated to assess its effectiveness.

3. **Adopt best practices from other SBIR programs, as applicable.**
   - Evaluate other agencies' approaches to commercialization assistance and adopt the best approaches where applicable.[43]

4. **Expand the relationship between states and spin-out SBIR projects.**
   - This may replace the phased out Regional Technology Transfer Centers (RTTC) approach to tech transfer.

D. Additional management resources are needed.

1. Effective management and evaluation requires adequate funding.[44] An evidence-based program requires high-quality data and systematic assessment.

2. To enhance program utilization, management, and evaluation, the NASA SBIR program should be provided with additional funding for management and evaluation.

3. Increased funding is needed to provide effective oversight, including site visits, program review, systematic third-party assessments, and other necessary management activities.

4. In considering how to provide additional funds for management and evaluation, there are three ways that this might be done:
   - Additional funds might be allocated internally, within the existing budgets of the services and agencies, as the Navy has done.
   - Funds might be drawn from the existing set-aside for the SBIR program to carry out these activities.
   - Congress may consider marginally increasing the set-aside for the program, currently at 2.5 percent of external research budgets, with the goal of providing management resources necessary to maximize

[43]Best practices include the Navy's strategic approach to procurement and NSF's Phase I-B and Phase II-B supplemental awards.

[44]As noted above, a recent OECD report, the International Benchmark for program evaluation of large SME and Entrepreneurship Programs is between 3 percent for small programs and 1 percent for large-scale programs. See Organization for Economic Cooperation and Development, "Evaluation of SME Policies and Programs: Draft OECD Handbook," Paris: Organization for Economic Cooperation and Development.

the program's return to the nation.[45] These increased resources should not be used to create new or separate management but should go to enable existing management to enhance their efforts with respect to the program. The Committee recommends this third option.

E. Develop data for evaluation and conduct regular assessments.

1. **Develop data objectives.** The NASA SBIR program should develop a series of specific data objectives—identifying both the data needed to run the program well and the means of acquiring those data. Possible benchmarks include:
   - The percentage of companies achieving Phase III.
   - The development time of high priority NASA technologies from R&D in Phase I to NASA utilization in Phase III.
   - The fraction of important technology used by NASA to advance its own capabilities.
   - Benchmarks for spillovers at the regional and national level.
2. **Recording of Phase III outcomes.**
   - Benefits of the SBIR program are likely to be significantly underestimated unless this is improved. Better data collection on outcomes is necessary, even though it will use some additional resources.
   - NASA may also wish to consider whether the DoD model—and technology—for producing a Company Commercialization Report, updated each time the company applies for further awards, might be a useful way of generating better data about commercial outcomes.
3. **Summary annual report:** Each year, NASA should provide Congress with a summary report on the SBIR program. This annual report should include descriptive statistics for applications, awards, and outcomes along the dimensions identified in this report, including knowledge creation,

[45]Each of these options has its advantages and disadvantages. For the most part, over the last 25 years, the departments, institutes, and agencies responsible for the SBIR program have not proved willing or able to make additional management funds available. Without direction from Congress, they are unlikely to do so. With regard to drawing funds from the program for evaluation and management, current legislation does not permit this and would have to be modified. This would also limit funds for awards to small companies, the program's core objective. The third option, involving a modest increase to the program, would also require legislative action and would perhaps be more easily achievable in the event of an overall increase in the program. In any case, the Committee envisages an increase of the "set aside" of perhaps 0.03 percent to 0.05 percent on the order of $35 million-40 million per year or, roughly, twice what the Navy currently makes available to manage and augment its program. In the latter case (0.05 percent), this would bring the program "set aside" to 2.55 percent, providing modest resources to assess and manage a program that is approaching an annual spend of some $2 billion. Whatever modality adopted by Congress, the Committee's call for improved management, data collection, experimentation, and evaluation may prove moot without the benefit of additional resources.

technology innovation, and impact on agency mission, as well as commercialization. As part of this process, NASA should produce regular reports from the commercialization database.

4. **Regular assessments.** The proposed annual report noted above could become a focus for wider efforts to develop improved internal assessment capabilities that can be used to enhance program operations. It could also tie proposed improvements to evidence-based analysis and, for example, include an evaluation of the predictive power of selection scoring with regard top commercialization and other outcomes. NASA should also commission regular external arms-length evaluations to assess the program progress and the impact of new initiatives.

F. NASA should consider the creation of an independent advisory board that draws together senior agency management, SBIR managers, and other stakeholders as well as outside experts to review current operations and achievements and recommend changes to the SBIR program.

1. The purpose of such an advisory board is to provide a regular monitoring and feedback mechanism that would address the need for upper management attention, and encourage internal evaluation and regular assessment of progress towards definable metrics.

2. The annual report of the NASA SBIR program, recommended above, could be presented to the board. The board would review the report that would include updates on program progress, management practices. It would make recommendations to senior agency officials.

3. The board could be assembled on the model of the Defense Science Board (DSB) or perhaps the National Science Foundation's SBIR Advisory Board.[46] In any case, it should include senior agency staff and the Director's Office on an *ex officio* basis, and bring together, *inter alia*, representatives from industry (including award recipients), academics, and other experts in program management.

G. Evaluate the impact of NASA's reorganization on SBIR.
Following the recent agency restructuring, NASA seeks to make "spin-in" the main priority for the SBIR program. Because management structures at NASA have changed so extensively, data from past projects are of limited relevance in guiding current management." NASA should study how the new agency orientation towards spin-in will impact SBIR program outcomes. Such studies may include:

[46]The intent here is to use the DSB or the NSF SBIR Board as a model, not something necessarily to be copied exactly.

1. **The impact of NASA's reorganization on the availability of SBIR solicitation topics should be evaluated.**
   - As NASA adjusts to its new mission priorities, the breadth of SBIR topics may well narrow, discouraging some applicants. The impact of this adjustment should be evaluated and efforts to ensure that the program is effectively integrated should be undertaken.

2. **The new NASA structure and the Innovative Partnership Program (IPP) should be evaluated in terms of its technology transfer management goals.**
   - The challenge to create a successful SBIR program can be appreciated by pondering NASA's own description of its technology transfer management goal: to manage NASA technology transfer from "top-to-bottom, coast-to-coast, and cradle-to-grave."
   - "Top-to-bottom" refers to all levels of management; "coast-to-coast" highlights the importance of the ten NASA centers and NASA's regional infrastructure; and "cradle-to-grave" points out the difficulty of managing SBIR from solicitation through Phase III.

3. **Given the new NASA orientation towards spin-in, the role of risk-taking in NASA SBIR should be evaluated.**
   - The stronger orientation towards infusion may push NASA toward opting for lower risk SBIR projects. A balance must be struck between encouraging and funding riskier projects at lower Technology Readiness Levels (TRL) that may be very challenging to commercialize or use immediately by NASA and the emphasis on applications for NASA.[47]
   - The "innovation" focus of the Small Business Innovation Research program suggests that such risk taking should be encouraged. This trade-off should be evaluated fully.

4. **NASA should study how the new agency orientation towards spin-in will impact SBIR program outcomes.**
   - NASA may often provide only a limited market for a product. Concentrating on infusion makes the NASA SBIR program more technology-driven rather than market-driven.
   - A critical balance in the portfolio of projects needs to be struck and the impact of this shift on SBIR program outcomes should be evaluated.

5. **NASA should consider how SBIR can be used to maintain technological capacity in areas facing declining budgets.**

[47] Technology Readiness Level (TRL) is a measure used by NASA to assess the maturity of evolving technologies prior to incorporating them into an operational system or subsystem. See John C. Mankins, Technology Readiness Levels: A White Paper, NASA, Office of Space Access and Technology, Advanced Concepts Office, 1995.

- NASA faces substantial change as resources are increasingly focused on the Moon-Mars mission. The result is declining resources for R&D in other parts of NASA, especially aeronautics and earth sciences.
- As NASA becomes increasingly dependent on externally-developed technologies in areas that are being defunded, SBIR could perhaps be a useful and relatively inexpensive way of maintaining technological capacity in these areas, allowing NASA to maintain currency in important technologies at reduced cost.

3

Applications and Awards at NASA

3.1 INTRODUCTION

This chapter outlines the information available on Small Business Innovation Research (SBIR) program applications and awards at NASA. The objective is to provide a quantitative overview of award patterns by looking at the data for SBIR Phase I and Phase II applications and awards both overall and broken down by state, by firms that have won multiple awards, and by demographics.

3.2 PHASE I APPLICATIONS[1]

Since 1997, NASA has attracted on average 2,224 proposals annually for Phase I awards. During this period, the number of applications fluctuated, declining from 1997-2001 and then rebounding sharply with the collapse of the VC-funded boom of 1999-2001 (see Figure 3-1).[2]

Over the nine years from 1997-2005, the average number of Phase I applications was 2,223. The overall trend is slightly downward, despite the uptick in 2002-2003.

3.2.1 Phase I Awards

The number of Phase I awards made by NASA has been trending steadily down since 1992, the start of the study period for this report (see Figure 3-2).

[1]NASA maintains data on applications only since 1997. Accordingly, where we utilize applications data—for example, in the calculation of success rates for applications, our analysis will focus on 1997-2005. Where we are working only with awards data, our analysis will cover 1992-2005.

[2]All data in this chapter were provided by NASA to the NRC, unless otherwise labeled.

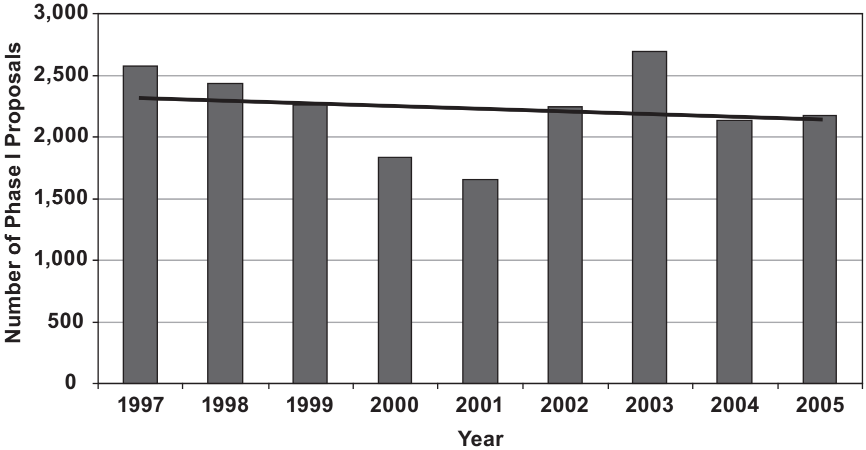

FIGURE 3-1 Phase I proposals for 1997-2005.
SOURCE: National Aeronautics and Space Administration.

Just under 300 Phase I awards are made annually, down from over 350 in 1993-1994.

NASA sticks quite closely to its internal guidelines on award size—there is very limited variation: Only four awards are confirmed as being more than $70,000 since 1983, with one of more than $100,000.

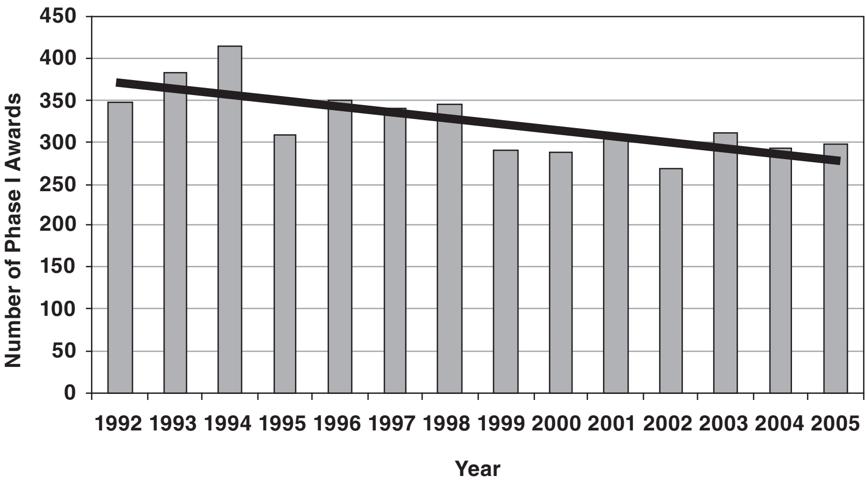

FIGURE 3-2 NASA SBIR Phase I awards, 1992-2005.
SOURCE: National Aeronautics and Space Administration.

3.2.2 Phase I Awards by State

Like other agencies, NASA awards are widely dispersed, with the research hubs accounting for a significant number of awards. However, in light of recent state efforts to encourage more applicants from their states, it is also worth noting that some states—and not necessarily those expected—have companies that are significantly more successful in generating awards from applications.

Table 3-1 shows that five states plus the Virgin Islands and Puerto Rico generated 54 applications, with zero awards. In contrast, Mississippi, Arkansas, and Vermont all had success rates well above average (note that the sheer number of awards and applications from the major research states suggests that these will tend to fall near the median for the group as whole.

TABLE 3-1 SBIR Phase I Application Success Rates by State, 1997-2005

State	Number of Phase I Applications	Number of Phase I Awards	Success Rate (%)	State	Number of Phase I Applications	Number of Phase I Awards	Success Rate (%)
MS	69	13	18.8	KY	16	2	12.5
AR	54	10	18.5	NY	571	69	12.1
VT	39	7	17.9	TX	1,062	128	12.1
NH	234	41	17.5	DE	86	10	11.6
WY	29	5	17.2	MN	246	28	11.4
MT	123	21	17.1	FL	659	73	11.1
CO	1,123	188	16.7	MI	380	42	11.1
LA	30	5	16.7	WV	37	4	10.8
WA	306	51	16.7	AZ	704	75	10.7
AL	694	111	16.0	ID	67	7	10.4
NM	402	64	15.9	HI	44	4	9.1
OR	259	41	15.8	GA	208	18	8.7
IA	38	6	15.8	NV	72	6	8.3
MA	2,395	376	15.7	IL	279	23	8.2
WI	320	50	15.6	KS	56	4	7.1
PA	426	66	15.5	ME	29	2	6.9
UT	155	23	14.8	DC	36	2	5.6
CT	334	49	14.7	SC	36	2	5.6
OH	744	106	14.2	OK	49	1	2.0
NJ	503	71	14.1	AK	13		0.0
MO	66	9	13.6	ND	4		0.0
IN	126	17	13.5	NE	4		0.0
VA	1,196	159	13.3	PR	2		0.0
TN	204	27	13.2	RI	19		0.0
NC	91	12	13.2	SD	10		0.0
CA	4,285	565	13.2	VI	2		0.0
MD	1,074	141	13.1	ALL	20,010	2,734	13.7

SOURCE: National Aeronautics and Space Administration.

The fact that success rates vary so substantially indicates that state economic development and innovation agencies may wish to address the quality of applicants that they support, as well as the quantity.

NASA is—substantially more than other SBIR agencies such as NIH and NSF—a widely dispersed agency, with 12 research centers recommending SBIR topics and applications for approval from NASA Headquarters. (See Chapter 5, Program Management, for details.) And NASA centers are also the managers of specific SBIR projects within their areas of technical leadership. Consequently, some states have clearly benefited from the presence of these centers, in terms of their ability to generate SBIR awards among local firms. In Alabama, for example, home of NASA's Marshall Space Flight Center in Huntsville, NASA made 111 Phase I awards from 1997-2005; NIH—with an SBIR program five times the size—made 67, and NSF 34.

Using the standard NRC metric for award aggregation by states, the top five Phase I states received 2,381 awards from 1992-2005, or 52.5 percent of all awards. The bottom 15 states received 64 awards, or 1.41 percent of all awards. Alaska, the Virgin Islands, and Puerto Rico received no Phase I awards.

3.2.3 Phase I Awards by Company

3.2.3.1 Multiple-award Winners

Overall, 41 companies received at least ten Phase I awards 1997-2005. Orbital Technologies was the most prolific winner, with 40, equivalent to 4.4 awards per year. Four firms received at least 30 awards. (See Table 3-2.) The top 20 winners, however, made up only 16.5 percent of all Phase I awards.

Overall, the top twenty winners averaged 22.6 Phase I awards over 9 years—an average of 2.4 Phase I awards per year.

Some of these firms were much more successful than others in translating applications into awards. For example, GNC made 310 applications during this period—a success rate of 6 percent. Foster-Miller made only 73 applications—a success rate of 40 percent. Given the substantial amount of agency effort involved in evaluation applications, it does appear that the agency may wish to evaluate application rates further, with a view to perhaps discussing poor quality applications with some companies.

3.2.3.2 New Applicants

The numbers of new applicants and new winners attracted into the program is an important measure of program openness. NASA maintains records on whether a firm is a first-time applicant to the NASA SBIR program.

Data in Figure 3-3 indicate that on average about 19 percent of NASA applicants are applying to NASA for the first time. The data also indicate that after

TABLE 3-2 Top 20 Multiple NASA SBIR Winners, 1997-2005

Company Name	Number of Phase I Awards
Orbital Technologies Corporation	40
Intelligent Automation, Inc.	37
Physical Optics Corporation	32
Creare, Inc.	31
Foster-Miller, Inc.	29
Lynntech, Inc.	27
Physical Sciences, Inc.	26
Pioneer Astronautics	25
Los Gatos Research	20
American GNC Corporation	19
Luna Innovations, Inc	19
TDA Research, Inc.	19
MER Corporation	18
Umpqua Research Company	18
Southwest Sciences, Inc.	17
Ultramet	15
Stottler Henke Associates, Inc.	15
Eltron Research, Inc	15
Triton Systems, Inc.	15
Continuum Dynamics, Inc.	15
Total (top 20 winners)	452
Percent of all Phase I Awards	16.5

SOURCE: National Aeronautics and Space Administration.

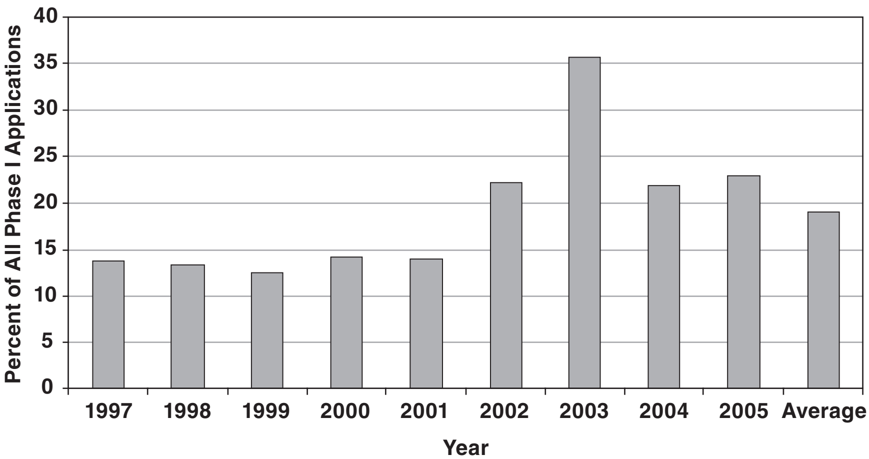

FIGURE 3-3 First-time applications to the NASA SBIR program.
SOURCE: National Aeronautics and Space Administration.

an uptick in new applicants in 2002-2003, the share of new applicants in overall applications is now trending back down toward the level that prevailed before 2002 (around 14 percent).

While the circumstances of each agency are different and the pool of available firms from which applications must come are also different, it is worth noting that this figure is on the low side compared to other agencies. NASA management may wish to consider whether more outreach efforts are needed.

3.2.4 Phase I Applications and Awards: Woman- and Minority-owned Firms

Support for woman- and minority-owned firms is one of the four primary objectives for the SBIR program set by the Congress. This section examines data related to applications and awards by these demographics.

3.2.4.1 Application Shares and Trends

A key step in providing such support lies in the attraction of sufficient applications for funding from these demographic groups. Figure 3-4 shows application trends for 1997-2005 by demographics. The chart indicates that the share of all applications from woman- and minority-owned firms has remained remarkably stable at NASA, barely varying from the mean of 26.5 percent of all awards.

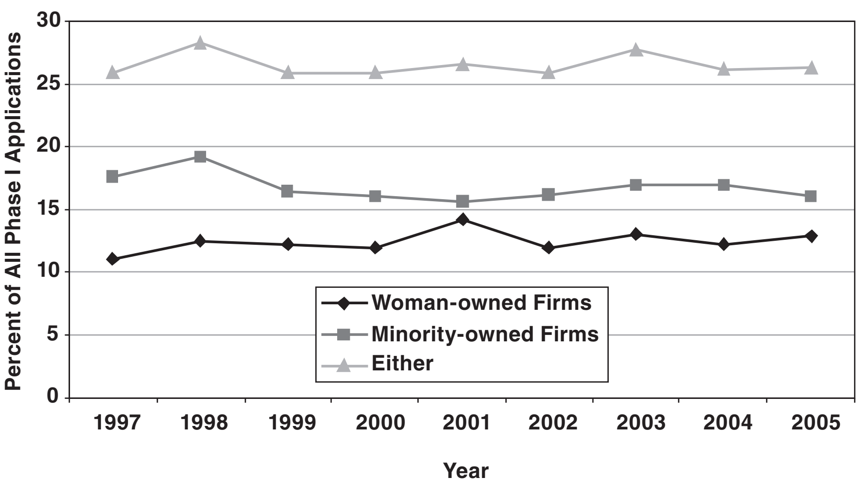

FIGURE 3-4 Shares of Phase I applications, by demographic group, 1997-2005.
SOURCE: National Aeronautics and Space Administration.

3.2.4.2 Phase I Awards, by Demographics

Figure 3-5 shows Phase I awards by demographics, 1992-2005. Data on Phase I awards show little change in the award shares to woman- and minority-owned firms, which have moved narrowly between 20 percent and 25 percent of all awards since 1992.

Minority firms continue to receive a larger share of Phase I awards than woman-owned firms, but the gap between the two groups is narrowing.

3.2.4.3 Phase I Success Rates by Demographic Group

This section concludes by reviewing the relative success rates of minority-owned, woman-owned and other firms within the NASA SBIR program. These success rates—defined as the ratio of contracts to applications in percentage terms—are described in Figure 3-6. The chart indicates that there has been relatively little change in success rates for any group, except for the spike for "other" applicants in 2001.

Overall, success rates for woman and minority-owned firms are significantly lower than for applications from other firms—averaging 11.0 percent and 10.9 percent respectively compared with 14.9 percent of all other firms. NASA might wish to examine the sources of this disparity in more detail in subsequent research.

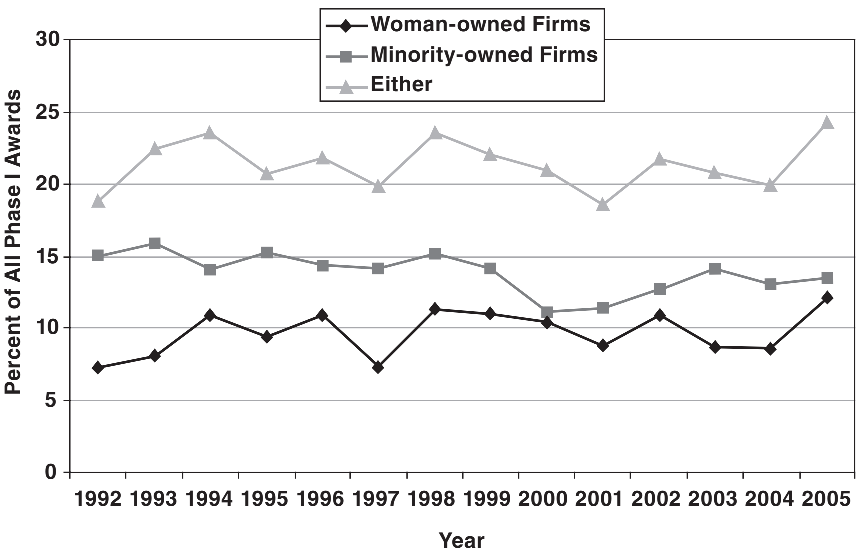

FIGURE 3-5 NASA SBIR Phase I awards, by demographic group, 1992-2005.
SOURCE: National Aeronautics and Space Administration.

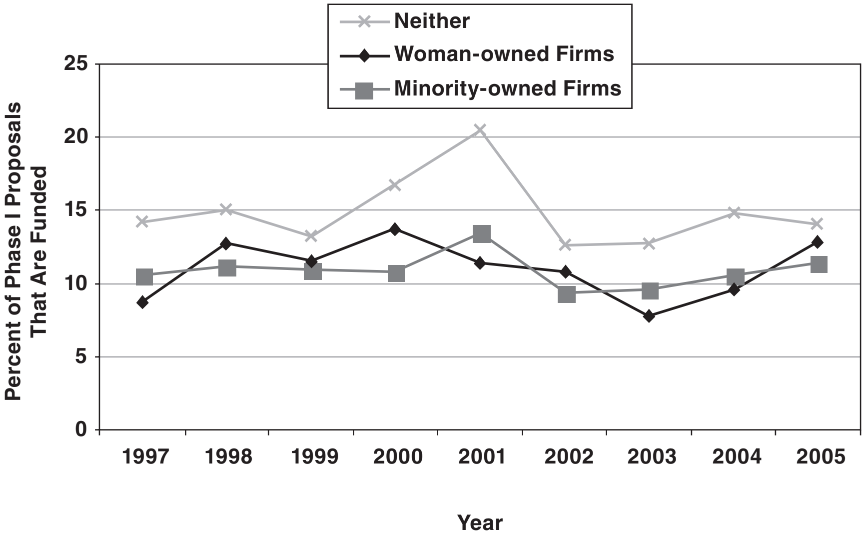

FIGURE 3-6 NASA SBIR Phase I success rate, by demographic group, 1997-2005.
SOURCE: National Aeronautics and Space Administration.

3.3 PHASE II AWARDS

As with Phase I, the number of Phase II awards made by NASA has remained relatively constant, as indicated in Figure 3-7. From 1997 onwards, the number of awards has fluctuated within the range from 125-155.

Average award size has stayed close to the agency guidelines, as indicated in Figure 3-8. The increase in 1993 reflected changes in the enabling legislation. However, the decrease in 2004 is as yet unexplained.

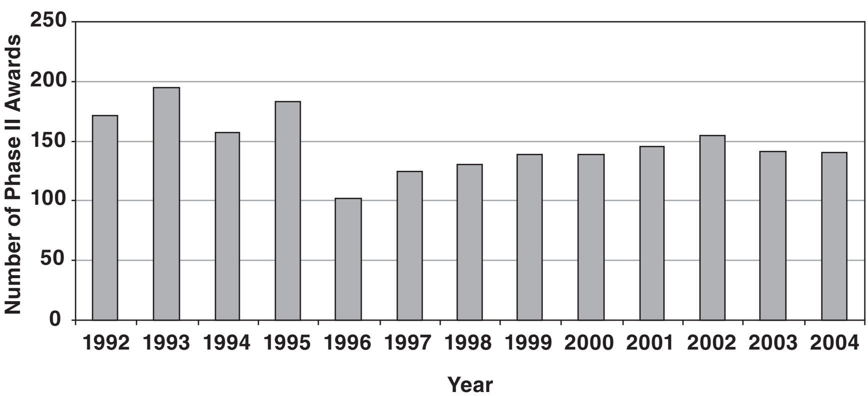

FIGURE 3-7 NASA SBIR Phase II awards, 1992-2004.
SOURCE: National Aeronautics and Space Administration.

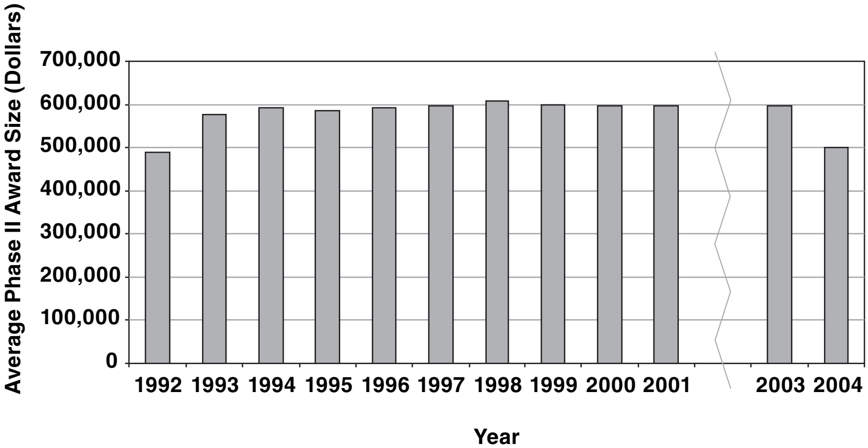

FIGURE 3-8 NASA SBIR Phase II average award size, 1992-2001; 2003-2004.
NOTE: Data for 2002 not available.
SOURCE: National Aeronautics and Space Administration.

3.3.1 Phase II Awards by State

Patterns of award by state follow the pattern for Phase I quite closely, although as Table 3-3 shows, the "conversion rate"[3] for states vary widely. As with Phase I, states with NASA research centers are likely to generate more awards (e.g., Alabama, Maryland).

3.3.2 Phase II Awards by Company

Between 1992 and 2004, NASA awarded a total of 1,924 Phase II awards to 903 different companies. Most firms received just one or at most two awards; a few however were more successful, as Table 3-4 indicates. Creare, the top award winner, received 36 Phase II awards during this period—an average of 2.76 awards per year. The top 20 Phase II award winners collectively received 327 Phase II awards, accounting for 17 percent of all awards made by NASA during this period.

NASA has not provided data on new Phase II winners.

[3]The conversion rate is the rate at which Phase I awards are converted to Phase II. It is a useful indicator of average progress toward commercialization.

TABLE 3-3 NASA SBIR Phase I to Phase II Conversion Rate, by State, 1997-2004

State	Number of Phase I Awards, 1997-2005	Number of Phase II Awards, 1997-2004	Conversion Rate (%)	State	Number of Phase I Awards, 1997-2005	Number of Phase II Awards, 1997-2004	Conversion Rate (%)
AL	111	45	40.5	ND			n/a
AR	10	4	40.0	NE			n/a
AZ	75	28	37.3	NH	41	24	58.5
CA	565	237	41.9	NJ	71	30	42.3
CO	188	78	41.5	NM	64	28	43.8
CT	49	24	49.0	NV	6	2	33.3
DC	2		0.0	NY	69	24	34.8
DE	10	3	30.0	OH	106	34	32.1
FL	73	26	35.6	OK	1	1	100.0
GA	18	4	22.2	OR	41	18	43.9
HI	4	3	75.0	PA	66	29	43.9
IA	6	4	66.7	PR			n/a
ID	7	3	42.9	RI			n/a
IL	23	9	39.1	SC	2		0.0
IN	17	8	47.1	SD			n/a
KS	4	3	75.0	TN	27	10	37.0
KY	2	1	50.0	TX	128	50	39.1
LA	5	2	40.0	UT	23	9	39.1
MA	376	150	39.9	VA	159	65	40.9
MD	141	58	41.1	VI			n/a
ME	2	1	50.0	VT	7	5	71.4
MI	42	15	35.7	WA	51	24	47.1
MN	28	10	35.7	WI	50	20	40.0
MO	9	3	33.3	WV	4	3	75.0
MS	13	6	46.2	WY	5	3	60.0
MT	21	11	52.4	Total	1,813	738	40.7
NC	12	2	16.7				

NOTE: N/A means not applicable.
SOURCE: National Aeronautics and Space Administration.

3.3.3 Phase II Applications and Awards: Woman- and Minority-owned Firms

3.3.3.1 Phase II Applications Shares and Trends

Applications from woman- and minority-owned firms have remained relatively static over time at NASA, as Figure 3-9 shows. Overall, woman-owned firms have made somewhat fewer applications than minority-owned firms. Overall, woman- and minority-owned firms account for a slightly smaller percentage of applications—22.2 percent, compared to 26.5 percent for Phase I.

TABLE 3-4 Top 20 SBIR Phase II Award Winners for NASA, 1997-2004

Company Name	Number of Phase II Awards
Creare, Inc.	36
Orbital Technologies Corporation	26
Foster-Miller, Inc.	23
Physical Optics Corporation	21
Lynntech, Inc.	21
Intelligent Automation, Inc.	21
Ultramet	19
Physical Sciences, Inc.	18
Triton Systems, Inc.	15
CFD Research Corp	14
TDA Research, Inc.	14
Materials & Electrochemical Research	12
Stottler Henke Associates, Inc.	12
Coherent Technologies, Inc.	12
Nielsen Engineering & Research, Inc.	11
Umpqua Research Company	11
Composite Optics, Incorporated	11
Accurate Automation Corporation	10
Los Gatos Research	10
Eltron Research, Inc	10
Total (top 20)	327
Percent of all NASA Phase II Awards	17.0
Total Firms with Phase II Awards	903
Total Phase II Awards (all firms)	1,924

SOURCE: National Aeronautics and Space Administration.

3.3.3.2 Phase II Awards, by Demographics

Overall, woman- and minority-owned firms receive about 20 percent of NASA Phase II awards. This is slightly down from the end of the 1990s, as Figure 3-10 indicates. And since 2001, the share of awards going to minority-owned firms has consistently exceeded that going to woman-owned firms. These data also indicate that Phase II awards by demographics closely track results from Phase I.

3.3.3.3 Phase II Success Rates, by Demographic Group

Figure 3-11 describes the respective success rates for the different demographic groups. These data indicate that there is general upward trend in success rates, and that success rates for woman- and minority-owned firms is generally in line with those for other firms.

FIGURE 3-9 NASA SBIR Phase II applications, by demographics, 1997-2005.
SOURCE: National Aeronautics and Space Administration.

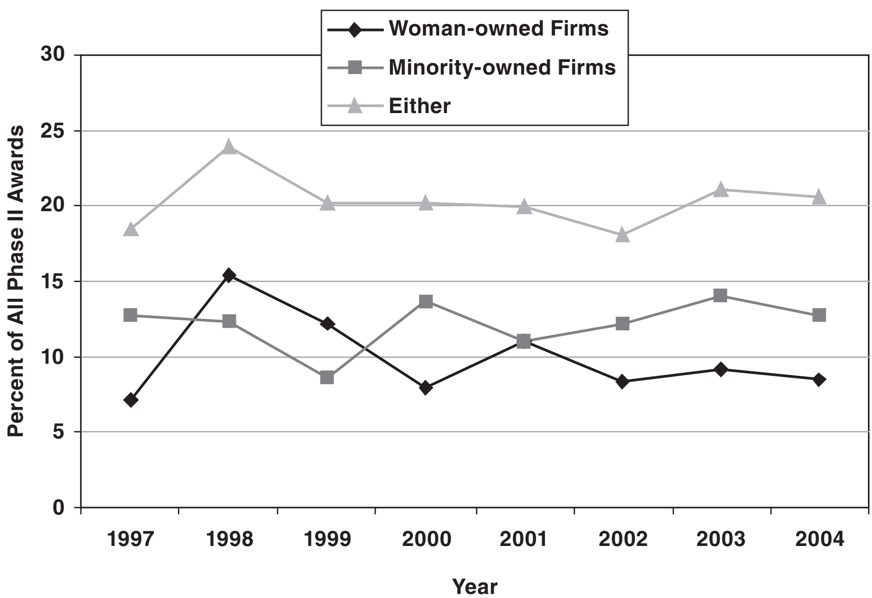

FIGURE 3-10 NASA SBIR Phase II awards, by demographic group, 1997-2004.
SOURCE: National Aeronautics and Space Administration.

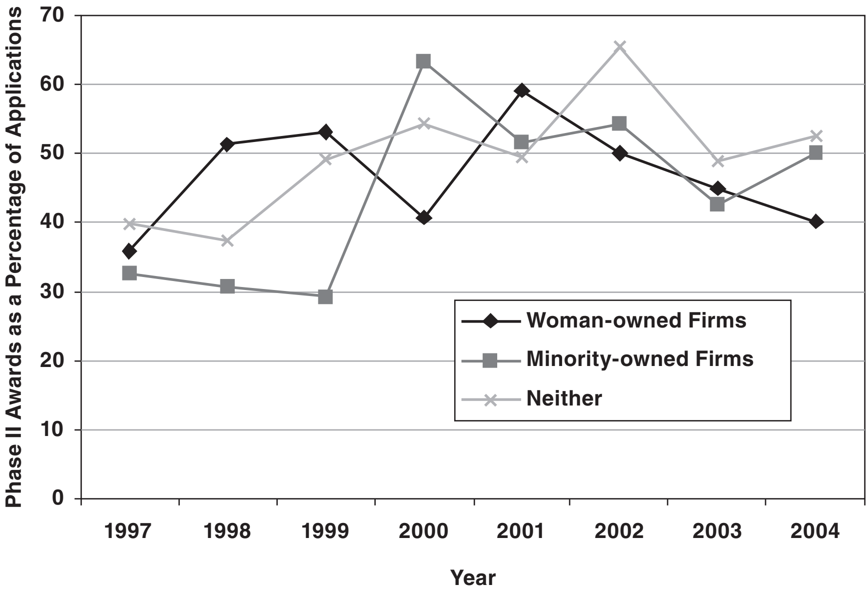

FIGURE 3-11 NASA SBIR Phase II success rates, by demographics, 1997-2004.
SOURCE: National Aeronautics and Space Administration.

4

SBIR Program Outcomes

4.1 INTRODUCTION

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 to make recommendations on still further improvements to the program.[1]

The Small Business Innovation Act, sets out four goals for the program: "(1) to stimulate technological innovation; (2) to use small business to meet federal research and development needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and (4) to increase private-sector commercialization derived from Federal research and development."[2]

The legislation does not set priorities among these four objectives. However, discussions with congressional staff suggest that commercialization has become increasingly important to Congress. Still, it remains important to assess each of the four objectives; each should be taken as equally important in evaluating the achievements and challenges of the SBIR program. These four objectives help to define the structure and content of this chapter.

Assessing program outcomes against these four objectives entails numerous

[1]See the SBIR Reauthorization Act of 2000 (H.R. 5667—Section 108).
[2]The Small Business Innovation Development Act (PL 97-219).

methodological challenges. These challenges, discussed in detail in the National Research Council's Methodology Report, are briefly reviewed below.[3]

4.1.1 Compared to What?

Assessment usually involves comparison—comparing programs and activities, in this case. Three kinds of comparison seem possible: with other programs at each agency, among SBIR programs at the various agencies, and with early-stage technology development funding in the private sector, such as venture capital activities. Yet, as we see below, the utility of each of these three types of comparison is limited.

Comparison with Other NASA Programs

Within NASA, no other program is dedicated to support innovative small businesses. This fundamental difference in objectives makes it difficult to compare the NASA SBIR program with other programs at the agency.

Comparison with Other SBIR Programs

Comparing the NASA SBIR program with those at other agencies is superficially more useful. However, as discussed in Chapter 1 of this volume, the SBIR programs at each of the agencies are shaped by the different agency missions. This, in turn, is reflected in the different mechanisms and approaches taken by the agencies. Agencies whose mission is to develop technologies for internal agency use via procurement—notably DoD and NASA—have a different orientation from agencies that do not procure technology and are instead focused on developing technologies for use outside the agency.

There are important differences between the two "procurement" agencies. At DoD, once an SBIR technology is proven, there are opportunities for integration of that technology into a very substantial stream of acquisitions dollars. At NASA, such proven technologies may also be taken up for use by the agency—often only for one or two copies of a technology, for use on NASA space missions. Thus, the character of commercialization is quite different.

[3]National Research Council, *An Assessment of the Small Business Innovation Research Program—Project Methodology*, Washington, DC: The National Academies Press, pp. 20-21, 2004. For a broader discussion of the scope and limitations of surveys by the University of Michigan Survey Research Center, see Robert M. Groves, Floyd J. Fowler, Jr., Mick P. Couper, James M. Lepkowski, Eleanor Singer, and Roger Tourangeau, *Survey Methodology*, Boston, MA: WileyBlackwell, 2004.

Comparison with Early-stage Venture Capital

Finally, SBIR might be compared with venture capital (VC) activities, but there are important differences. VC funding is typically supplied later in the development cycle when innovations are in, or close, to market. Indeed, most venture investments are made with the expectation of an exit from the company within three years. VC investments are also typically larger than SBIR awards. In 2007, the median investment made by VC firms in a company was $7.6 million, compared to less than $1 million for a NASA SBIR over a two to three year cycle.[4] VC investments are also focused on companies, not projects, and often come both with substantial management support and influence (such as through seats on the company's board).

4.1.2 Multiple Metrics

The lack of direct comparators means that multiple metrics must be deployed, using a wide array of information sources.[5] This is what the NRC Committee has done:

- **The NRC Phase II Survey** covers every firm that received a Phase II award between 1992 and 2001 inclusive.
- **The NRC Phase I Survey** covers projects that failed to proceed beyond Phase I.
- **The NRC Project Manager Survey.**
- **Case Studies** commissioned by the NRC Committee provide context and illustration, in addition to user perspectives of the program.
- **Interviews** with agency staff both within and outside the SBIR program office, as well as other experts inform the Committee's findings.
- **NASA Databases**, in particular the NASA awards database, as well as a NASA outcomes assessment, have provided basic information about the program.[6]

While the surveys broke important ground, and provided a central base of information on which considerable parts of the assessment are based, it is important to note that surveys of innovation awards can suffer from several forms of survey bias. These issues are discussed in Box 4-1.

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[4]2007 saw some 2,648 deals, with an overall capital investment of $29.9 billion, according to data from National Venture Capital Association. See <*https://www.pwcmoneytree.com/MTPublic/ns/index.jsp*>.

[5]For a more detailed discussion of the methodology, see National Research Council, *An Assessment of the Small Business Innovation Research Program—Project Methodology*, op. cit.

[6]Access the NASA Commercialization Metrics Survey at <*http://www.sbir.nasa.gov/SBIR/survey.html*>.

BOX 4-1
Multiple Sources of Bias in Survey Response

Large innovation surveys involve multiple sources of bias that can skew the results in both directions. Some common survey biases are noted below. These biases were tested for and responded to in the NRC surveys.[a]

- **Successful and more recently funded firms are more likely to respond.** Research by Link and Scott demonstrates that the probability of obtaining research project information by survey decreases for less recently funded projects and it increased the greater the award amount.[b] Nearly 40 percent of respondents in the NRC Phase II Survey began Phase I efforts after 1998, partly because the number of Phase I awards increased, starting in the mid 1990s, and partly because winners from more distant years are harder to reach. They are harder to reach as time goes on because small businesses regularly cease operations, are acquired, merge, or lose staff with knowledge of SBIR awards.

- **Success is self-reported.** Self-reporting can be a source of bias, although the dimensions and direction of that bias are not necessarily clear. In any case, policy analysis has a long history of relying on self-reported performance measures to represent market-based performance measures. Participants in such retrospectively analyses are believed to be able to consider a broader set of allocation options, thus making the evaluation more realistic than data based on third-party observation.[c] In short, company founders and/or principal investigators are in many cases simply the best source of information available.

- **Survey sampled projects at firms with multiple awards.** Projects from firms with multiple awards were underrepresented in the sample, because they could not be expected to complete a questionnaire for each of dozens or even hundreds of awards.

- **Failed firms are difficult to contact.** Survey experts point to an "asymmetry" in their ability to include failed firms for follow-up surveys in cases where the firms no longer exist.[d] It is worth noting that one cannot necessarily infer that the SBIR project failed; what is known is only that the firm no longer exists.

- **Not all successful projects are captured.** For similar reasons, the NRC Phase II Survey could not include ongoing results from successful projects in firms that merged or were acquired before and/or after commercialization of the project's technology. The survey also did not capture projects of firms that did not respond to the NRC invitation to participate in the assessment.

- **Some firms may not want to acknowledge the full SBIR contribution to a project's success.** Some firms may be unwilling to acknowledge that they received important benefits from participating in public programs for a variety of reasons. For example, some may understandably attribute success exclusively to their own efforts.

- **Commercialization lag.** While the NRC Phase II Survey broke new ground in data collection, the amount of sales made—and indeed the number of projects that generate sales—are inevitably undercounted in a snapshot survey taken at a single point in time. Based on successive data sets collected from NIH SBIR award recipients, it is estimated that total sales from all responding projects will likely be on the order of 50 percent greater than can be captured in a single survey.[e] This underscores the importance of follow-on research based on the now-established survey methodology.

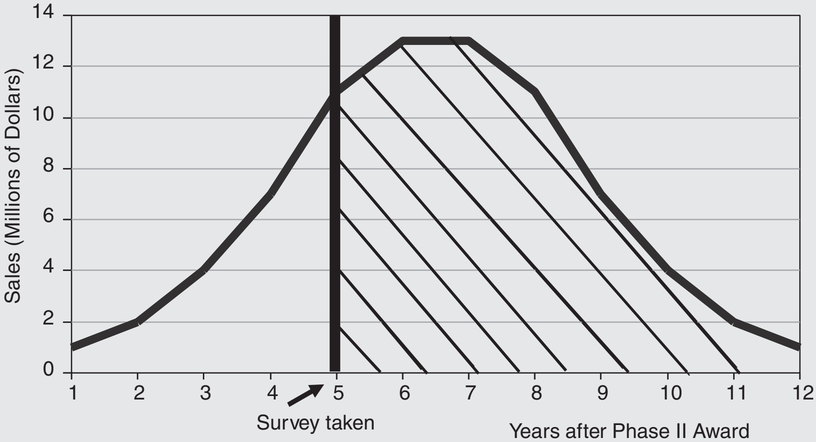

FIGURE B-4-1 Survey bias due to commercialization lag.

These sources of bias provide a context for understanding the response rates to the NRC Phase I and Phase II Surveys conducted for this study. For the NRC Phase II Survey, of the 534 NASA firms that could be contacted out of a sample size of 779, 181 responded, representing a 34 percent response rate. The NRC Phase I Survey captured 9 percent of the 3,363 awards made by NASA over the period of 1992 to 2001. See Appendixes B and C for additional information on the surveys.

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[a]For a technical explanation of the sample approaches and issues related to the NRC surveys, see Appendixes B and C.

[b]Albert N. Link and John T. Scott, *Evaluating Public Research Institutions: The U.S. Advanced Technology Program's Intramural Research Initiative*, London: Routledge, 2005.

[c]While economic theory is formulated on what is called "revealed preferences," meaning individuals and firms reveal how they value scarce resources by how they allocate those resources within a market framework, quite often expressed preferences are a better source of information especially from an evaluation perspective. Strict adherence to a revealed preference paradigm could lead to misguided policy conclusions because the paradigm assumes that all policy choices are known and understood at the time that an individual or firm reveals its preferences and that all relevant markets for such preferences are operational. See Gregory G. Dess and Donald W. Beard, "Dimensions of Organizational Task Environments." *Administrative Science Quarterly* 29:52-73, 1984; and Albert N. Link and John T. Scott, *Public Accountability: Evaluating Technology-Based Institutions*, Norwell, MA: Kluwer Academic Publishers, 1998.

[d]Albert N. Link and John T. Scott, *Evaluating Public Research Institutions: The U.S. Advanced Technology Program's Intramural Research Initiative*, op. cit.

[e]Data from NIH indicates that a subsequent survey taken two years later would reveal very substantial increases in both the percentage of firms reaching the market, and in the amount of sales per project. See National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

4.1.3 NASA's Changing Program Priorities

NASA's mission objectives are defined in very specific terms—placing a man on Mars and returning him safely, for example. These mission objectives require the development and acquisition of highly specialized technologies, often with limited commercial applications.[7] There is, for example, little need for Mars-hardened technologies on Earth.

To address NASA's unique needs, subtopic and selection decisions for the NASA SBIR program were managed by those with a primary interest in using SBIR technologies for NASA missions. Seeking, at the same time to improve the commercialization outcomes of its SBIR program, NASA also provided support for technology incubators.

In time, NASA recognized that this compromise was not successful. On one hand, the NASA's mission realities limited the commercial potential of NASA SBIR projects. On the other hand, the focus on commercialization limited a tighter linkage between SBIR projects and agency mission objectives.

Recognizing this challenge, NASA's senior management shifted the program in 2006 away from this uneasy balance between commercialization and mission support objectives, and to a new commitment focused almost exclusively on mission support.[8] As a result of this reorganization, commercialization has become a secondary objective for the agency's SBIR program.

The reorganization changed in the structure of the program from one where key decisions were primarily made by centers and specific topic managers to one where those decisions are made at Headquarters by Mission Directorate staff, with input from the centers and project managers. With authority for strategic planning, NASA's Mission Directorate staff were seen as best placed to identify the technology areas with greatest needs, and hence to set the appropriate priorities for the SBIR program. By moving SBIR from the periphery of NASA planning to become a potentially valuable solution to current mission challenges, the reorganization is designed to ensure that SBIR is used to the maximum extent possible to help develop technologies needed by NASA.

4.2 COMMERCIALIZATION: A LONG-TIME PROGRAM PRIORITY

Commercialization of SBIR-funded technologies has been a key congressional objective for the SBIR program since its inception. In fact, the program's initiation in the early 1980s in part reflected a concern that American investment in research was not adequately deployed to the nation's competitive advantage.

[7]Unlike DoD, NASA does not itself constitute a major market for commercial sales. And at the same time, the technologies developed specifically for NASA have relatively little relevance to the private marketplace—for example, compared to some applications developed at NIH.

[8]These administrative changes, made in 2006, are described in Chapter 5 (Program Management).

Directing a portion of federal investment in R&D to small businesses was thus seen as a new means of meeting the mission needs of federal agencies while increasing the participation of small business and thereby the proportion of innovation that would be commercially relevant.[9]

Congressional and Executive branch interest in the commercialization of SBIR research has increased over the life of the program. Drawing from a 1992 GAO study[10] that focused on commercialization, the 1992 reauthorization specifically "emphasize[d] the program's goal of increasing private-sector commercialization of technology developed through Federal research and development"[11] and noted the need to "emphasize the program's goal of increasing private-sector commercialization of technology developed through Federal research and development." The 1992 reauthorization also changed the order in which the program's objectives are described, moving commercialization to the top of the list.[12]

The term "commercialization" is subject to widely varying interpretations. Several agencies have taken it to mean "first sale"—that is, the first sale of a product in the market place, whether to public- or private-sector clients. This definition, however, misses significant components of commercialization that do not result in a discrete sale. It also fails to provide any guidance on how to evaluate the scale of commercialization, an important element in assessing the degree to which SBIR programs successfully encourage commercialization. The NRC methodology has determined that multiple metrics can and should be used to assess the extent of commercialization.

The following sections review commercialization outcomes for NASA through 2005. consequently, the recent change in emphasis to mission support is not addressed.

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[9]A growing body of evidence, starting in the late 1970s and accelerating in the 1980s indicates that small businesses were assuming an increasingly important role in both innovation and job creation. See, for example, J. O. Flender and R. S. Morse, *The Role of New Technical Enterprise in the U.S. Economy*, Cambridge, MA: MIT Development Foundation, 1975, and David L. Birch, "Who Creates Jobs?" *The Public Interest*, 65:3-14, 1981. Evidence about the role of small businesses in the U.S. economy gained new credibility with the empirical analysis by Zoltan Acs and David Audretsch of the U.S. Small Business Innovation Data Base, which confirmed the increased importance of small firms in generating technological innovations and their growing contribution to the U.S. economy. See Zoltan Acs and David Audretsch, "Innovation in Large and Small Firms: An Empirical Analysis," *The American Economic Review*, 78(4):678-690, September 1988. See also Zoltan Acs and David Audretsch, *Innovation and Small Firms*, Cambridge, MA: MIT Press, 1990.

[10]U.S. General Accounting Office, *Small Business Innovation Research Program Shows Success But Can Be Strengthened*, GAO/RCED–92–37, Washington, DC: U.S. General Accounting Office, 1992.

[11]PL 102-564, October, 28, 1992.

[12]These changes are described by R. Archibald and D. Finifter in "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*, Charles W. Wessner, ed., Washington, DC: National Academy Press, 2000.

4.2.1 Assessing Commercialization

Clear metrics for assessing commercialization are elusive.[13] It is not possible to quantify in full all commercialization from a given research project, for the reasons listed below.

- Numerous additional development steps are often needed *after* the research has been concluded. Thus, a single, direct line between research inputs and commercial outputs rarely exists in practice; cutting-edge research is only one contribution among many leading to a successful commercial product.
- Markets themselves have major imperfections, often caused by information asymmetries. Hence high quality—even path-breaking—research does not always result in commensurate commercial returns.
- There are often long lags between an early-stage research project and an eventual commercial product. This means that for a significant number of the more recent SBIR projects, commercialization is still in process, and sales—often substantial sales—will be made in the future (see the "snapshot effect" discussed in Box 4-2).
- Research rarely results in stand-alone products. Often, the output from an SBIR project is combined with other technologies. The SBIR technology may provide a critical element in developing a winning solution, but that commercial impact is hard to measure in simple dollars.
- In some cases, the full value of an "enabling technology" that can be used across industries is difficult to capture.

All this is to say that commercialization results must be viewed with caution. Our ability to track them is limited. Indeed, it appears highly likely that quantification of research awards through surveys substantially understates the true commercial impact of SBIR projects. In addition, a specific award cannot lay claim to all subsequent commercial successes, even though the technology developed with the award may have contributed to many significant outcomes.[14]

4.2.2 Commercialization Indicators and Benchmarks

This report uses four sets of indicators to assess commercialization success quantitatively:

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[13]See National Research Council, *An Assessment of the Small Business Innovation Research Program—Project Methodology*, op. cit.

[14]Data on infusion/commercialization of SBIR technologies from 1983 to 1996 was included in NASA's 2002 *Commercial Metrics* publication. Follow-on data gathering via this Commercial Technology Division initiative has been halted pending further funding. Of NASA's 1,739 SBIR Phase II awards during the target period, about 15 percent developed technologies used in NASA or other programs via Phase III funding, and 31 percent commercialized in the private sector. See *Commercial Metrics*; NASA Commercial Technology Division; October, 2002; Fig 4.

1. **Sales and licensing revenues** ("sales" hereafter, unless otherwise noted). Revenues flowing to a company from the commercial marketplace and/or through government procurement constitute the most obvious measure of commercial success. They are also an important indicator of uptake for the product or service. Sales indicate that the result of a project has been sufficiently positive to convince buyers that the product or service is the best available solution.

Yet if there is general agreement that sales are a key benchmark, there is no such agreement on what constitutes "success." Companies, naturally enough, focus on projects that contribute to the bottom line—that are profitable. Agency staff provide a much wider range of views. Some view any sales a substantial success for a program focused on such an early stage of the product and development cycle, while others seem more ambitious.[15] Some senior executives in the private sector view only projects that generated cumulative revenues at $100 million or more as a complete commercial success.[16]

Rather than seeking to identify a single sales benchmark for "success," it therefore seems more sensible to assess outcomes against a range of benchmarks reflecting these diverse views, with each marking the transition to a greater level of commercial success.

2. **Phase III activities within NASA.** As noted above, Phase III activities within NASA are a primary form of commercialization for NASA SBIR projects. These activities are considered in the mission support section (Section 4.3).
3. **R&D investments and research contracts.** Further R&D investments and contracts are good evidence that the project has been successful in some significant sense. These investments and contracts may include partnerships, further grants and awards, or government contracts.
4. **Sale of equity.** This is a clear-cut indicator of commercial success or market expectations of value. Key metrics include:
   a. Equity investment in the company by independent third party.
   b. Sale or merger of the entire company.

Sales and Licensing Revenues

A basic question on commercialization is whether results from a project have reached the marketplace. The NRC Phase II Survey[17] indicates that about

[15] Interviews with SBIR program coordinators at DoD, NIH, NSF, and DoE.

[16] Pete Linsert, CEO, Martek Biosciences, Inc., NRC Committee Meeting, June 5, 2005.

[17] Much of the primary data in this section of the report was derived from the NRC Phase II Survey. The NRC Phase II Survey of projects provides recent evidence on the extent by which NASA SBIR award recipients have achieved commercialization and/or progress toward commercialization. The survey provides information on sales, modes of commercialization, and on steps important to achieving commercialization, including marketing activities, interactions with other companies and

46 percent of NASA respondents had generated some sales or licensed their technology, and that a further 14 percent still expected sales though they had none at the time of the survey. In addition, 3 percent were still in the research stage of the project.[18] (See Figure 4-1.)

These results are broadly in line with other sources of information on commercial outcomes from SBIR program, including those at other agencies such as the DoD commercialization database, the NIH Phase II Survey, and the NSF Phase II survey.[19]

Distribution of Sales

Research on early-stage financing strongly suggests that a pronounced skew to the results is likely, and this turns out to be the case. Most projects that reach the market generate minimal revenues. A few awards generate substantial results, and a small number bring in large revenues.[20]

Of the 74 NASA SBIR Phase II projects reporting sales greater than $0, average sales per project were $1,154,156. About 40 percent of the total sales dollars were due to the two NASA projects responding to the survey that had received $5,000,000 or more in sales. The highest cumulative sales figure reported was $15,000,000.

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investors, and attraction of funding from non-SBIR sources. It also provides information on employment effects, including the extent to which woman and minorities are involved in the projects as principal investigators. Finally, it explores the extent to which the reported effects are believed by survey respondents to be attributed to impacts of the SBIR program. See Appendix B for additional information about the NRC Phase II Survey, including response rates.

[18] See Finding G on venture capital and SBIR in Chapter 2 of National Research Council, *An Assessment of SBIR at the National Institutes of Health*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

[19] See the NRC assessments of the SBIR program at DoD and NIH for discussion of these sources. National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, op. cit.; National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

[20] See John H. Cochrane, "The Risk and Return of Venture Capital," *Journal of Financial Economics*, 75(1):3-52, 2005. Drawing on the VentureOne database Cochrane plots a histogram of net venture capital returns on investments that "shows an extraordinary skewness of returns. Most returns are modest, but there is a long right tail of extraordinary good returns. 15 percent of the firms that go public or are acquired give a return greater than 1,000 percent! It is also interesting how many modest returns there are. About fifteen percent of returns are less than 0, and 35 percent are less than 100 percent. An IPO or acquisition is not a guarantee of a huge return. In fact, the modal or "most probable" outcome is about a 25 percent return." See also Paul A. Gompers and Josh Lerner, "Risk and Reward in Private Equity Investments: The Challenge of Performance Assessment." *Journal of Private Equity*, 1 (Winter 1977):5-12. Steven D. Carden and Olive Darragh, "A Halo for Angel Investors" *The McKinsey Quarterly*, 1, 2004 also show a similar skew in the distribution of returns for venture capital portfolios.

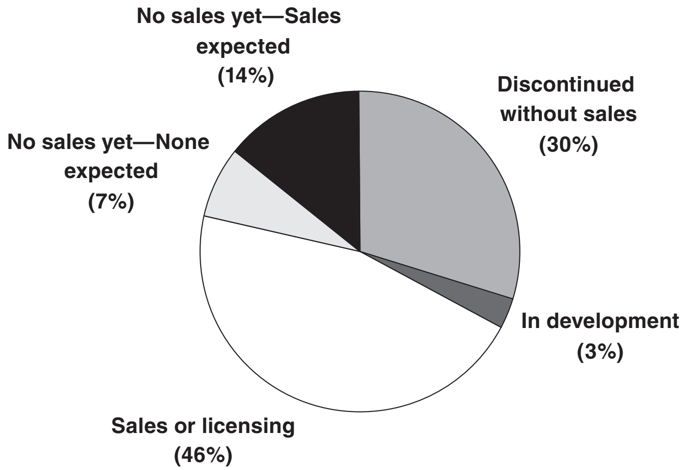

FIGURE 4-1 Results from NASA Phase II projects.
SOURCE: NRC Phase II Survey. Based on responses to Phase II Survey questions 1a, 1b, 3a, and 3b.

These figures appear lower than those for other agencies, notably DoD and NIH. However, direct comparisons of results from the NRC Phase II Survey are not valid because of survey response issues. And it should be noted that the very high degree of skew combined with smaller number of awards at NASA means that comparisons are likely to be even more inaccurate (NASA may simply not have made enough awards to generate a statistically significant number of big winners—firms with more than $10 million in sales—though it might be a matter of concern if current trends continued indefinitely). This distribution is reflected in Figure 4-2.

More than 80 percent of the projects reporting sales greater than zero had $1 million or less in sales, as seen in Figure 4-3.

The numerous projects with relatively low sales (below $1 million) are also in line with our understanding of commercialization within NASA itself. According to the SBIR liaison office at the Space Operations Mission Directorate, the average Phase II award at NASA is on the order of $500,000-600,000.[21] This is of course sharply lower than those at DoD, and reflects the particular needs and objectives of NASA programs. As a result, however, a an SBIR project that was successful from NASA's perspective—even one that resulted in technologies being adopted for a space flight mission—might well generate commercial returns of less than $1 million.

[21]Interview with Jason Crusan, Program Integration Office, Space Operations Mission Directorate, NASA, December 7, 2007.

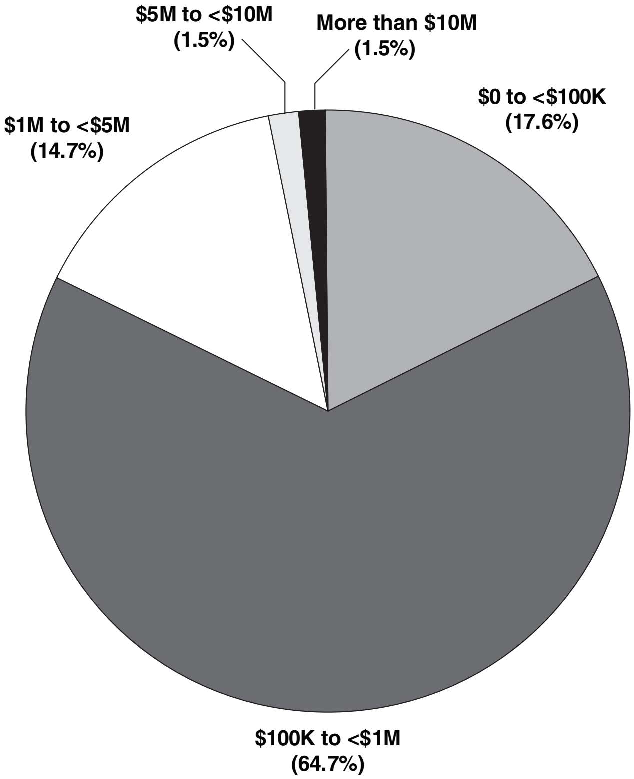

FIGURE 4-2 Distribution of projects with sales >$0.
SOURCE: NRC Phase II Survey, Detailed responses to question 4b.

The fact that 3 percent of projects generated more than $5 million in commercial returns is also approximately in line with results from other sources at other agencies.

Future Sales from Existing Projects

A complete accounting of all sales from the projects funded during 1992-2002 (the focus of the NRC Phase II Survey) will be possible only some years in the future. Many projects have only recently reached the market, so the bulk of their sales will be made in the future and are not captured in these survey data, which effectively capture initial sales (see Box 4-2). According to NASA staff, full commercialization of NASA SBIR projects usually occurs only 7 years after completion of the Phase II award.[22]

[22]Interview with Carl Ray, SBIR Program Director, November 12, 2007.

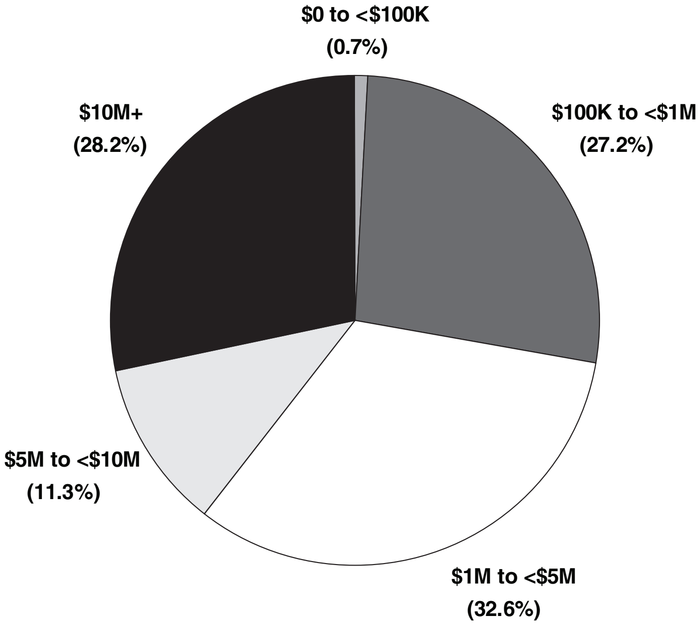

FIGURE 4-3 Distribution of sales, by total sales (percent of total sales dollars). Detailed responses to question 4b.
SOURCE: NRC Phase II Survey.

Responses to the NRC Phase II Survey also indicate that respondents expect to commercialize more in the future. About 66 percent of the NRC Phase II Survey respondents at NASA with no sales still expected sales in the future (14 percent of all projects responding).[23]

Sales by Sector

The NRC Phase II Survey asked respondents to identify the customer base for the products. Results for NASA projects are described in Table 4-1.

It is perhaps surprising that only 17 percent of sales went to NASA, plus some share of the 11 percent going to prime contractors for DoD and NASA. However, this may simply reflect the relatively small dollar size of sales to NASA, where only a few units of a given technology may be needed for a particular mission. The data also suggest significant spillover between NASA SBIR awards and DoD acquisitions. The 11 percent share of export markets might on first glance appear surprising, but space operations are a highly specialized field,

[23]NRC Phase II Survey, Question 3.

BOX 4-2
Underestimating Commercial Outcomes from the SBIR Program: The Impact of Systematic Characteristics of Survey Analysis

Among the SBIR agencies, only DoD requires that firms enter commercialization data into a database when applying for subsequent awards. This detailed database is a powerful source of information, primarily about DoD-oriented firms and projects. We would recommend that other agencies consider implementing the same requirement, and that all agencies utilize the existing DoD database for this purpose to minimize costs.

In the absence of such data, analysis of commercialization continues to rely on survey data. These data have important strengths and weaknesses.

The NRC Phase II Survey was sent to all firms with SBIR Phase II awards from 1992-2002. This represents the first effort to generate responses from the entire population of winning firms. The data generated are therefore the best available. However, there are three key sets of limitations, all of which have the effect of understating—perhaps very substantially—the amount of commercialization achieved.

These three limitations can be called the “multiple-awards effect,” the “snapshot effect,” and the “recent awards effect.”

The Multiple-awards Effect

Because some firms have received many awards, it is not feasible or reasonable to expect them to answer a similar questionnaire about each award that they received. As a result, the NRC Phase II Survey limited the number of questionnaires sent to multiple winners, sending one questionnaire per project to firms that had won three Phase II awards or less, and questionnaires to a sampling of awarded projects for firms with more than three awards.

The effect has been to bias survey responses away from firms with multiple awards. This matters when there are systemic differences between the results provided by these different groups of firms. And the NRC Phase II Survey indicates that firms with multiple awards are in fact likely to generate higher levels of commercialization than firms with smaller numbers of awards.

Using data from the DoD commercialization database to test this hypothesis, we found that firms receiving more than 15 awards generated an average of $1.39 million in sales per project; firms with fewer than 15 awards generated only $0.75 million per project. Firms with more awards generated on average 85 percent more sales per project.[a]

Thus, the selection bias away from firms with multiple awards appears likely to have had a significant downward impact on commercialization estimates.

The Snapshot Effect

Well-designed surveys provide an important insight into outcomes from SBIR projects. Necessarily, however, they provide a view of outcomes at the moment that the survey was completed.

For almost all products and services, sales follow some form of bell-shaped curve: relatively slow sales as products begin to penetrate the market, growth in sales until the market is saturated or competing products emerge, and decline until the product has been superseded. The shape of the curve differs between products, of course, and the entire curve can be completed in a matter of months for some software sales, or in decades for niche products in extremely long cycle industries (e.g., weapons platforms).

The survey, however, takes a cross-section of the bell curve. It asks about levels of commercialization at a particular point in time. In essence, it asks about past sales, but can generate little reliable data on future sales.

Thus, the average sales data generated by surveys reflects average sales *to date*. Using some simple analytic techniques, it is possible to estimate that on average, the NRC Phase II Survey (and other similar surveys such as the NIH Phase II Survey) excluded approximately 50 percent of the total lifetime sales of the products and services generated from SBIR awards.

This hypothesis is supported by recent data from NIH, where the first resurvey of firms was done in 2005, 3 years after the initial 2002 survey. Results from the survey indicate that the number of firms with some sales increased from 29 percent of surveyed firms to 63 percent (this partly reflects the number of firms still in precommercialization at the time of the first survey).

The Recent-awards Effect

The snapshot effect is further exacerbated by the distribution of responses to the surveys. For two reasons, responses are tilted toward awards from more recent years.

First, the number of awards has been rising rapidly, especially at NIH and DoD since the late 1990s. As a result, a larger number of awards are concentrated in recent years.

Second, firms with awards from many years ago are harder to find, and are less likely to respond to surveys. As one commentator notes, "there are no SBIR shrines" at SBIR recipient companies—no one may remember receiving an award 10 years ago; the company may be out of business; the PI may have left. As a result, awards that are more recent generate a higher percentage response rate.

The results of the factors are clear. At NIH for example, of the original 758 survey respondents, 258—34 percent of all respondents—reached the market *after* the date of the first survey. The first survey captured less than half of the projects that had reached the market three years later, in 2005.

This is unsurprising but very important. Responses come preponderantly from projects where awards were made relatively recently—precisely the projects where the snapshot effect is particularly important.

Conclusions

It is at this stage not possible to provide accurate estimates for the impact of these effects on commercialization estimates drawn from surveys. The limited evidence available to date suggests that the effect may be to reduce commercialization estimates by at least 50 percent, and possibly considerably more.

This analysis strongly suggests that follow-up surveys will be especially important, as they provide critical data for making precisely the assessments and modifications to the analysis that will be necessary to improve accuracy in the future.

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[a]See National Research Council, *An Assessment of the SBIR Program*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008, Chapter 4.

TABLE 4-1 Percentage of Sales by Type of Customer

Customer	Percent
Domestic private sector	35
Department of Defense (DoD)	22
Prime contractors for *DoD or NASA*	11
NASA	17
Other federal agencies	3
State or local governments	0
Export markets	11
Other	0

SOURCE: NRC Phase II Survey, Question 5.

and it is possible that technologies adopted for NASA are well placed for adoption by foreign space agencies.

Licensee Sales and Related Revenues

Licensee sales are one indicator of the extended effects of SBIR beyond the immediate awardee company and may capture important indirect commercial successes. However, the data—where survey respondents report sales not made by their own company—should be treated with an additional degree of caution as respondents do not necessarily have as accurate information about another company as they have about their own.

Licensing activity within the NASA SBIR program is limited. Only 3 projects at NASA report licensee sales greater than $0, with the largest being $300,000.[24] It thus seems reasonable to conclude that licensing is not a substantial mechanism for commercialization among NASA Phase II award recipients.

Although the numbers of licenses are limited, their impact can be significant, as the case studies show. For example, TiNi Alloy licensed its pneumatic valve technology for use by Lee Inc. in meeting NASA's needs for latching valves.[25] TiNi Alloy's Frangibolt(TM) has become a standard component on satellites (a shape memory alloy powered separation device), and was used for the Clementine Space Mission. The device has been used by TRW, the European Space Agency, and Lockheed-Martin. In addition, TiNi's pinpuller was used on the Mars Global Explorer, and is scheduled for use in NASA's STEREO program.

4.2.3 Additional Investment Funding

Further investment in a recipient company related to the SBIR award project is another indication that the project work is of value. On average, NASA SBIR

[24]NRC Phase II Survey, Question 4.
[25]See TiNi Alloy case study in Appendix E.

TABLE 4-2 Sources of Additional Investments in SBIR Projects

Source	Average Dollars
a. Non-SBIR federal funds	133,829
b. Private investment	
(1) U.S. venture capital	0
(2) Foreign investment	1,381
(3) Other private equity	3,825
(4) Other domestic private company	24,150
c. Other sources	
(1) State or local governments	13,812
(2) College or universities	966
d. Not previously reported	
(1) Your own company	100,450
(2) Personal funds	3,121
Total	281,534

NOTE: N=181 for NASA. See Table App-B-1 for a breakdown of Survey Response Rates.
SOURCE: NRC Phase II Survey, Question 23.

projects received almost $800,000 from non-SBIR sources, with over half of survey respondents (51.6 percent) reporting some additional funds for the project from a non-SBIR source (see Table 4-2).

To put this in perspective—and again noting that sampling issues limit exact comparisons among agencies—the average additional investment reported by NASA firms is less than half that reported by projects at all agencies.[26] Once again, this may reflect in part, the small size of the internal market at NASA.

So far as the source of funds is concerned, NASA projects generated no additional investment from venture capital, and largely depended for funding on internal company sources (about 35 percent of the total) and non-SBIR federal funding (just under half) (see Table 4-2). The lack of venture capital funding is unsurprising, as NASA-focused firms are almost by definition not working in markets large enough to interest venture investors.

Overall, 72 respondents (40 percent of all 181 NASA responses) reported non-SBIR funding greater than $0, with one firm receiving $15 million, and three others $1 million or more (although many more reported additional funding without committing to a specific dollar amount).

Equity Sales

Sales of equity by NASA SBIR awardees to others represent transfers of knowledge. Among the NRC Phase II survey respondents, activities to transfer equity centered on sales of technology rights to other domestic companies and

[26]Again, direct comparisons across agencies are invalidated by survey response issues. However, such comparisons can indicate areas for possible concern and future research.

TABLE 4-3 Equity Sales of NASA Phase II Awardees to U.S. and Foreign Companies and Investors

	Company Merger		Sale of Technology Rights		Partial Sale of Company		Sale of Company	
Focus of Interactions	Final (%)	Ongoing (%)	Final (%)	Ongoing (%)	Final (%)	Ongoing (%)	Final (%)	Ongoing (%)
Interactions with U.S. Companies and Investors	0	0	1	7	2	1	1	3
Interactions with Foreign Companies and Investors	0	0	1	3	0	0	0	0

SOURCE: NRC Phase II Survey, Question 12.

investors rather than sales abroad. Table 4-3 shows that much of this activity was still in process at the time of the survey. At the time of the survey, none of the awardee companies had been sold to foreign companies or investors.

Equity sales are sometimes an essential element in commercialization strategy. In some cases, companies with the ability to commercialize are located outside the U.S., and they may require ownership as a condition for commercializing.[27]

Additional SBIR Funding

Aside from providing non-SBIR funds, the federal government in many cases makes further investments via the SBIR program itself. This provides some indication that the technology and work completed to date are of continuing value to the agency. The NRC Phase II Survey asked respondents how many additional Phase I and Phase II awards followed each initial award, related to the original project. (See Table 4-4.)

About 35 percent of respondents reported receiving at least one additional related Phase II award, and slightly under half reported at least one additional Phase I award.[28]

However, a few projects received many related awards: 7.5 percent of re-

[27]For example, according to Brodd there are no volume lithium-ion battery manufacturers in the U.S. and this may influence commercialization strategies of small companies performing R&D in lithium-ion battery. Ralph J. Brodd, *Factors Affecting U.S. Production Decisions: Why are there no Volume Lithium-Ion Battery Manufacturers in the United States?* ATP Working Paper Series, Working Paper 05-01, June 2005.

[28]Note that these subsequent awards may have been made by other agencies.

TABLE 4-4 Related SBIR Awards

Related Phase I Awards		Related Phase II Awards	
Number of Awards	Percent of Responses	Number of Awards	Percent of Responses
0	52.2	0	65.4
1	18.9	1	15.1
2	11.9	2	12.6
3	6.9	3	2.5
4	2.5	4	1.3
5	2.5	5	1.3
6	0.6	6	0.6
7	0.6	7	0.6
8	1.3	12	0.6
9	0.6		
12	1.3		
19	0.6		

SOURCE: NRC Phase II Survey. Question 20

spondents reported at least 5 related Phase I awards, and 7 percent received at least three related Phase II awards.

SBIR Impact on Further Investment

The NRC Phase II Survey sought additional information about the impact of the SBIR program on company efforts to attract third party funding—the "halo effect" mentioned by some interviewees, who suggested that an SBIR award acted as form of validation for external inventors.[29]

The fact that 60 percent of NASA SBIR respondents reported no outside funding, and that none at all received venture funding, suggests that receiving a NASA Phase II SBIR award may have only a limited effect in improving the likelihood of external funding for these recipients.[30]

4.2.4 Small Company Participation and Employment Effects

Growing employment is another indicator of commercial success. It also provides evidence that the program is supporting small business.

The median size of company receiving SBIR awards is relatively small—far

[29]For a discussion of the 'halo effect' from awards by the Advanced Technology Program, see Maryann Feldman and Maryellen Kelley "Leveraging Research and Development: The Impact of the Advanced Technology Program," in National Research Council, *The Advanced Technology Program: Assessing Outcomes*, Charles W. Wessner, ed. Washington, DC: National Academy Press, 2001.

[30]See Chapter 4 in National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, op. cit.

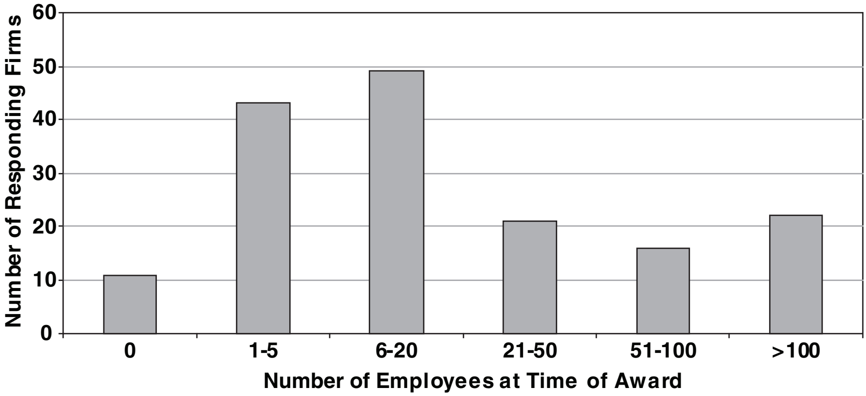

FIGURE 4-4 Distribution of companies, by number of employees at time of award.
SOURCE: NRC Phase II Survey, Question 16.

lower than the 500 employee limit imposed by the SBA. Most awards go to very small companies. Among NRC Phase II Survey respondents, about just over a quarter had between one and five employees at the time of award. A majority (64 percent) of respondents had 20 employees or fewer at the time of the Phase II award.

The NRC Phase II Survey sought detailed information about the number of employees at the time of the award and at the time of the survey and about the direct impact of the award on employment. Overall, the survey data showed that the average employment gain at each responding firm from the date of the SBIR award to the time of the survey was 16 full-time equivalent employees. Of course, few companies that went out of business have responded to the survey, so this question is particularly skewed toward firms that have been at least somewhat successful.

Table 4-5 shows that the percentage of companies with more than 50 employees grew from 24.5 to 31.5 percent of respondents.

26.5 percent of firms reported that they were in the smallest size group (1 to 5 employees) at the time of their first Phase II award. Only 16 percent remained at that size at the time of the survey. All other size groups have increased their share of the reporting firms. One of the reporting firms has outgrown the SBIR program size limitation of 500 employees (it had 520 at the time of the survey), and the second and third largest firms had 370 and 366 current employees, respectively.

The NRC Phase II Survey also sought to identify employment gains that were the direct result of the award. Respondents estimated that specifically as a result of the SBIR project, their firm was able to hire an average of 1.3 employees, and to retain 1.4 more.[31]

[31]NRC Phase II Survey, Question 16.

TABLE 4-5 Employment at Phase II Respondent Companies, at the Time of Award and at Time of Survey

Number of Employees	At Time of Award		At Time of Survey	
	Number	Percent	Number	Percent
0	11	6.8	3	1.9
1-5	43	26.5	26	16.0
6-20	49	30.2	56	34.6
21-50	21	13.0	26	16.0
51-100	16	9.9	16	9.9
>100	22	13.6	35	21.6
Total	162	100	162	100

SOURCE: NRC Phase II Survey, Question 16.

4.2.5 Sales of Equity and Other Company-level Activities

Company-level operations may offer another set of indicators for measuring commercial activity, as these may capture activities that indicate commercial value even absent sales. The NRC Phase II Survey explored whether SBIR awardees had finalized agreements or ongoing negotiations on various company-level activities. This information is summarized in Table 4-6.

The impact of these activities is hard to gauge using quantitative assessment tools only. Box 4-3 illustrates how research conducted using SBIR funding seeded an entire generation of spin-off companies and joint ventures in a technology of potential significance for homeland security.

TABLE 4-6 Company-level Activities

	Activities	U.S. Companies/Investors		Foreign Companies/ Investors	
		Finalized Agreements (%)	Ongoing Negotiations (%)	Finalized Agreements (%)	Ongoing Negotiations (%)
a.	Licensing agreement(s)	6	11	8	5
b.	Sale of company	1	3	0	0
c.	Partial sale of company	2	1	0	0
d.	Sale of technology rights	1	7	1	3
e.	Company merger	0	0	0	0
f.	Joint Venture agreement	1	4	0	2
g.	Marketing/distribution agreement(s)	7	5	6	2
h.	Manufacturing agreement(s)	2	6	2	0
i.	R&D agreement(s)	16	10	4	1
j.	Customer alliance(s)	11	9	6	0
k.	Other *Specify*____________	3	4	1	1

SOURCE: NRC Phase II Survey, Question 12.

BOX 4-3
Detecting Toxins at a Distance:
The Case of Intelligent Optical Systems[a]

Intelligent Optical Systems (IOS) has developed a system for using the entire length of a specially-designed fiber-optic cable as a sensor for the detection of toxins and other agents. This bridges the gap between point detection and standoff detection, making it ideal for the protection of fixed assets.[b]

Intelligent Optical Systems has leveraged its SBIR-supported research to develop subsidiaries and spin-offs. This activity has generated private investments of $23 million in support of activities oriented toward the rapid transition to commercially viable products.

Since January 2000, IOS has formed two joint ventures, spun out five companies to commercialize various IOS proprietary technologies, and finalized licensing/technology transfer agreements with companies in several major industries.

Optimetrics manufactures and markets active and passive integrated optic components based on IOS-developed technology for the telecommunication industry. Maven Technologies was formed to enhance and market the Biomapper technologies developed by IOS. Optisense manufactures and distributes gas sensors for the automotive, aerospace, and industrial safety markets, and will be providing H2 and O2 optical sensor suites designed to enhance the safety of NASA launch operations. Optical Security Sensing (OSS), which is IOS's newest spin-off company, was formed to commercialize chemical sensors for security and industrial applications.

IOS currently employs 40 scientists, and almost 80 percent of its revenues come from non-SBIR sources. The company currently holds 13 patents, with an additional 13 applications pending.

[a]See "SBIR and STTR Success Story for Intelligent Optical System," accessed at *<http://grants.nih.gov/grants/funding/sbir_successes/160.htm>*.

[b]*Point detection* means the contaminant comes into physical contact with the sensor and it is analyzed. In *standoff detection*, the sensor sees the contaminant at a distance and recognizes it, but the contaminant never comes in contact with the sensor.

Other companies that were at least initially strongly SBIR dependent have also utilized the spin-off approach. Creare, Inc., has spun off more than 12 companies, which together generate more than $250 million in annual revenues and employ 1,500 people.[32] Luna Innovations has created five new companies since 2000 while opening additional branches in Charlottesville, Danville, Roanoke, Hampton Roads, and Mclean, Virginia and Baltimore, Maryland.[33]

[32]See Creare, Inc., case study in Appendix E.
[33]See Luna Innovations, Inc., case study in Appendix E.

4.2.6 Commercialization: Conclusions

While accepting the view that there is no single, simple metric for determining the commercial success of an early stage R&D program such as SBIR, numerous metrics do provide the basis for making a broad determination of commercial outcomes at SBIR.

These data, taken together, support the view that while the NASA SBIR program has traditionally had a strong commercial focus, with considerable efforts to bring projects to market, overall success in this area has been elusive. The number of major commercial successes has been few, and while this is normal for early stage high-risk projects, the fact that no NASA project reports more than $15 million in related sales does indicate the challenges that NASA companies face.

Despite the challenges, the overall commercialization rate for the NASA SBIR program has been comparable to those identified using other data at other agencies. The NRC Phase II survey respondents indicated that 46 percent of NASA SBIR projects had reached the market. These conclusions broadly align with views from within the agency: according to the NRC Project Manager Survey, about 35 percent of projects are believed to have commercialized.[34]

Still, the small number of big winners means that overall commercialization from the program has been limited. Average commercialization is well below $1 million per project.[35]

The structural difficulties facing commercialization for NASA-funded SBIR projects have been a major factor in the 2006 restructuring of the SBIR program. The restructuring was also driven by a recognition at NASA that the number of projects reporting sales made to NASA—the adoption of SBIR technology by NASA—was also relatively low. Only 17 percent of projects with sales report that these went to NASA.

The impact of this switch from a commercialization focus to an agency mission focus has been noted by companies interviewed for this report. For example, DCT (a small Ohio software maker), finds that NASA is, in its experience, increasingly focusing the SBIR program on specific space-related needs that have with little commercial significance. Narrowly focused topics with specific mission objectives significantly limit opportunities for commercialization, in the view of DCT.[36]

[34]NRC Project Manager Survey, Table App-D-19.

[35]NRC Phase II Survey, Question 4. From the 181 projects that responded to the survey, 78 reported a year of first sale and only 74 reported sales greater than zero. Their average sales were $1,154,156. Over half of the total sales dollars were due to 7 projects, each of which had $3,200,000 or more in sales. The highest reporting project had $15 million in sales. Similarly, of the 19 projects that reported a year of first licensee sale, only 3 reported actual licensee sales greater than zero. Their average sales were $127,000. Ninety-nine percent of the total dollars was due to one project, which had $30,000 or more in licensee sales.

[36]It is worth noting that the shift in emphasis will have negative effects as well as positive ones. At DCT, earlier awards funded nearly 100 percent of company R&D, which implies that DCT will

Internal tracking capabilities at NASA are very limited. The last update to the internal outcomes spreadsheet apparently halted before data for the FY1998 Phase II awards could be entered. Better utilization of the NASA SBIR program by the agency must be matched by improved and timelier tracking of outcomes.

4.3 AGENCY MISSION

Agency missions vary substantially by agency—indeed, each agency has a unique mission by design. Thus, each agency must address the extent to which the SBIR program supports its mission. However, some more general observations can be made.

An assessment of the extent to which SBIR supports an agency's mission can be divided into two areas:

- *Procedural alignment*—the extent to which the procedures of the agency SBIR program are aligned with the needs of the agency.
- *Program outcomes*—the extent to which outcomes from the program have the effect of supporting the agency mission.

In addition, the subjective views of program managers can be introduced as an important source of evidence about program effectiveness.

It is important to note that the different missions of the agencies mean that some agencies define agency mission support more narrowly, or at least have much tighter metrics for assessing this element of the program. In particular, the procurement agencies—primarily DoD and NASA—assess contribution to agency mission primarily against the extent to which the agency itself *uses* outputs from the SBIR program. In contrast, the nonprocurement agencies—NIH, NSF, and, to a great extent, DoE—see support for mission much more broadly: for NIH, for example, support for mission can be construed as anything that improves medical knowledge or public health.

4.3.1 Procedural Alignment of SBIR Programs and Agency Mission at NASA

A procedural assessment reviews the steps taken by each agency program to ensure that the design and procedures of their SBIR program are aligned with the needs of the agency.

be increasingly unable to continue making software advances. In particular, they see themselves less able to compete with European companies where governments support research and technical implementation.

BOX 4-4
NASA Mission

NASA's mission is to pioneer the future in space exploration, scientific discovery, and aeronautics research.

SOURCE: NASA Web site. Access at *<http://www.nasa.gov/about/highlights/what_does_nasa_do.html>*.

Topics and Solicitations

To align SBIR with its agency mission, NASA must ensure that the topics that guide applicants (and at NASA define the limits of what can be funded) are themselves aligned with agency mission needs. These topics are published in an annual solicitation of proposals. Within each solicitation, specific subject areas of interest are defined by individual *topics and subtopics*. These can be focused tightly on a specific problem or requirement, or they may broadly outline an area of technical interest to the agency.

Aside from NIH, which expressly indicates that its topics are guidelines, and not mandatory limits or boundaries on research that could be funded, all the SBIR funding agencies use topics to specify the technical boundaries of the research they are prepared to fund. In doing so, they are specifically delimiting areas of technical interest to the agency.

At NASA, the structure of the SBIR solicitation, and the technical taxonomies used to define topics and subtopics, parallel the structure and taxonomies of the Mission Directorate technology program roadmaps. This supports alignment between SBIR projects and agency mission.

This is *prima fascia* confirmation that the SBIR programs support agency mission: Unless there is evidence that agencies are generating topics that are *not* aligned with the agency mission—and our analysis and interviews with staff and awardees found no trace of this—the use of topics and solicitations indicates that agencies are working to ensure that awards are aligned with the stated scientific and technical needs of the agency.

However, what is less clear is how the alignment of topics meshes with the changing management priorities. For SBIR, the pre-2006 management structure strongly favored the priorities of the centers and individual researchers, over the priorities of the Mission Directorates and Headquarters. Thus while the SBIR program pre-2006 was closely aligned with NASA mission needs, these were not always the priorities of the Mission Directorates or the technology programs that eventually funded the take-up ("infusion" as NASA calls it) of SBIR-funded technologies into NASA space missions.

Award Selection Process

The selection of awards can also support an agency's mission, to the extent that the process reflects the agencies' priorities. A wide range of awards procedures are used at the various agencies and these may differ substantially even between components of the same agency. For example, DoD, Army, and Navy use different approaches, staff, and methodologies for selecting awardees.

At NASA, evaluation of Phase I proposals is performed by NASA scientists and engineers at the center(s) identified in the Solicitation as responsible for the applicable subtopic.

While initial rankings are developed at the Centers, where the relevant technical expertise resides, final decisions are made by the NASA Source Selection official after input form the Mission Directorates. A high center ranking does not guarantee funding. However, this process too has changed since 2006; Mission Directorate input is now much stronger. According to Parminder Ghuman of the Science Mission Directorate, of the 95 Phase I proposals recommended for funding by the centers, 86 eventually received an award after MD review.[37]

Mr. Ghuman also notes that the commercialization section of proposals is accorded relatively little weight in the NASA selection process. This is unsurprising given the limited commercial success of NASA-funded projects in general.[38]

Phase II selection is strongly influenced by the report of NASA's Phase I technical representative (the COTR); these staff a responsible for managing the Phase I and help to determine whether Phase II funding is appropriate. After 2005, increased efforts have been made to ensure that the COTR for a Phase I project is also likely to be the official running the section of the Mission Directorate's technology program where any post Phase II work will be funded.

NASA has now also formalized the previous practice of providing additional SBIR awards to centers that provide matching funds—a clear sign that the proposed project is a high priority item. The new program is called Phase IIe. There are no data either on the number of projects that were funded this way in the past, or on the impact of formalizing this part of the selection program.[39]

Overall, then, the selection process is designed to ensure that funded proposals are in all cases aligned with both the broad mission of the agency and the specific technical needs of the agency in designated areas. Those needs are written by the project managers who will be responsible for meeting them, and thus have every incentive to ensure that the topics published are those that meet their most important needs.

Interviews with NASA staff also determined that SBIR funds can constitute a significant proportion (often more than 50 percent) of the funding available to a program manager for immediate and flexible deployment. Most NASA

[37]Interview with Parminder Ghuman, Science Mission Directorate, December 7, 2007.
[38]Ibid.
[39]Interview with Paul Mexcur, NASA's SBIR & STTR Program Manager, June 2005.

funds—like DoD—are committed years in advance, so flexible funding like SBIR can be highly prized.

4.3.2 Program Outcomes and Agency Mission

In contrast to the discussion above, program outcomes for agency mission are more difficult to assess. All of the methodological difficulties in assessing outcomes discussed at the beginning of this chapter apply here; moreover, (unlike commercialization) there are few widely accepted benchmarks.

Like other agencies, NASA maintains a list of "success stories," describing SBIR awards that meet congressional goals. Some of these are focused on agency mission. However, the stories themselves, while illustrative of the power of the program to help develop new technologies, are of variable quality.

The NRC Phase II Survey data suggest that NASA SBIR has found limited take-up within the agency. Only about 10 percent of NASA Phase II awards have attracted NASA Phase III funding for either further development or purchase of product or service.

However, the NRC Project Manager Survey of agency technical managers (COTR) provided an additional source of important information in this area. These agency staff are in charge of the research areas within which SBIR awards are made. The survey sought to measure the *quality* of SBIR research from the perspective of technical staff who managed both SBIR and non-SBIR programs. The NRC therefore surveyed all COTRs with responsibilities for SBIR projects at NASA.

4.3.2.1 Results from the NRC's Project Manager Survey

COTRs tend to be involved with the SBIR Phase II projects to which they are assigned. This involvement gives them a unique basis for evaluating the quality, usefulness, and value of each project to NASA. We used the survey of project managers to develop measures of these dimensions of program outcomes. Program managers at other agencies—primarily DoD but also DoE—were also included in the survey.

Project Quality

COTRs were asked to rank their SBIR projects in terms of quality on a scale of 1 to 10. The mean score was 6.98 (with a standard deviation of 1.846) as seen in Table 4-7.

This metric however does not adjust for "toughness of the grader." To compensate for the fact that different project managers have different standards in mind when evaluating a research project, COTRs were also asked to rate the average quality of other research projects conducted for their research unit/office. They gave this other research a mean score of 7.45 (standard deviation of 1.268). (See Table 4-8.)

TABLE 4-7 Ratings for SBIR Projects

Measure of Quality of SBIR Project	Total Sample	NASA
Mean Score	6.93	6.98
Standard Deviation	2.072	1.846
Median Score	7	8
Sample Size	513	82

SOURCE: NRC Project Manager Survey.

TABLE 4-8 Ratings for Non-SBIR Research Projects

Measure of Average Quality of Research (non-SBIR)	Total Sample	NASA
Mean Score	7.29	7.45
Standard Deviation	1.594	1.268
Median Score	8	7
Sample Size	513	82

SOURCE: NRC Project Manager Survey.

A comparison of the scores for the SBIR and non-SBIR projects allows us to gauge how COTRs view the relative quality of the SBIR projects. The differences in means between the score for the sample of SBIR and non-SBIR projects are given in Table 4-9.

For the total sample of NASA SBIR projects, the SBIR projects were on average somewhat lower.[40]

Linkage to Research Mission

The NRC Project Manager Survey also addressed the usefulness of the research for the research unit/office, and in particular the extent of linkages between the SBIR research project and other research conducted by the agency. About 44 percent of NASA responses indicated no linkage, compared with about 30 percent at other agencies. Approximately a quarter of NASA managers encouraged firms to continue their research through further SBIR awards, or through other agency-funded research projects, compared with nearly 50 percent at other agencies. About 10 percent of projects were "blind alleys." (See Table 4-11.)

Overall, these responses suggest that while COTR's at NASA do see value in SBIR projects, they have seen significantly less value than in other similar research projects, and they have made less effort to use the results of SBIR projects in other agency/unit research.

[40]As judged by NASA project managers, the difference in the measure of project quality was 0.476. Using a statistical "t-test," these differences are statistically significant (at the .01 level). In interpreting this statistic, it is worth keeping in mind that the magnitude of the difference in perceived research quality is rather small—on a scale from 1-10, the difference is only .476.

TABLE 4-9 Mean Difference in Scores SBIR Quality Minus Average Non-SBIR Project Quality

Measure of Difference in Scores of Project Quality	Total Sample	NASA
Mean Difference in Score—SBIR Quality Minus Average Non-SBIR Project Quality	–.364*	–.476**
Standard Deviation	2.15	2.10

NOTES: *Statistically significant at the .01 level; **Statistically significant at the .05 level.
SOURCE: NRC Project Manager Survey.

Comparative Value of SBIR Projects

Another way to look at the value of SBIR-funded research from the agency's perspective is to consider the utility of money spent on SBIR projects compared with money spent on other R&D.

As Table 4-12 shows, about 30 percent of NASA respondents indicated that SBIR projects gave fewer mission benefits than the average dollar spent on other contracts, while 18 percent thought SBIR projects gave more benefits. Fifty percent saw the benefits as equivalent. Once again, NASA COTRs had a less positive view of SBIR projects than did those at other agencies surveyed by the NRC.

Abundance of Fundable SBIR Proposals

A majority of NASA COTR's (56 percent) believe that, in general, their research office/unit receives more good SBIR proposals than they can fund (see Table 4-13). About one-fifth reported more money on hand than high quality

TABLE 4-10 Distribution of Scores SBIR Quality and Average Non-SBIR Project Quality (NASA)

	Quality of Research (SBIR)		Average Quality of Research (Non-SBIR)	
Score of Project Quality	Number of Responses	Percent	Number of Responses	Percent
1	0	0.00	0	0.00
2	2	2.44	0	0.00
3	3	3.66	0	0.00
4	4	4.88	1	1.22
5	7	8.54	7	8.54
6	10	12.20	9	10.98
7	20	24.39	19	23.17
8	20	24.39	31	37.80
9	12	14.63	13	15.85
10	4	4.88	2	2.44
TOTAL	82	100.00	82	100.00

SOURCE: NRC Project Manger Survey.

TABLE 4-11 Effect of SBIR Project's Research on Your Research Unit

	Number of Responses		Percent	
	Other Agencies	NASA	Other Agencies	NASA
No, this project was a separate project, and the knowledge generated by this SBIR contract has had no impact on the other research we conduct or sponsor.	130	36	30.2	43.9
Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract by encouraging the firm to apply for additional SBIR awards.	127	21	29.5	25.6
Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract in other research we conduct or sponsor.	208	26	48.3	31.7
Yes, but this project found a blind alley, so we have not followed up on this line of inquiry.	41	8	9.5	9.8
Total Sample	431	82	N/A	N/A

NOTE: Multiple answers were permitted.
SOURCE: NRC Project Manager Survey.

proposals. This suggests that the marginal value of increased SBIR funding is likely to be high.

This response helps to confirm the view that SBIR in general receives high quality applications, and that these are more applications that could be funded than there is funding available.

TABLE 4-12 Comparative Dollar Value of Projects

	Number of Responses		Percent	
Dollar Value	Other Agencies	NASA	Other Agencies	NASA
SBIR project had fewer benefits for your agency's mission than the average dollar spent on other contracts you sponsor	119	26	27.6	31.7
SBIR project had more benefits for your agency's mission than the average dollar spent on other research contracts you sponsor	128	15	29.7	18.3
Same Benefits	184	41	42.7	50.0
TOTAL SAMPLE SIZE	431	82	100.0	100.0

SOURCE: NRC Project Manager Survey.

TABLE 4-13 Relative Number of Fundable SBIR Projects

	Number of Responses		Percent	
	Other Agencies	NASA	Other Agencies	NASA
More fundable proposals than can fund	180	40	65.2	56.3
About the right number of proposals	66	16	23.9	22.5
Fewer fundable proposals than can fund	30	15	10.9	21.1
Total Sample Size	276	71	100.0	100.0

SOURCE: NRC Project Manager Survey

"Ownership Effect"

One important finding from the NRC Project Manager Survey was that early "ownership" of an SBIR project by agency staff leads to much more positive views of project outcomes. This is in itself not a surprising finding—projects where managers were involved at the design stage are more likely to align with their larger research agendas. However, the size of this effect was substantial.

The COTR sample was broken into two subsamples: project managers with a potentially strong degree of ownership in the project; and those with less potential for ownership. In this context, "ownership" means that the project manager had a potential stake in the project as demonstrated either by being involved in defining the topic or being involved with the recipient firm before the Phase I proposal.

Table 4-14 shows that managers with ownership had a much higher opinion of their SBIR projects than those with more of a connection to their projects.

- The ownership managers has a much more favorable view of research quality.
- Three quarters of the nonownership group saw the SBIR-funded research as "not useful," compared with under 30 percent for the ownership group.

TABLE 4-14 Analysis of Ownership Effects—NASA

Area of Interest	Ownership Group (n=55)		Remaining Project Managers (n=27)	
Research Quality	–.236		–.963	
Usefulness of Research				
a. No, not useful	16	29.09%	20	74.07%
b. Yes, more SBIR	16	29.09%	5	18.52%
c. Yes, general follow-up	23	41.82%	3	11.11%
d. Yes, but blind alley	8	14.54%	0	0.00%
Mission Benefits (Q6)				
a. More than average		20.00%		14.81%
b. Same as average		52.73%		44.44%
c. Less than average		27.27%		40.74%

SOURCE: NRC Project Manager Survey.

- Almost four times the share of ownership respondents indicated that they were looking for non-SBIR support for subsequent research or acquisition.
- The ownership group also identified stronger mission benefits, though the differences between the groups were not so pronounced on this area.

Cause and effect are not identified here. However, evidence from elsewhere—e.g., the NRC Phase III Conference Report—indicates that ownership effects of this kind can be encouraged by agency management and policies, and also that their impact persists into Phase III.

Project Managers and Phase III

Project managers were asked whether their projects received Phase III funding from NASA. As shown in Table 4-15, slightly fewer than 16 percent of Phase II Projects got additional funding from NASA. More than half did not, and just over a quarter of respondents did not know. This finding quite closely tracks results from the NRC Phase II Survey.

This Phase III funding was evenly distributed between direct procurement, incorporation of the technology into a larger system, and additional non-SBIR research funding. These results were broadly comparable with NRC COTR Survey data from other agencies (including of course DoD). They also indicate significant room or improvement in the linkage between the program managers who fund SBIR research and outcomes from that research, both at NASA and at other agencies.

Overall, these results suggest that NASA's SBIR program will require substantial changes to achieve its recent increased emphasis on "spin-in" outcomes.

Project Manager Involvement

Overall, NASA projects managers indicated extensive involvement in the projects they funded (see Table 4-16). However, the proceedings from the NRC Phase III Conference and other agency interviews at NASA and DoD indicate that the timing of that involvement is important.[41]

About 40 percent of NASA respondents reported that they became involved with the SBIR project before Phase I—i.e., during the topic development stage. However, this was true for almost 70 percent of project mangers reporting from other agencies. This difference may possibly result in part form the extensive efforts made by DoD since the late 1990s to improve the alignment between topic development, SBIR program managers, and the acquisitions community. The 2006 structural changes in the SBIR program are partly designed to address this specific issue.

The actual role of the project manager also appears to vary from project-to-

[41] See the conference remarks by Michael McGrath of the U.S. Navy summarized in National Research Council, *SBIR and the Phase III Challenge of Commercialization*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007, pp. 59-62.

TABLE 4-15 SBIR Project Received Phase III Funding from Your Agency

	Number of Responses		Percent	
Phase III Funding from your Agency—Form	Other Agencies	NASA	Other Agencies	NASA
Direct procurement of the product of this SBIR	10	5	2.3	6.1
Procurement through incorporation of the result of this project into system	15	3	3.5	3.7
Further non-SBIR R&D funding	48	5	11.1	6.1
No Phase III from agency	253	46	58.7	56.1
Unknown	105	23	24.4	28.0
Total	431	82	100.0	100.0

SOURCE: NRC Project Manager Survey.

TABLE 4-16 When Did Project Manager Become Involved in Project?

	Number of Responses		Percent	
When Involved in SBIR Project?	Other Agencies	NASA	Other Agencies	NASA
Before Phase I	300	34	69.6	41.5
After Phase I, Before Phase II	81	37	18.8	45.1
After Phase II started, Before Phase II completed	42	11	9.7	13.4
After Phase II completed	8	0	1.9	0.0
Total	431	82	100.0	100.0

SOURCE: NRC Project Manager Survey.

project, and from project manager to project manager. Table 4-17 summarizes the project managers' role(s) with respect to the particular SBIR project in question. Over 97 percent of NASA respondents claimed a "technical" role, while only 5 percent claimed a "financial" role and 12 percent claimed a "commercial" role.

Finally, NASA project management appears more closely focused on technical issues, and much less on financial controls. However, it is unclear whether this distinction has any impact on commercialization or other outcomes.

Evidence from the NRC Project Manager Survey: Conclusions

The NASA SBIR project managers in our sample appear to be, for the most part, engaged with the SBIR program. Many were involved with their projects early and often. In general, they ranked the quality of SBIR research as similar to that of non-SBIR research. Most believed their projects ere useful to NASA's

TABLE 4-17 Role of Project Manager with Respect to this SBIR Project

	Number of Responses		Percent	
Role of Project Manager	Other Agencies	NASA	Other Agencies	NASA
Technical	413	80	95.8	97.6
Financial	105	4	24.4	4.9
Commercialization Assistance	74	10	17.2	12.2
Other	50	5	11.6	6.1
Total Sample Size	431	82	N/A	N/A

NOTE: Multiple responses permitted.
SOURCE: NRC Project Manager Survey.

mission, and the majority of respondents reported that they had more high quality SBIR proposals than they could fund. NASA SBIR project managers seem uninvolved in Phase III activity.

4.3.2.2 Case Studies and Agency Mission

A second avenue for gathering important information about the impact of the SBIR program on NASA's mission lies in the use of case studies. These are collected in Appendix E, but it is also worth highlighting summaries of some of the more notable cases below. It should be understood that these cases are specifically designed to highlight cases where SBIR did indeed make a significant difference to NASA's space mission.

Restoring the Hubble Space Telescope: The Creare–NCS Cryocooler

The NCS Cryocooler was used on the Hubble Space Telescope to restore the operation of the telescope's near-infrared imaging device. This was a mission-critical adjustment to the operations of the Hubble, in light of the failure of a key component.

The Independent Space Science Board Report on the project concluded that

> *On the technical side, the cryocooler system had been successfully flown and tested in space; and great care had been taken to characterize the thermal, mechanical, and electro-optical changes that NICMOS had undergone late in 1998 and during the rapid warm-up of January 1999. We now know a great deal more about the technical issues surrounding the feasibility of successfully prolonging the life of NICMOS through the installation of a cryocooler. We commend the GSFC and Creare teams for developing and successfully flight testing the cryocooler on such a short time scale.*[42]

[42] Report of the Independent Science Review: NICMOS Cryocooler, March 4-5, 1999. <*http://www.stsci.edu/observing/nicmos_cryocooler_isr1999.html*>.

The technologies that were required to build that cryogenic refrigerator started being developed in the early 1980s as one of Creare's first SBIR projects. Over 20 years, Creare received over a dozen SBIR projects to develop the technologies that ultimately were used in the cryogenic cooler.

Additionally, Creare has been awarded "Phase III" development funds from programmatic areas that were ten times the magnitude of the cumulative total of SBIR funds received for fundamental cryogenic refrigerator technology development. However, until the infrared imaging device on the Hubble telescope failed due to the unexpectedly rapid depletion of the solid nitrogen used to cool it, there had been no near-term application of the technologies that Creare had developed.

Monitoring the Space Shuttle's Surface: The Wireless Data Acquisition Project

In light of the Columbia disaster, NASA became aware of the need to develop new technologies that could wirelessly transmit data from key points on the surface of space vehicles to instruments inside the vehicle, for download to mission controllers on Earth.

Figure 4-5 shows how the Johnson Space Center used SBIR to develop some of the critical technologies used for the acquisition of wireless data—a key component in monitoring space flight.

Data developed using this technology development program was used to monitor the leading edge of space shuttle wings—a new requirement for the shuttle after the Columbia tragedy.

The chart shows that SBIR technologies were infused into the overall wireless instrumentation system at several points in its 6-year development cycle.

4.3.3 Conclusions: Agency Mission

The case studies and data from the NRC Project Manager Survey both show that NASA has in the past successfully used SBIR to develop technologies that were critically important for some NASA missions.

However, NASA itself determined that the existing approach, driven largely from the bottom up by the needs and interests of specific centers, was not working well enough. Accordingly, as detailed in Chapter 5 (Program Management) NASA started to change the way SBIR works at the agency specifically to improve outcomes related to supporting agency mission.

The new approach is designed to ensure a tighter alignment between the needs of the agency, as expressed through requirements and roadmaps developed by the Mission Directorates, and the selection of topics and proposals.

In effect, NASA is seeking to switch the primary emphasis of the SBIR program from commercialization to support for agency mission. One challenge that Mission Directorate staff are now focusing on is that there are currently no metrics in place to help assess the success or otherwise of this change of emphasis.

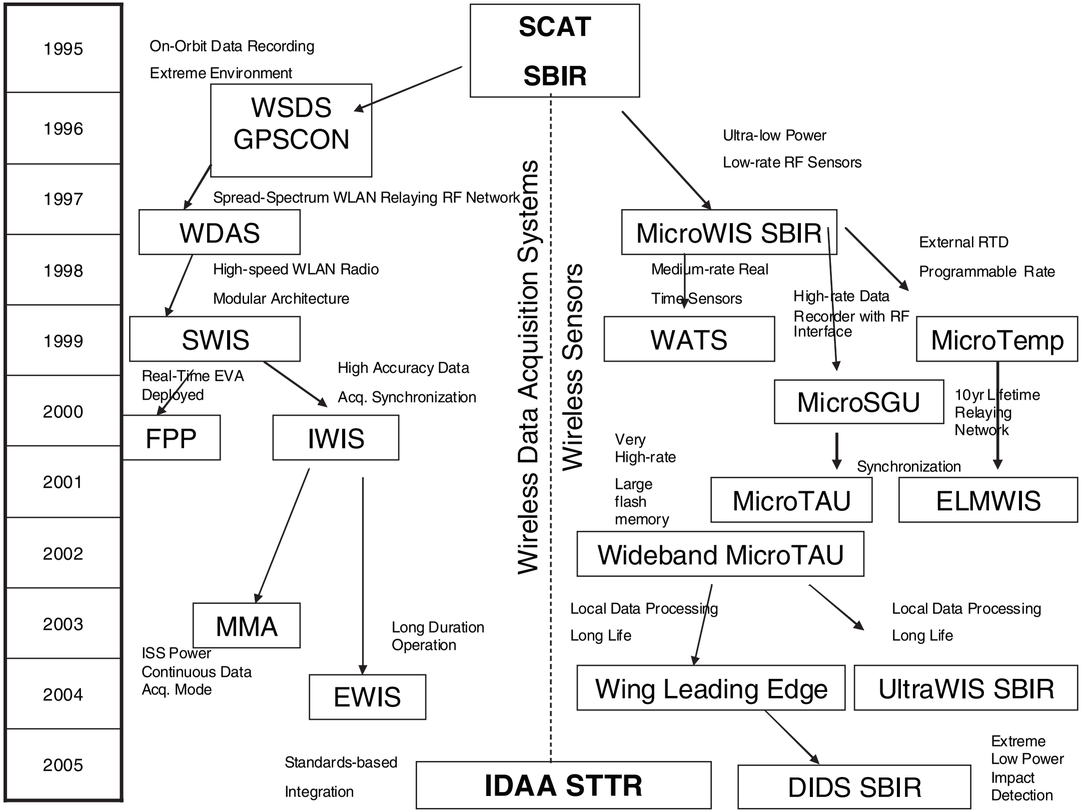

FIGURE 4-5 Technology Development Tree for Wireless Data acquisition.
SOURCE: John Saiz, Johnson Space Center, Houston, TX.

4.4 SUPPORT FOR SMALL, WOMAN-OWNED, AND DISADVANTAGED BUSINESSES

4.4.1 Support for Woman- and Minority-owned Firms

Support for woman and disadvantaged persons is one of the four primary congressional objectives for the SBIR program. In the context of SBIR, NASA has used, as its primary metric, the extent of support for woman- and minority-owned businesses.

Award Patterns

The trends for both Phase I and Phase II awards at NASA are relatively flat for both woman- and minority-owned businesses, with a recent positive shift for women.

The absence of detailed applications data for woman- and minority-owned businesses at NASA means that it is not possible at present to determine whether these trends are the result of an increase in the number of applications from woman- and minority-owned firms, improved success rates, a combination of both, or some other factor.

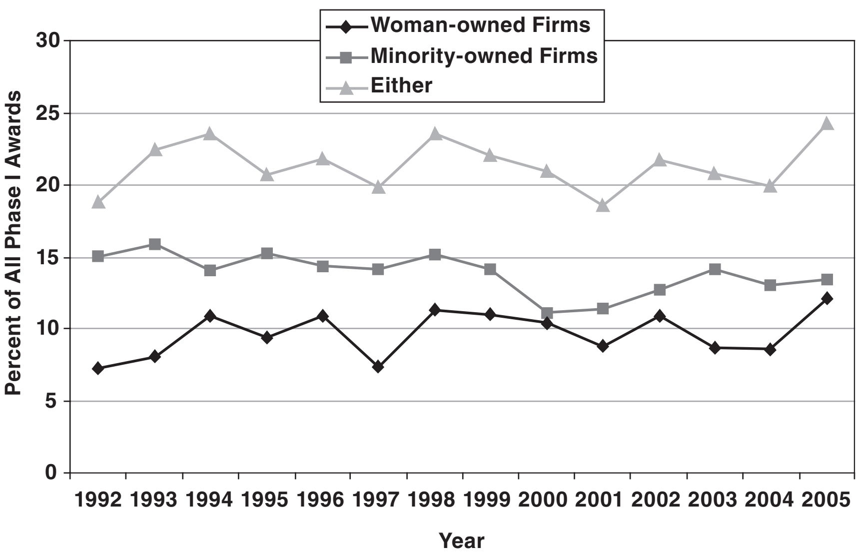

FIGURE 4-6 NASA SBIR Phase I awards, by demographic group, 1992-2005.
SOURCE: National Aeronautics and Space Administration.

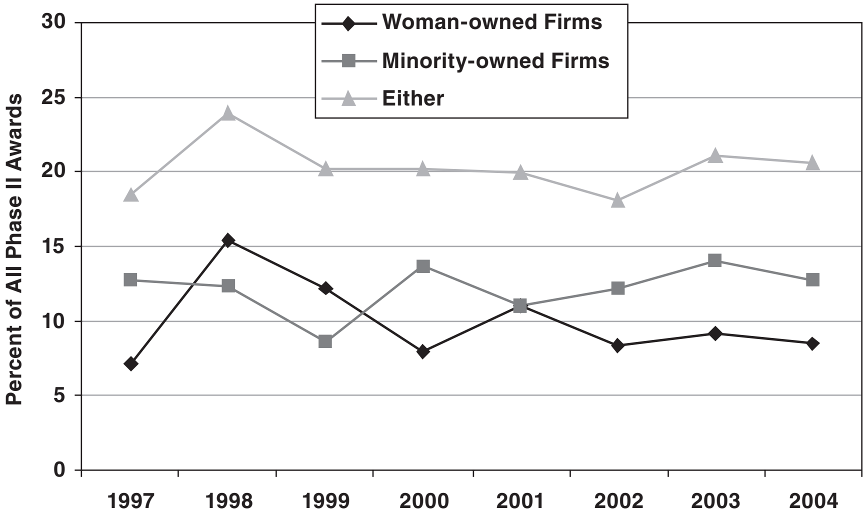

FIGURE 4-7 NASA SBIR Phase II awards, by demographic group, 1997-2004.
SOURCE: National Aeronautics and Space Administration.

4.4.2 Small Business Support

At one level, the SBIR program obviously provides support for small business, in that it gives funding only to businesses with no more than 500 employees—the SBA definition of a small R&D business.

This positive view is strongly reflected in the case studies undertaken by the NRC for this volume. Companies utilize SBIR for a range of purposes, and founders and senior staff interviewed for the NRC study were in many cases willing to credit a government funding program at least partially for their success.

However, it has been less clear whether SBIR has provided additional support for small business, or simply aggregates existing small business research dollars under the program's umbrella.

Project-level Impacts

One way of measuring SBIR's impact is to ask awardees whether their projects would have been implemented without SBIR program funding. Data in Figure 4-8 from the NRC Phase II Survey strongly suggest that SBIR provides funding that plays a determinant role to most of the projects that receive it.

According to the NASA respondents, about 68 percent of projects would likely not have proceeded at all without SBIR.[43] This finding reflects the known

[43]NRC Phase II Survey, Question 13.

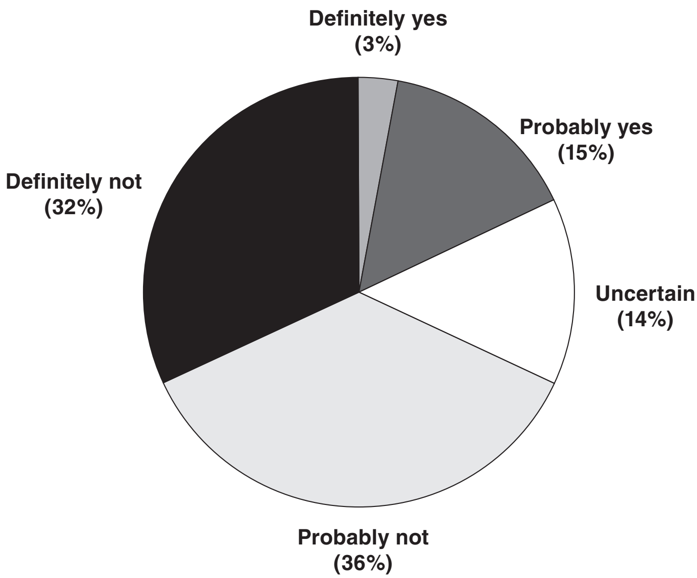

FIGURE 4-8 Would the project proceed without SBIR funding? (Percent of respondents).
SOURCE: NRC Phase II Survey, Question 13.

difficulties in funding high-risk early-stage research in all scientific fields. SBIR seems to provide critical funding necessary to fund many early-stage projects.

Respondents also indicated that many of the 18 percent of projects that were "definitely" or "likely" to have continued in the absence of SBIR funding would have had significant delays and other changes.[44] Forty-three percent of these respondents noted that the project's scope would have been narrower. Seventy-six percent of projects that would have continued would have been delayed, and 48 percent expected the delay would have been at least 24 months.[45]

In short, SBIR has a profound effect on project initiation for the high tech projects that it funds and, in turn, on the commercialization outcomes of these projects.

Impacts Different Types of Companies

Professor Irwin Feller has suggested a typology to describe five common profiles of companies supported by SBIR funding. This typology captures the critical differences in company capabilities and aspirations.

[44] Ibid.
[45] NRC Phase II Survey, Question 15.

1. **Start-up firm.** This is a new firm, typically without marketable products, and usually with minimal funding and limited personnel resources.
2. **R&D Contractor.** As described by Reid Cramer, these firms make a strategic choice to specialize in the performance of R&D rather than in marketing products or services.[46,47]
3. **Technology Firm.** These firms have developed a core technology, which is then deployed into products and services.
4. **Scientific firm.** These businesses are described by Reid Cramer as "firms [that] are generally small and were founded by scientists to explore whether a particular research areas can generate ideas or products that might attract investors"[48]
5. **Transformational firm.** These companies start out as highly (or partially) dependent on SBIR or other government R&D contracts, which they use to develop a product that turns out to have considerable commercial value. This leads the company to become a production-oriented commercial vendor, with a concomitant decrease in the role of SBIR on the firm progression.

Examples of these firm types can be seen in the case studies of SBIR awardees. Further research in this area may help to establish better, how the NASA SBIR program supports these different kinds of businesses, and businesses at different stages of development.

Conclusions

SBIR supports small high technology businesses at a time when other sources of financial support are especially difficult to find. Businesses use these funds for a variety of purposes, in pursuit of several distinct strategies.

Awards data also indicate the role of woman- and minority-owned firms at NASA. It would be helpful if further analysis in this area focused on the role and incidence of minority and female Principal Investigators (PI), as these positions my be an important stepping stone on the path to forming the kinds of companies that can qualify for SBIR awards.

4.5 SBIR AND THE EXPANSION OF KNOWLEDGE

Quantitative metrics for assessing knowledge outputs from research programs are well-known, but far from comprehensive. Patents, peer-reviewed pub-

[46]See for example Polymer case study in National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, op. cit. Polymer was in its early years primarily a contractor, but has since developed many cutting-edge products of its own.

[47]See Cramer, Reid, "Patterns of Firm Participation in the Small Business Innovation Research Program in Southwestern and Mountain States," in National Research Council, *SBIR: An Assessment of the Department of Defense Fast Track Initiative*, op. cit.

[48]Ibid.

TABLE 4-18 Patents from NASA SBIR Projects

Number of Patents	Applied	Received
0	121	128
1	30	25
2	8	7
3	2	1
Total	161	161

SOURCE: NRC Phase II Survey, Question 18.

lications, and, to a lesser extent copyrights and trademarks, are all widely used metrics, and are discussed in detail below.

However, these metrics do not capture the entire transfer of knowledge involved in programs such as SBIR.

It is therefore quite important to understand that the quantitative metrics discussed below are only an *indicator* of the expansion of knowledge; they reflect that expansion but do not fully capture it. In particular, they say little about the impact of that knowledge.

4.5.1 Patents

According to the Small Business Administration, small businesses produce 13 to 14 times more patents per employee than large patenting firms. These patents are twice as likely as large firm patents to be among the one percent most cited.[49]

The data show that 40 projects—about 25 percent of respondents—reported at least one patent application, and that 33 projects (20 percent) generated at least one patent.

No projects generated more than three applications, and only one received three or more patents.

4.5.2 Scientific Publications

Publication in peer-reviewed journals and conference proceedings are a standard method for disseminating scientific knowledge. Several case study in-

[49]Accessed on May 16, 2007, at <*http://app1.sba.gov/faqs/faqindex.cfm?areaID=24*>. Drawing on seminal empirical research, Acs and Audretsch found that small businesses have comparatively higher rates of innovation—specifically, that "the number of innovation increases with increased industry R&D expenditures but at a decreasing rate. Similarly, while the literature has found a somewhat ambiguous relationship between concentration and various measures of technical change, our results are unequivocal—industry innovation tends to decrease as the level of concentration rises." See Zoltan J. Acs and David B. Audretsch, "Innovation in Large and Small Firms: An Empirical Analysis," op. cit.

terviewees noted that publication in peer-reviewed journals was an essential part of the firm's work, and provided valuable exposure.

The NRC Phase II Survey asked respondents about this aspect of these activities as well. (See Table 4-19 for a summary of the results.) About 40 percent of respondents reported at least one peer-reviewed publication. Five projects reported at least ten such publications.

These data fit well with case studies and interviews, which suggested that some SBIR companies are proud of the quality of their research. Publications are featured prominently on many company Web sites.

Publications therefore fill two important roles in the study of SBIR programs:

- First, they provide an indication of the quality of the research being conducted with program funds. In this case, more than half of the funded projects were of sufficient value to generate at least one peer-reviewed publication.
- Second, publications are themselves the primary mechanism through which knowledge is transmitted within the scientific community. The existence of the articles based on SBIR projects is therefore direct evidence that the results of these projects are being disseminated widely, which in turn means that the congressional mandate to support the creation and dissemination of scientific knowledge is being met.

We note that like other SBIR agencies, NASA does not have evaluation programs in place to compare knowledge effects within and outside the SBIR program.

Tracking Knowledge Dissemination by Citation Analysis

Citation studies have been used extensively to show the transfer of knowledge from federally funded projects to others outside the walls of the funded

TABLE 4-19 Publications from NASA SBIR Phase II Awards

Number of Publications	Number of Responses
0	97
1	20
2	19
3	6
4	4
5	8
8	2
10	3
12	1
30	1
Total	161

SOURCE: NRC Phase II Survey, Question 18.

projects, thereby demonstrating the wider potential impact of the federal funds. In the case of paper-to-patent citations, this is done by examining references to scientific and engineering papers on the front pages of U.S. patents. References are also made to previously issued patents. Both sets of patent and nonpatent references comprise the "prior art" of patents.

Citation analysis has been used at various times by the U.S. Department of Energy, the National Institute of Standards and Technology, the Agricultural Research Service, the National Science Foundation[50], and other federal agencies to show movement of knowledge from scientific research programs—where impacts are difficult to measure—to industrial technology—where impact measurement is more tractable.[51] Patent citation trees are routinely used by ATP, for example, to show the dissemination of technical knowledge via patents from completed projects to other companies and other organizations.[52]

No evidence was found, however, of publication or patent citation analysis by the NASA SBIR program. Further, no evidence was found of the systematic collection by NASA of the detailed publication, and patent data from SBIR projects needed to support citation studies.

Yet, as indicated by the results of the NRC Phase II Survey, patents and scientific publications are being produced by the NASA SBIR program. Hence, opportunities exist to encourage program participants to publish when it will not compromise their ability to commercialize. Both publication and patent citation analysis could be used to demonstrate and track knowledge dissemination from NASA SBIR projects to others.

4.5.3 Licensing

Licensing agreements depend on the protection of the intellectual property. They are another indicator of the creation and dissemination of knowledge.

Respondents reported licensing as an important activity they engaged in with other companies and investors both in the U.S. and abroad. Table 4-20 shows the frequency with which respondents said they had finalized or were negotiating licensing agreements to commercialize technologies resulting from the referenced award. Respondents formed licensing agreements with both foreign companies and investors and with domestic companies and investors.

The use of licensing signals the underlying importance of intellectual prop-

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[50]The referenced use of citation analysis by NSF lies outside the NSF SBIR program. NSF supported extensive work by CHI Research, Inc. to develop and "clean" databases needed to perform publication citation analysis.

[51]For an example of a citation study performed for a federal R&D program, see J. S. Perko and Francis Narin, CHI Research, Inc., "The Transfer of Public Science to Patented Technology: A Case Study in Agricultural Science," *Journal of Technology Transfer* 22(3):65-72.

[52]Advanced Technology Program, *Performance of 50 Completed ATP Projects, Status Report—Number 2*, NIST Special Publication 950-2, Gaithersburg, MD: National Institute of Standards and Technology, pp. 266-270.

TABLE 4-20 Licensing Activities of Phase II Surveyed Awardees with U.S. and Foreign Companies and Investors

Focus of Interactions	Finalized Agreements (%)	Ongoing Negotiations (%)
Interactions with U.S. Companies and Investors	6	11
Interactions with Foreign Companies and Investors	8	5

SOURCE: NRC Phase II Survey, Question 12.

erty protection to high-tech small businesses. Case-study results also highlight the importance of intellectual protection and licensing activities as a major commercialization strategy for several small businesses. Licensing activities tend to increase the diffusion of a technology's effect, and as noted by Jaffe, licensing tends to increase spillover effects, particularly market spillovers.[53]

4.5.4 Partnerships of Small Firms with Other Companies and Investors

Partnering with other organizations and people also accomplishes knowledge transfer. For small companies, the formation of partnerships with other companies is often an essential strategy for commercializing a technology. The larger companies they partner with often have manufacturing capacity, marketing know-how, and distribution paths in place. Awardees whose technology is far upstream of consumer goods may need to: partner with other companies for the additional research needed to integrate their technologies into larger systems; partner with Original Equipment Manufacturers who purchase the awardees' output as intermediate goods; and form alliances with customers to more effectively reach markets.

The NRC Phase II Survey provided insight about the kinds of partnerships being formed by SBIR recipients. As shown in Table 4-21, partnerships for R&D, for marketing and distribution, with customers, and for manufacturing were found to be formed by these awardees.

Licensing agreements may or may not entail close partnering, whereas the other listed forms generally do require close alliances and partnering.

4.5.5 Interactions Among Small Firms and Universities

Many companies with NASA also have relationships with universities through which knowledge is created and disseminated. Many funded projects in-

[53]Adam Jafee, *Economic Analysis of Research Spillovers: Implications for the Advanced Technology Program*, NIST GCR 97-708, Gaithersburg, MD: National Institute of Standards and Technology, pp. 42-44.

TABLE 4-21 Percent of Phase II Surveyed Awardees Forming Partnerships with U.S. and Foreign Companies and Investors

	With U.S. Companies and Investors		With Foreign Companies and Investors	
Partnering for:	Finalized (%)	Ongoing Negotiations (%)	Finalized (%)	Ongoing Negotiations (%)
Licensing Agreement(s)[a]	6	11	8	5
R&D Agreement(s)	16	10	4	1
Marketing/Distribution Agreement(s)	7	5	6	2
Customer Alliance(s)	11	9	6	0
Manufacturing Agreement(s)	2	6	2	0
Joint Venture Agreement(s)	1	4	0	2

SOURCE: NRC Phase II Survey, Question 12.

volve university faculty, graduate students, and/or university developed technologies. University faculty and students establish small businesses. Faculty members serve as proposal reviewers. Universities assist firms with proposal preparation and sub-contracts or consult on projects. They also sometimes provide facilities and equipment to assist projects. The NRC Firm Survey showed that over 62 percent of all respondents had at least one founder with an academic background. Around 31 percent of company founders had been most recently employed by a college or university prior to founding the company.

The NRC Phase II Survey showed that 29 percent of NASA projects involved some form of university involvement. The survey data show the prime mode of involvement to be faculty members or adjunct faculty members working on the referenced project in a role other than PI—as a consultant, for example. The next most frequent modes of involvement were those of universities/colleges as subcontractors, graduate students working on the project, and university or college facilities or equipment being used on the project. In some instances, project technologies were originally developed in universities or colleges by one of the participants in the referenced projects. On occasion, the technologies for the referenced projects were licensed from a university or college. Table 4-22 indicates the extent to which each type of university involvement occurred in the sample Phase II projects.

The NRC Phase II Survey results show that the NASA SBIR plays some role in moving research concepts out of the university. Of the Phase II survey projects, 4 percent involved technology that was originally developed at a university by a project participant. Two percent of the technologies in the Phase II survey projects were licensed from a university. In addition, some of the case-study firms were found to have on-going affiliations with universities.

Although only 7 percent of the Phase II awards reported that they had received assistance in Phase I or Phase II proposal preparation, universities were

TABLE 4-22 Involvement by Universities and Colleges in NRC Phase II Survey Projects

Type of Relationship Between Referenced Project and Universities/Colleges	Respondents Reporting the Relationships (%)
Faculty members or adjunct faculty member worked on the project in a role other than PI.	17
Graduate students worked on the project.	15
University/College facilities and/or equipment were used on the project.	13
A university or college was a subcontractor on the project.	16
The technology for this project was originally developed at a university or college by one of the participants in the referenced project.	4
The technology for the project was licensed from a university or college.	2
The Principal Investigator (PI) for the project was at the time of the project an adjunct faculty member.	1
The Principal Investigator (PI) for the project was at the time of the project a faculty member.	2

SOURCE: NRC Phase II Survey, Question 31.

responsible for providing most of that assistance. When asked to evaluate the usefulness of the proposal assistance, five of the 11 Phase II recipients which reported receiving assistance rated it as “very useful” and the other six rated it as “useful;” none said it was “not useful.”

As shown in Table 4-23, overall, 29 percent of the respondents reported involvement in their Phase II project by faculty, graduate students, or university-developed technologies. This result is reinforced by the sample of firm case studies. Of the 22 firms, 14 demonstrated important linkages with the university sector. Many SBIR projects therefore do seem to promote the transfer of knowledge between the private sector (the awardee) and universities.

TABLE 4-23 In Executing the Phase II Award Was There Involvement by University Faculty, Graduate Students, and/or University-developed Technologies—(N=161)

Response	Percent of Respondents
Yes	29
No	71

SOURCE: NRC Phase II Survey, Question 31.

4.5.6 Assessing Knowledge Expansion

Developing and disseminating knowledge derived in some part from SBIR projects depend on both the riskiness of the project and the often indirect ways though which knowledge spreads.

Risk Profile

One question about the SBIR program is the extent to which it funds projects that are truly innovative.

This is a difficult and important area. There are pressures on program managers to ensure that levels of commercialization are high—yet commercialization outcomes are inversely related to the riskiness of the research: Very high risk projects are less likely to reach the market than modest adjustments to a technology that already has customers.

In interviews, program managers at all agencies recognize this potential difficulty. However, in the main they remain focused on the need to enhance commercialization. The risk of insufficient innovation is both lower priority and, perhaps in the long run more important, is not easily assessed. Sales can be counted; innovation lies in the eye of the beholder.

It is therefore important that agencies continue to use existing indicators to monitor the riskiness of the projects they fund, and to seek to develop new ones. Much information can be found in a better understanding of why and when projects fail:

- The NRC Phase II survey reported that technical difficulties were one important reason for discontinuing Phase II projects—they were the fifth most cited reason.
- The NRC Phase I survey also suggested that technical risk among NASA projects was high. Of the Phase I projects that did not get a follow-on Phase II award, a leading reason was technical barriers.

Indicators, Not Measures of Benefit

No economic benefits are generated from knowledge efforts until the knowledge flows are actually used by others to develop new and improved products, processes, and services. Hence, collection of data on knowledge generation and dissemination activities does not provide direct measurement of impacts. Such data can, however, serve to construct indicators of potential impacts. Examples of possible indicators are number of patents per research dollar, characteristics of collaborative networks formed, and sales of commercialized goods and services. Trends in these and other indicators may indicate that developments are occurring along an indirect path—as would be expected for projects that are progressing toward the generation of broad impacts.

It is apparent from the NRC Phase II Survey results that it would be possible to compile multiple indicators of knowledge generation and dissemination and early commercialization achievements from NASA SBIR projects, and to track them over time. Thus far, however, it appears that such indicators have been developed only partially and on an ad hoc basis. It appears that more could be done to systematically compile and track indicators of knowledge generation and dissemination if desired.

4.5.7 Conclusions on SBIR's Knowledge Impact

Given its descriptions and proposal selection criteria which emphasize the achievement of broad impacts (i.e., not just the commercialization goal), it might be expected that NASA's SBIR program would demonstrate a strong interest in measures of knowledge outputs. But, in fact, broader impacts appear to be defined by the program largely as commercial results and the infusion of the new technologies in the agency's mission. Little evidence was found that the program pays much attention to knowledge outputs per se.

As a first step, NASA (and other agencies) might consider requiring that recipient firms provide bibliographic citations for papers appearing in peer-reviewed journals, the proceedings of scientific societies, or conference reports, as part of their outcome reporting process.

4.6 CONCLUSIONS

There is no single simple metric that adequately captures "results" from the program, as discussed in the NRC's Methodology Report for the SBIR assessment.[54] Each of the four congressional mandates is best assessed separately, and within each, there are a multiple issues to be addressed.

Bearing all these points in mind, it is still possible to summarize the results of our research in straightforward terms.

4.6.1 Commercialization

Approximately 30-40 percent of Phase II projects produce innovations that reach the market, with a small number generating substantial returns. Other indicators of commercialization, such as licensing activities, marketing partnerships, and access to and utilization of further investments from both private and public sources, all confirm that while returns are highly skewed, and the results in general are positive, firms operating within the NASA SBIR program face significant

[54] National Research Council, *An Assessment of the Small Business Innovation Research Program—Project Methodology*, op. cit.

structural barriers that make it hard to develop substantial markets based on the highly NASA-specific technologies the agency tends to fund.

4.6.2 Agency Mission

While it is difficult to find good data on the extent to which SBIR supports NASA's mission we can conclude the following:

- The SBIR program has been aligned with the agency needs, primarily through the topic development and award selection processes. This process has been considerably altered by changes made in FY2006.
- Outcomes from the SBIR program appear to be aligned with agency needs, although the small number of projects that are selected for NASA Phase III funding helped to drive the FY2006 reforms.
- Agency staff in general indicate that SBIR awards are of comparable quality to other NASA research projects.

This analysis also indicates that early involvement with and "ownership" of SBIR projects by NASA technical staff is an important factor in the successful utilization of SBIR for agency purposes.

4.6.3 Support for Woman- and Minority-owned Businesses

NASA's SBIR program supports the participation of minority and woman-owned small business in innovation research.[55]

More widely, SBIR significantly supports small high technology businesses in general, and the NRC research determined that SBIR had an important catalytic effect in terms of company foundation—providing the critical seed money to fund a company's first steps. SBIR also had strongly influenced companies' decisions to initiate individual projects: 68 percent of NRC Phase II Survey respondents at NASA believed that their projects would not have gone forward without SBIR, and, of the remainder, most believed that the projects would have been delayed and/or would have had a reduced scope.[56]

4.6.4 Support for the Advancement of Scientific and Technical Knowledge

The program funds cutting-edge research, as it was designed to do. One of the key selection criteria at NASA is "technical innovation."

NASA SBIR funding also supports the dissemination of knowledge through traditional vectors such as peer-reviewed publications, as well traditional indica-

[55] See Chapter 3 of this report for more details.
[56] NRC Phase II Survey, Questions 13-14.

tors that valuable intellectual property has been produced, such as patents. About 40 percent of projects led to at least one peer-reviewed publication, and about 20 percent of projects generated at least one successful patent application.

It is therefore appropriate to conclude that the NASA SBIR program is meeting all four of the congressional objectives.

5

Program Management

5.1 INTRODUCTION: ASSESSING SBIR IN A RESTRUCTURING NASA

As with other parts of NASA, the NASA SBIR program has, experienced sequential waves of reorientation and restructuring. Mission objectives have changed very substantially, far more than at other SBIR agencies.

During NASA's reorganization of 2003-2004, the agency's SBIR program became a component of the Advanced Space Technology Program within the Exploration Systems Mission Directorate (ESMD), which is charged with implementing NASA's planned exploration of Mars and other space exploration projects. In 2006, further reorganization led a change in the balance of management power between the Mission Directorates and the centers, with the former assuming much more direct authority over SBIR topic and award selection.

Because of this churn, any assessment of program management at NASA must deal with a moving target. Extensive changes in management structures mean that data regarding past activities is of limited relevance in guiding current management.

This chapter details how NASA implements its SBIR management strategy.[1] It begins by focusing on issues related to the SBIR award cycle, including topic

[1]The NASA SBIR/STTR management team *during the course of this analysis* was led by:

- Carl G. Ray (Code RC)—SBIR/STTR Executive Director; Oversight-Strategic Direction; SBIR/STTR Selection Official, NASA Headquarters, Washington, DC.
- W. Paul Mexcur (GSFC)—SBIR/STTR Program Manager; SBIR/STTR Program Operations; Program Management, Goddard Space Flight Center, Greenbelt, MD.
- Karin Huth (GRC)—SBIR/STTR Procurement Manager; Procurement Oversight.

selection, the evaluation of proposals, and selection of awards. The chapter then examines NASA's commercialization effort that includes a detailed review of the regional dimension of NASA's SBIR program. The chapter closes with an analysis of challenges for the future of SBIR at NASA, given the agency's new organizational structure and mission focus. An annex to this chapter describes the SBIR program at each NASA center.

5.2 MANAGING SBIR AT NASA

5.2.1 Guiding Principles

NASA has based the management of its SBIR program on the following four principles:

- Aligning research topics to the highest technology priorities of the agency.
- Focusing on program effectiveness as measured by Phase III commercialization.
- Enhancing program efficiency by using advanced information technology.
- Providing opportunity for a cross section of small U.S. business.[2]

5.2.2 Program Administration

The NASA SBIR program has varied over the years in terms of its degree of centralization. Currently, NASA's SBIR program is managed at multiple levels.

- Level 1—SBIR Program Executive (Headquarters; agency-wide).
- Level 1—SBIR program Mission Directorate liaisons (Headquarters, Mission Directorates).
- Level 2—SBIR Program and Procurement Policy Managers (agency wide).
- Level 3—SBIR Field Center Program Managers (Centers).
- Level 4—Contract Officer Technical Representative (COTR) (projects).

Level 1. Program Executive.[3] Located at NASA Headquarters, and supported by a national office, the program executive focuses on overall program administration. Overall program policy, effectiveness, and assessment are the responsibility of the Headquarters Program Executive. The national office, located until recently at Goddard, has now moved to Ames.

[2]NASA Program Management Web site, accessed at <*http://sbir.nasa.gov/*>, July 2005.

[3]The current program executive is Carl G. Ray. His title is Program Executive, Technology Infusion, Innovative Partnerships Program (IPP) Office.

Level 1. Mission Directorates. Each of four Mission Directorates (MDs) has assigned a senior staffer as liaison between the technology programs run by the MD's and the SBIR program. Following the 2006 restructuring, the Mission Directorates now dominate topic selection, and approve project selection.[4]

Level 2. SBIR Program and Procurement Policy Managers. The NASA SBIR Program Management Office, at the NASA Ames Research Center, runs SBIR in conjunction with NASA Mission Directorates and centers. The NASA Shared Services Center provides the overall procurement management for the programs.

Level 3. Field Centers. Prior to FY2006, program operations were managed at each of the ten NASA Field Centers. Following the FY2006 reorganization, the program will run through only four field centers (Ames, JPL, Glenn, and Langley) At each center, an SBIR Field Center Program Manager administers the program. Contracts are managed by NASA's Contracting Officer at each center.

Level 4. The COTR. The Contract Officer Technical Representative (COTR) serves as the primary contact between the project and NASA on a contract's technology focus and objectives, and handles assessment of project progress. The COTR is a staffer at one of the centers.

5.2.3 Administrative Budget

NASA's budget for administering the SBIR programs is approximately $3.8 million per year. This funding—3.2 percent of the $119 million SBIR budget—comes from separate agency funds (not SBIR). This budget does not include the substantial costs associated with employee time used on the program, including in particular the time needed to develop and approve topics and subtopics, and to evaluate proposals. NASA has not calculated the value of this time, although the recent change to a full-cost accounting approach will make it easier to estimate full administrative costs in the future.

5.2.4 FY2006 Reforms

The impact of the 2006 reorganization has been to refocus SBIR on the NASA's core mission objective, de-emphasizing the previous stress on outside commercialization.

Interviews with all of the Mission Directorate liaisons indicate that the balance of power between the centers and Headquarters changed substantially in FY2005-2006.

The reorganization helps to address a dissatisfaction with the outcomes of the

[4]The FY2006 reforms are described in Section 5.2.4.

previous approach. The 2002 *Commercial Metrics* report (covering 1983-1996) found that only about six percent of NASA's 1,739 SBIR Phase II awards during this period supported technologies that were eventually infused into NASA or other federal programs *via* Phase III funding.[5]

The reorganization also reflects changing needs and priorities within NASA. The addition of new missions and the expansion of existing ones have placed additional demands on Mission Directorates, squeezing funding for basic research.

As a result of the reorganization, Mission Directorates are now focusing on aligning research funded through SBIR with specific technologies that can be taken up (or in NASA-speak "infused") into the their own technology development programs. Whereas commercialization was the primary priority of NASA's SBIR program (or, at least, an priority equal to the support for the agency's mission) the focus of the program since the 2006 reorganization is squarely on support for the NASA mission. For SBIR, this involves finding and developing technologies that can help NASA meet its very specific needs and requirements.

Overall, this new clarity of focus appears to be a positive development. As described in some detail in Chapter 4 (Outcomes), the low volume and high degree of specificity (e.g. space-hardiness) required to meet NASA's needs makes it less likely that SBIR funded technologies can spin off into commercial sales.[6]

5.3 THE AWARDS PROCESS

In this section, we discuss the details of the NASA awards process. This can be disaggregated into the following components:

- Topic development, including efforts to align topics with the needs of the agency.
- Outreach into the business and technology communities, to help ensure that the best possible proposals reach NASA.
- Project selection, including an assessment of commercialization potential.

NASA sets aside 2.5 percent of its extramural research and development budget for SBIR awards. Each year NASA identifies various R&D topics, representing scientific and technical problems that the agency needs to solve, for

[5] "Phase III funding" comprises contractual or other monies awarded to a SBIR project for federal agency use of the subject technology after expiration of a SBIR Phase II award.

[6] Of course, some companies have made this transition successfully, but overall, there are significant structural impediments standing against successful commercialization from NASA SBIR project—as opposed for example to DoD, where there may be a huge potential market within the agency, or NIH where the private-sector market for SBIR-funded technologies is also potentially enormous.

pursuit by small businesses under the SBIR program. These topics are bundled together into annual NASA "solicitations," which are publicly announced requests for SBIR proposals from interested small businesses.[7] A small business can identify an appropriate topic that it wants to pursue from these solicitations and, in response, propose a project for an SBIR award.

The following sections describe the SBIR award process that was in place at NASA throughout much of the study period for this assessment. This structure, implemented in the mid-1990s, has since been substantially altered by reforms in 2005-2006, as noted above.

5.3.1 Selecting SBIR Topics

5.3.1.1 Aligning Topics with Agency Needs

Topic and subtopic development and selection are the primary tools used to ensure that the SBIR program is closely aligned with agency needs.

Beginning in 1995, NASA's SBIR program initiated a series of steps to make the program more consistent with NASA's mission. The goal was to make the SBIR program a strategic asset for NASA by integrating all aspects of these programs with NASA's mission. The change involved implementing an organizational structure that better supported the technology goals of what were then NASA's four Mission Directorates: Aeronautics, Exploration Systems, Science, and Space Operations.

This set into motion several initiatives that included selecting topics integral to NASA's overall mission, creating a system that closely tracks each contract for program management, leveraging non-SBIR agency funds to support unfunded high quality projects, and developing metrics for evaluating commercial outcomes.

5.3.1.2 Deciding on Topics

A tension exists between encouraging proposals focused on solving very specific problems facing NASA, and making the topics broad enough to encourage enough firms to apply, and the application of innovative solutions. NASA's staff acknowledges this tension; they note that topic definitions at NASA are designed to walk the necessarily fine line between overly tight specifications and the development of exciting technologies that are not however needed by the agency.

Program management issues guidelines to each of the centers. Centers may then propose subtopics. These are eventually prioritized at NASA Headquarters.

To facilitate this decision-making process, NASA holds an annual Solicitation Development Workshop. This is attended by both Mission Directorate repre-

[7] See NASA solicitation Web page. Accessed at <*http://sbir.gsfc.nasa.gov/SBIR/solicit.htm*>.

sentatives and center managers. Centers propose subtopics at the workshop, while the Mission Directorates note which subtopics support their goals.

Program management then tries to design solicitations based on the agency's highest priority technology needs, as reflected by center rankings and Mission Directorate needs. If a technology is needed by more than one center, the topic and subtopic are assigned to the center that ranked it highest.

Subsequently, NASA's SBIR/STTR Program Manager makes prioritizing recommendations about topics to the SBIR/STTR Executive Director, who makes the final decisions.

5.3.2 Agency Outreach

5.3.2.1 Agency Outreach Objectives and Methods

Like other agencies, NASA staff note it is important to reach out to the small business community, in order to encourage higher quality proposals from a wide range of applicants. At NASA, this outreach is undertaken mainly through participation in national and regional SBIR conferences. NASA does not organize these events.[8] Representatives from the ten NASA field centers regularly attend these conferences, where they set up briefing charts and displays, and hand out literature about the program.

The NASA SBIR/STTR office also works with NASA's Office of Small and Disadvantaged Business Utilization (known as "Code K" at NASA) to increase participation by small and disadvantaged businesses.

As a key part of its outreach, NASA maintains an extensive SBIR Web site. NASA's application process is entirely Web-based. NASA does not believe that lack of information about the program is a significant barrier for potential applicants.[9]

5.3.2.2 Agency Outreach Benchmarks

NASA receives a large number of applications—from 1,099 companies in 2003. NASA staff note that the agency receives far more high quality applications than it can fund, as evidenced by the scores garnered by applicants.

Agency staff also note that about a third of Phase I awards go to firms that have not previously won awards from NASA.

NASA has made awards to firms in 48 out of 50 states,[10] NASA staff believe that the decentralized nature of NASA, with numerous centers located often in

[8]Interview with Paul Mexcur, Program Manager, November 21, 2003.
[9]Ibid.
[10]North and South Dakota are the two states that have not received a NASA SBIR grant.

areas outside the main U.S. research hubs, provides sufficient geographical diversity for the program.[11]

While there are no formal benchmarks or metrics for agency outreach, NASA officials point to the influx of new firms and the continuing 8:1 applications to award ratio as evidence that new companies have little difficulty finding out about the NASA SBIR program, and that a significant increase in outreach is not needed.

5.3.3 Submission, Evaluation, and Selection[12]

5.3.3.1 Proposal Submission

Small businesses submit their proposals to NASA through a sophisticated multipurpose online system called *Electronic Handbooks and E-Submission (EHB)*. NASA describes this Electronic Handbook as a "set of Internet-based tools that support the paperless documentation and management of complex distributed processes," including the SBIR program.[13] EHB helps guide users through the program and provides real-time, online, paperless documentation and process management.

5.3.3.2 Evaluation Criteria

Once submitted electronically via the Electronic Handbook, NASA screens the proposals to ensure that they are complete before sending them to the NASA center that "owns" the relevant topic for technical review. Evaluation is based on:

- Scientific/Technical Merit and Feasibility.
- Experience, Qualifications and Facilities.
- Effectiveness of the Proposed Work Plan.
- Commercial Merit and Feasibility.

5.3.3.3 Peer Review Panels—Membership, Selection, Qualifications

Peer review in the NASA SBIR program is done internally by NASA technologists.[14] NASA staff scientists are used as technical experts. External reviewers are also used for many Phase II applications, primarily for reviewing

[11]Interview with Paul Mexcur, Program Manager, November 21, 2003.

[12]This is based on an interview with Carl Ray, Executive Director and Paul Mexcur, Program Manager of the NASA SBIR/STTR Program. The interview was on November 10, 2003.

[13]National Aeronautics and Space Administration, *The Paperless Solution*, p.1, accessed <*http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020062196_2002101422.pdf*>.

[14]Interview with Paul Mexcur, Program Manager, November 21, 2003.

commercial potential. These reviewers include the Research Triangle Institute (RTI), independent experts, retired senior executives, and others. The total cost of all Phase II external reviews is $80,000 to $100,000 annually. All Phase II applications are subjected to a peer review by at least one non-NASA person. It should be noted that some award recipients have questioned the value of the external review, on the grounds that these staff may not be sufficiently familiar with the NASA programs—alignment with which will in the end be decisive for any proposal.

To enhance fairness in the selection process, NASA screens for multiple applications from a single company, as well as duplication of proposals or technologies.[15] NASA will not accept more than ten Phase I applications from the same firm in a given year, and will make not more than five Phase I awards to a single firm.[16] Program management also makes sure that awards are spread appropriately across different technical areas and Mission Directorates. Problems are resolved by adjusting the rankings of proposals.

5.3.3.4 Phase I Evaluation and Selection

Submitted Phase I proposals must be complete, as evaluators are not expected to seek additional information. Evaluations are performed by NASA scientists and engineers at the center(s) identified in the solicitation as responsible for the applicable subtopic. In some cases, qualified experts from outside NASA (from industry, academia, and other government agencies) may provide additional advice. Applicants should not assume that evaluators are acquainted with the firm, its key individuals, or with any experiments or other information. Any pertinent references or publications should be noted in the technical proposal.

NASA gives primary consideration to (a) the proposal's scientific and technical merit and feasibility and (b) the proposal's benefit to NASA. According to NASA, each proposal is judged and scored on its own merits using the factors described below:

- **Factor 1. Scientific/Technical Merit and Feasibility.** The proposal is evaluated on whether it offers an innovative and feasible technical approach to the described NASA problem area. Proposals must demonstrate relevance to the subtopic. Specific objectives, approaches, and plans for developing and verifying the innovation must demonstrate a clear understanding of the problem and the current state of the art. The applicant must also define risks involved in the proposal.
- **Factor 2. Experience, Qualifications and Facilities.** The technical capabilities and experience of the Principal Investigator or project manager, key

[15] Based on interview with Paul Mexcur, Program Manager, November 21, 2003.
[16] NASA sdoliciation Web site. Accessed at <*http://sbir.gsfc.nasa.gov/SBIR/solicit.htm*>.

personnel, staff, consultants and subcontractors (if any), are evaluated for consistency with the research effort and their degree of commitment and availability. The necessary instrumentation or facilities must be shown to be adequate. The proposal should specify if the project will rely on any external sources, such as government furnished equipment or facilities.

- **Factor 3. Effectiveness of the Proposed Work Plan.** The work plan is reviewed for its comprehensiveness, effective use of available resources, cost management, and proposed schedule for meeting Phase I objectives. The methods proposed for achieving each objective or task must be described in detail.
- **Factor 4. Commercial Merit and Feasibility.** The proposal is evaluated for any potential commercial applications in the private sector or for use by the federal government.

Factors 1, 2, and 3 are scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 comprise the Technical Merit score. The score for Commercial Merit is in the form of an adjectival rating (Excellent, Very Good, Average, Below Average, Poor). For Phase I proposals, Technical Merit carries more weight than Commercial Merit.

Each center ranks the proposals recommended for award relative to all other proposals recommended by that center.

Center rankings are then forwarded to the Program Management Office for analysis, and are then presented to the Source Selection Official and Mission Directorate Representatives.

Final selection decisions take into consideration the center rankings as well as overall NASA priorities, program balance, and available funding. Recommendations and relative rankings developed by the centers do not guarantee selection for award. The Source Selection Official has the final authority for choosing the specific proposals for contract negotiation.[17]

5.3.3.5 Phase II Evaluation and Selection

The Phase II evaluation process is similar to the Phase I process. NASA plans to select for award those proposals offering the best value to the agency. Each proposal is reviewed by NASA scientists and engineers, and by qualified experts outside of NASA as needed per the factors identified below.

Those proposals with high technical merit are reviewed for commercial merit. NASA uses a peer review panel to evaluate commercial merit. Panel membership includes non-NASA experts in business development and technology commercialization.

[17]The list of proposed selections is posted on the NASA SBIR/STTR Homepage. Accessed at <*http://sbir.nasa.gov*>. Additionally, all firms receive a formal notification letter.

- *Factors 1-3.* The first three selection factors for Phase II are essentially identical to those for Phase I, except that Factor 1 (Scientific/Technical Merit and Feasibility) also addresses the extent to which Phase I objectives were achieved, and the impact of Phase I results on Phase II feasibility.
- *Factor 4. Commercial Potential and Feasibility.* NASA assesses the proposed commercialization plan in terms of its credibility, objectivity, reasonableness of key assumptions and awareness of key risk areas and critical business vulnerabilities, as applicable to the following factors:
    - Commercial potential of the technology.
    - Commercial intent of the applicant.
    - Capability of the applicant to realize commercialization.

Factors 1, 2, and 3 are scored numerically with Factor 1 worth 50 percent and Factors 2 and 3 each worth 25 percent. The sum of the scores for Factors 1, 2, and 3 comprise the Technical Merit score. Proposals receiving numerical scores of 85 percent or higher are evaluated and rated for their commercial potential using the criteria listed in Factor 4, and by applying the same adjectival ratings described above for Phase I.

For Phase II proposals, commercial merit is a critical factor. This sequential evaluation (of technical merit followed by commercialization) is an interesting innovation, allowing NASA to focus scarce resources for assessing commercialization only on the most promising application.

Once again, each center makes recommendations for awards among those proposals that it evaluates. The center recommendations are forwarded to the Program Management Office for analysis and presented to the Source Selection Official and Mission Directorate Representatives. Final selection decisions consider the center recommendations, overall NASA priorities, program balance and available funding, as well as any other evaluations or assessments (particularly pertaining to commercial potential). Recommendations provided by the centers do not guarantee selection for award. The Source Selection Official has the final authority for choosing the specific proposals for contract negotiations.

5.3.4 Funding "Gaps"

Funding gaps can be found between the end of financial support under Phase I and the start of support under Phase II. About two thirds of respondents to the NRC Phase II Survey reported a gap between Phase I and Phase II funding at NASA; the average length of the gap was 6 months. Only 3 percent of respondents reported a gap of one or more years.[18]

NASA cites the efficiency of its Electronic Handbook in minimizing this gap. Nevertheless, several firms interviewed for case studies indicated that the funding

[18]NRC Phase II Survey, Question 26.

gap remains an important issue, especially for smaller, less developed firms. In addition, three-quarters of NRC Phase II Survey respondents who experienced a gap responded by stopping work on the project.[19] It is unclear whether NASA has benchmarked its own funding gap against those of other agencies.

NASA does not appear to have adopted any of the "gap-reducing" initiatives initiated at other agencies. These include:

- Development of a Phase I "option" that provides bridge funding for selected projects at the end of Phase I (DoD).
- Simultaneous application for Phase I and Phase II (the NIH Fast Track).
- Work at risk (NIH).[20]
- Expedited processing of Phase II awards (DoE).

Several of the small firms interviewed for this study suggested that it would make sense to find a more standardized way to operate contracts, given that both the funding amounts and time to delivery are essentially fixed.

5.3.5 Other Aspects of Award Selection

5.3.5.1 Reporting

Phase II typically requires quarterly reports, submitted electronically. In addition, NASA Phase II awards usually require a prototype as a deliverable. These reports are used by the COTR and the COTR's management to help identify potential for Phase III.[21]

The NASA contracting officer is supported by the Contract Officer's Technical Representative (COTR). The COTR is the firm's primary contact within NASA on the contract's technology focus and objectives. Given that one primary goal of the SBIR program at NASA is the eventual infusion of the firm's technology into NASA's programs and missions, the interaction with technologists within NASA is critically important, and the COTR is both the link and the facilitator for such interaction.

5.3.5.2 Resubmission Procedures and Outcomes

Resubmissions of rejected applications are not allowed.[22] However, NASA can select an applicant at any point in time. Although rare, a previous application

[19]NRC Phase II Survey, Question 28.

[20]At NIH, firms scoring well inside the likely Payline may decide to continue work before a Phase II award is made. The Phase II award covers up to three months work of pre-contract expenses incurred for Phase II work.

[21]Based on interview with Paul Mexcur, Program Manager, November 21, 2003.

[22]Based on interview with Paul Mexcur, Program Manager, November 21, 2003.

BOX 5-1
Tracking SBIR Technology Progress

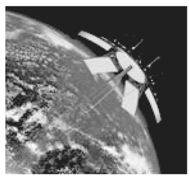
NASA has developed mechanisms to track and make available information on the progress of the technology it funds. Previously, NASA simply made note of the technology at the beginning and at the end of the project. NASA now maintains a database on each project and updates each project's specifications on a continuing basis.

As the technology in question matures through the phases of SBIR, the program manager regularly updates a progress chart, called a "Quad" chart (see Figure B-5-1). This chart includes items such as expected outcomes from the project, commercial potential and intended utilization. The data provided by the chart also serve internal marketing purposes, with the ultimate goal being to move projects from Phase II to Phase III.

Technology Development for a Low-Cost Deployable Lidar Telescope

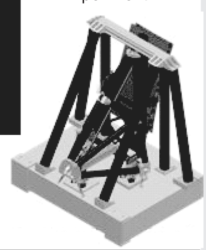
Project No. 258-70-117 **Dr. Lee Peterson, University of Colorado, Boulder**

Objectives
- Develop and validate precision deployment technology for low-cost, optical UV Lidar telescopes.
- Develop new optical precision deployment technology.
- 50:1 improvement in structural performance.
- Minimize need for active optical figure control.
- Validate technology in a sub-system test.
- Single petal and mirror segment.
- Use integrated structural-optical models to extrapolate to full system flight behavior.



System Concept

Sub-System Experiment



Technical Elements
- Segmented mirror with a deployed depth reaction structure.
- New components with sub-micron deployment repeatability and microdynamic stability.
- Sub-system deployment and microdynamic experiments on single-petal prototype hardware.
- Innovative virtual boundary condition sub-system test methodology.
- Component-, sub-system-, and system-level models updated and validated including uncertainty tolerances.

Impact
- 4-10 times improvement in sensitivity.
- Delta-II diameter mirror in a Pegasus-size package.
- Enables UV, VIS, and IR Lidar/DIAL systems for O_3, H_2O, CO_2, aerosol, and cloud measurements from space.

Schedule and Deliverables
- 03-04 Component development and experiment design.
- 04-05 Component experiments and models complete.
- 05-06 Sub-system experiments and models complete.
- Final Report: March 2006.

Co-Is/Partners
- Co-I: Dr. Syed Ismail, NASA LaRC.
- Co-I: Dr. Mark Lake, Consultant.
- Co-I: Dr. Jason Hinkle, CU.
- Science Advisor: Dr. Ed Browell, NASA LaRC.
- Technical Advisor: Tim Collins, NASA LaRC.
- Partner: Dr. Ed Friedman, Boeing-SVS.

TRL_{In} = 2

ESTO

Instruments **Passive Optical**

FIGURE B-5-1 Technology Development for a low-cost deployable Lidar telescope.
SOURCE: National Aeronautics and Space Administration.

may be reconsidered because a particular technology became a higher priority for NASA.[23] In these cases, the relevant center goes back to the firm to verify that it still wants to do the project and can do what was proposed.

5.3.5.3 Other Agency Funding

In recent years, NASA has begun to encourage centers to match SBIR funding for recommended high-quality proposals that might otherwise remain unfunded. NASA SBIR's program tells its centers that the program will put up half the funds for a project if a center can come up with the other half of the money. While only three or four proposals have been funded in this manner, this innovative effort to leverage resources and to ensure that SBIR projects are high priority for the agency deserves more attention.

5.3.5.4 Debriefing of Unsuccessful Applicants

After Phase I and Phase II selection decisions have been announced, debriefings for unsuccessful proposals are available to the applicant's corporate official or designee via email. Debriefings are not opportunities to reopen selection decisions. Instead, they are intended to acquaint the applicant with the perceived strengths and weaknesses of their proposal and to identify constructive options for the applicant.

Debriefings do not disclose the identity of the proposal evaluators, proposal scores, or the content of, or comparisons with, other proposals. Perhaps as a result, several interviewees from case studies indicated that they received little of value from the debriefings. It is unclear why NASA takes such a restrictive view of the information disclosed in its debriefings.

For Phase I proposals, debriefings are automatically emailed to the designated business official within 60 days of the selection announcement. Unsuccessful Phase II applicants are contacted by the appropriate field center for debriefing within 60 days of the selection announcement.

5.4 BEYOND PHASE II—THE TRANSITION TO PHASE III

As NASA wrestles with the problem of increasing the take-up of SBIR technologies within the agency, it will be necessary to address a number of different related issues.

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[23]Historically it has happened just two times in eight years.

5.4.1 No Phase III Transition Support

NASA says that it encourages Phase II awardees to continue on to Phase III.[24] However, NASA does not appear to have programs in place to support this challenging transition. Indeed, small businesses participating in the SBIR program across the federal government find the transition to Phase III difficult, not least because of NASA's changing mission priorities.[25]

NASA does not have a Phase IIB incentive linked to third-party financing, like that of the NSF SBIR program.[26]

5.4.2 Training Programs for Agency Phase I and Phase II Awardees

Other agencies have also tried to address the Phase II transition by improving the commercial aptitude of funded firms, through a range of training and support programs. Such programs include:

- The Navy Technology Assistance Program, a training program run by a third party, and culminating in a widely attended forum connecting firms to possible funders.
- The NIH CAP program, also with third-party training (a different provider), and a forum focused more on attracting funding from venture capital.
- The DoE technology support programs, which focus on developing individual marketing and development plans for firms.

NASA does not provide formal commercialization training such as that provided at other SBIR agencies. NASA cites constraining factors such as funding, availability of personnel, and widely dispersed geographic locations.

NASA has variously employed incubators, Technology Utilization Centers, a university grant program, and state science and technology centers to help SBIR entrepreneurs improve their business skills to prepare for commercialization.[27] However, there is little evidence that these projects have generated much in the way of positive returns, and a number are now apparently defunct.

There are important structural obstacles to the development of commercially

[24] Based on interview with Paul Mexcur, Program Manager, November 21, 2003.

[25] The issue of changing mission priorities at was raised by NASA at the NRC 2005 conference on the Phase III in Transition Conference. See National Research Council, *SBIR and the Phase III Challenge of Commercialization*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007.

[26] The NSF SBIR program adds Phase IIB grant supplements following a Phase II grant conditional on attraction of third-party financing. For a description of the NSF Phase IIB program, see National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008. Unlike the NSF Phase IIB supplements, the Phase IIe program at NASA focuses on Phase II and not the transition to Phase III.

[27] Based on interview with Carl Ray, Executive Director, November 14, 2003.

successful products from the NASA SBIR program. A program that is focused on building specific one-off solutions to the unique challenges and rigors of space flight or aeronautical testing is not likely to discover technologies with wider commercial potential and appeal.[28]

5.4.3 Take-up Within the Agency

Phase III can of course also mean take-up within the agency—the granting of continuation contracts, which under the rules governing SBIR have a privileged contracting status, in that a Phase II award satisfies government contracting rules that require competition before contracts can be awarded. Thus Phase III can be sole source. However, this is little evidence that this potential advantage for SBIR contractors has played much part at NASA—according to interviews with Mission Directorate staff.[29]

More significantly, NASA does not track Phase III awards across the agency on an ongoing basis. As a result, there is little evidence on which to support management initiatives in this area.

5.5 PROGRAM EVALUATION

NASA appears committed to improving its evaluation and assessment program, and to utilizing results from that process to help guide program management. In interviews, both the Program Director and the Mission Directorate liaison officials stressed that this was a priority issue for NASA.

5.5.1 The Challenge of Evaluation

Evaluating NASA's SBIR program presents major challenges. The agency itself has utilized SBIR for different strategic objectives over time, and the relative prioritization of commercialization and agency mission has also changed over time.

Moreover, technology often unfolds in complex ways, taking different paths. As a result, available metrics in for tracking program successes may miss important outcomes.[30] For example, measures that quantify knowledge effects, such as patents, trademarks, and licenses usually occur well after the end of the SBIR contract period, and may miss the transfer of knowledge through less formal mechanisms (e.g. a shift of principal investigator to a new company). Moreover,

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[28]The myth that Teflon technology, used to coat cooking utensils, is a spin-off from the space program is widespread and long standing. In fact, Teflon was invented by DuPont in 1938. Dr. M. Gregoire was granted a patent on the Teflon coating of a steel pan in 1954.

[29]Interview with Jason Cruzer, December 7, 2007.

[30]Interview with Carl Ray and Paul Mexcur, November 10, 2003.

for NASA, successful infusion and/or commercialization is expected to occur seven years or later after a Phase I award.[31]

Well aware that its metrics do not capture important benefits and, thus, underestimate SBIR benefits, NASA's SBIR program managers recognize the need to improve assessment and data collection. Currently, for example, NASA's Phase III metrics do not include subcontracts, bids for other procurement opportunities, use of prototypes through other mechanisms, or future developments of SBIR-supported technology.

NASA does, however, produce an SBIR Management Report that invites feedback from managers.[32] NASA also conducts an annual self-assessment on the year's solicitation process and outcomes. The latter includes a statistical analysis of how each subtopic performed; about one-third of the solicitation subtopics are changed each year. Before each solicitation, NASA does a "lessons learned" exercise.

5.5.2 Resource Constraints

What NASA spends on evaluation and assessment is not easily determined because there is no line item in the budget for evaluation. Only a small part of the program's $3.8 million administrative budget is devoted to evaluation and assessment, according to the Program Executive.

While NASA tracks the progress of each project during the contract phase using the quad chart and other reports (see Box 5-1), information on outcomes is less robust.[33] This means that NASA's SBIR metrics likely underestimate the program's total benefits, both to NASA as well as to the private sector.

Partly, this is because NASA has not implemented a tracking program such as that developed at DoD. Such a program requires that companies update outcomes data for *all* previous SBIR awards (at all agencies) whenever they apply for a new award from DoD. NASA may be able to piggy-back on the DoD program at minimal cost—and at relatively low resource cost to companies, as there is considerable overlap between DoD and NASA firms. In addition, all firms applying at DoD already provide the requested information about all projects, including those funded by other agencies such as NASA.

While NASA might adopt the DoD model of long term data collection through the Company Commercialization Reports database (CCR), NASA's SBIR program management has not had sufficient time or the resources nec-

[31] Interview with Jack Yadvish, research team leader for *Commercial Metrics*, March 7, 2005.

[32] Based on interview with Paul Mexcur, Program Manager, November 21, 2003.

[33] NASA tracks changes in the technology over the course of the project, distinguishing between the times required for a supported technology to move from Phase II to Phase III. (Interview with Carl Ray and Paul Mexcur, November 10, 2003.) Currently, NASA data—unlike that of DoD—does not distinguish between Phase III research support and Phase III procurement.

essary to follow the knowledge and economic effects of its SBIR-supported technology.

5.5.3 Phase III

At the agency level, there appears to be no formal tracking of NASA procurement from SBIR winners. While some field center SBIR programs attempt to track Phase III activity by SBIR contractors, there appears to be no common, standard approach, and some centers perform no tracking. Also, there is no shared definition of the investment threshold for infusion activity or any agreement on the preferred data sources for such activity. Some field center SBIR program offices use agency procurement data. Others rely on self-declarations by the small businesses.

The absence of reliable data on Phase III—especially on Phase III contracts within NASA, is a matter of concern both to the SBIR program office and the Mission Directorates. It is hard to manage a program effectively if there are no reliable indicators for the most important dimensions of success.

Resource limitations have played a major role in this area, as have concerns about the imposition of additional reporting requirements on companies or indeed within the agency. However, addressing this problem should be among the agency's most pressing priorities as SBIR becomes a more central component in the agency's overall research and operations strategy.

5.5.4 Assessing Outreach

Outreach activities at NASA's SBIR Level 1 are not formally evaluated. Inreach activities are carefully evaluated. For the NASBO program (described in Section 5.6.1) evaluation is informal at the Southern California pilot chapter, and at the SBIR Program Executive level.

Information does exist on the distribution and frequency-of-use of NASA's key outreach/inreach publications:

- *Spin-off* (annual print and CD publication)—in 2004, 35,000 print or CD units were distributed at conferences, expos, and other events.
- *Technology Innovation* (print quarterly)—15,000 copies were circulated in 2004 at conferences, expos and other events. Downloads from NASA Web sites are not tracked.
- *Technology Briefs* (print and electronic monthly)—about 500,000 subscribers were mailed the briefs in 2004. Downloads from NASA Web sites are not tracked.
- *Success Stories* (a NASA Web site record of 1,262 technologies)—Web site hits are not tracked.
- *TechFinder* (electronic portal; a technology transfer database)—the most

recent data shows that during November, 2004 *TechFinder* averaged 4,000 hits daily, and 130 daily visits in which a specific technology description was viewed. However, this covers all NASA technology, not just SBIR.

No other outcome metrics exist for outreach, and these data do not fully address the core question: are potential buyers of SBIR-funded NASA technologies aware of what is available? Do they use this information effectively? Could this outreach be improved?

5.5.5 Assessing Alignment with Agency Mission

Given a lack of funding, NASA's Commercial Technology Division does not anticipate an update to its 2000 publication, *Commercial Metrics*. Based on an extended survey of SBIR awardees, this 2000 study found that during 1983-1996 about 15 percent of the 1,739 NASA SBIR Phase II awardees who responded to the NASA survey[34] generated technologies that infused into NASA or other federal programs via Phase III funding.[35] Thirty-one percent commercialized in the private sector.[36]

NASA defines commercialization as the sale of NASA technology-derived products or services that resulted in actual revenues for the SBIR firm. The *Commercial Metrics* survey noted "a minimum of 612 products and services" commercialized from 1983-1996 that generated at least $2.28 billion of cumulative revenues in nonfederal markets. NASA's total SBIR investment for that same period was $1.11 billion. Of course, these data cover a funding period that ended more than 10 years ago.

Although agency budget constraints prevent a comprehensive update of this survey, more recent data shows that at least 267 NASA Phase III contracts have resulted from SBIR technology. Those contracts totaled $157,769,228.

Assessing NASBO

The NASA Alliance for Small Business Opportunity (NASBO) supports incubators to improve NASA SBIR commercialization and prepare potential firms as investor ready companies. The evaluation of NASBO has also become part of NASA's strategic discussion about revitalization of its Innovative Technology Transfer Program, as "spin-in" activity (supporting Mission Directorate program

[34]Access the NASA SBIR *Commercial Metric* Survey at <*http:sbir.nasa.gov/SBIR/survey.html*>. Eighty-four percent of eligible firms responded to the NASA survey. NASA claims that many SBIR firms that did not respond had multiple Phase III contracts and/or commercial success.

[35]NASA uses the term "Phase III funding" here means contractual or other monies awarded to a SBIR project for federal agency use of the subject technology after expiration of a SBIR Phase II award.

[36]The extent of infusion/commercialization overlap is unknown for these data.

work) has been added to complement "spin-out" activity, and both SBIR and technology transfer work fall under NASA's Innovative Partnership Program.

This discussion was triggered by a 2003-2004 external review of NASA technology transfer practices, conducted by the National Academy of Public Administration (NAPA) at the request of the Federal Office of Management and Budget.[37] That review cited NASA's need for a comprehensive strategy for identifying technology needs and commercialization opportunities, and called for a reform of NASA technology transfer practice to better balance spin-in and spin-out activity.

5.5.6 SBIR Success Stories

NASA publishes "success stories" to document and publicize information on positive SBIR outcomes. These success stories represent one way of detailing outcomes from SBIR-funded projects. As of 2006, NASA had documented 510 success stories and 287 Phase II contracts. Success is defined as contributing technology that helps NASA accomplish its missions and/or producing commercial value in the private sector.

Both forms of success are documented on the NASA SBIR Web site.[38] The site allows users to search by project, state, NASA center, and year. Each success story contains specific information on the innovation, the company's commercialization activities, the project's key accomplishments, applications in government and science, and an image of the product.

Table 5-1 shows the number of success stories produced by each NASA center, and provides one indication that "success" varies considerably by centers and regions. NASA centers with fewer success stories include Stennis, Dryden, Ames, Kennedy, and Langley. By comparison, Johnson, the Jet Propulsion Laboratory (JPL), Marshall and Goddard have a higher proportion of successes. The Glenn Research Center accounts for nearly 30 percent of all success stories. It should be noted that success stories are self-reported by firms and centers, and some centers are likely to be more aggressive in reporting success stories than others. This is not therefore a reliable quantitative metric for assessing center activities.

Why do such differences exist? SBIR budget shares and differences in core areas of technology explain some of the variation. Differences in success rates may also be due to specialized regional infrastructure focused on commercialization—such as the Regional Technology Transfer Centers (RTTC), NASA incubators, and various state and local partnerships—though this remains to be studied.

Although the "success stories" approach is illustrative, it is of limited use. For example it is not clear exactly who determines which projects qualify as a

[37]Access information on the NAPA study at <*http://www.napawash.org/pc_management_studies/ongoing_nasattf.html*>.

[38]Accessed at <*http://sbir.gsfc.nasa.gov/sbirweb/successes/Success_Story_Search.jsp*>.

TABLE 5-1 NASA Success Stories by Center Since the Program's Beginning

Center	Number of Success Stories	Percent of Success Stories
Ames Research Center	19	3.90
Dryden Flight Research Center	8	1.7
Glenn Research Center	137	28.3
Goddard Space Flight Center	86	17.8
Jet Propulsion Laboratory	58	12
Johnson Space Center	56	11.6
Kennedy Space Center	20	4.1
Langley Research Center	29	6
Marshall Space Flight Center	64	13.2
Stennis Space Center	7	1.4
TOTAL	484	100

SOURCE: National Aeronautics and Space Administration.

success story, and on what basis. The stories themselves are essentially anecdotes, though sometimes persuasive ones. And while the stories are searchable along several dimensions, "value to the agency" is not one of them.

Thus the success stories should be viewed as a useful adjunct to more data driven assessments. They could also be improved by deploying a more systematic and transparent approach to their collection.

5.5.7 Evaluation and Assessment: Conclusions

NASA is aware of the challenge it faces in developing the data sources and analytic tools needed to help manage the SBIR program effectively. The 2002 Commercial Metrics report began to lay the groundwork for more definitive evaluation of the SBIR program, but little has been built on that basis since then.

Discussions with NASA staff indicate that they are well aware of deficiencies in this area, and are eager to correct them. Tools that will support program management effectively should therefore be a high priority. The survey underlying the 2000 *Commercialization Metrics* report can be viewed only as a very preliminary step toward the gathering of useful data.[39] It is focused on company level outcomes rather than on projects.

It is also important to remember that summary statistics on market sales and NASA funding do not capture the overall return—economic and otherwise—to the NASA SBIR investments. On the one hand, sales alone ignore other costs: the $2.3 billion in sales generated by SBIR firms also involved *financial* as well as *opportunity costs* for the firms and for NASA far beyond NASA's $1.1 billion investment in SBIR funding. On the other hand, the calculations did not

[39]Access the NASA SBIR *Commercial Metric* Survey at <*http:sbir.nasa.gov/SBIR/survey.html*>.

include the support SBIR projects provide to NASA missions, the technology spillover benefits produced, or the knowledge spillovers that augment NASA's own ability to solve technology problems. So better data is important, but rigid application of conclusions drawn from what are inevitably limited data should also be avoided.

5.6 COMMERCIALIZATION SUPPORT

This section examines the infusion and commercialization assistance available through NASA's SBIR program at the national and field center levels.[40]

Unlike some other agencies (e.g., NIH, parts of DoD, DoE), NASA does not provide a formal training program. However, it does offer support for commercialization at different levels of SBIR management.

NASA SBIR senior staffers understand that the technological excellence of SBIR contractors is not always matched by entrepreneurial skill. As a result, the SBIR Program Executive has focused on "stakeholdership"—increased SBIR program interface with prospective customers and investors.

The three main agency-wide efforts underway are *external outreach activities* aimed at "marketing" SBIR funded technologies in the commercial marketplace and at other agencies, *internal inreach activities* (sometimes called "infusion" activities) focused on increasing the adoption of SBIR-funded technologies within NASA, and the *NASA Alliance for Small Business Opportunity* (NASBO), which leverages internal and external resources to mature SBIR technologies for customers. A fourth effort, focused on *"incentivizing"* Mission Directorate program offices to infuse SBIR technologies, is under development. Most recently, since 2006 the focus has shifted decisively away from commercialization and external marketing toward improving the uptake of SBIR-funded technologies within NASA. At the same time, the NASBO program appears to be of declining interest, and is currently under management review.

NASA does not formally market its SBIR-derived technologies. However, because the agency understands the difficulties facing companies as they approach Phase III, it has developed a range of mechanisms through which to publicize the technologies developed using SBIR (and other NASA R&D activities). As noted earlier, these include *Spin-off*, an annual publication; *Technology Innovation*, a quarterly publication; *Technology Briefs*, released monthly; *Success Stories*; *TechFinder*, NASA's electronic portal and database, and other materials such as a 2003 DVD portfolio of NASA SBIR projects.

All materials are provided free to potential technology customers and end-users on a subscription basis, as handouts at selected technical and investment community events, and online at NASA's Web site. Senior SBIR staffers see such

[40]At NASA, the effort to link SBIR technology development with mission program utilization is termed "infusion," defined as a Phase III occurrence at the end of the SBIR Phase I—Phase II program.

TABLE 5-2 Total NASA Phase I and Phase II Awards, 1983-2001

NASA Center	Number of Awards	Percent to Home State
ARC, DFRC, JPL (California)	575	38
GRC (Ohio)	328	8
GSFC, LaRC (Maryland, Virginia, DC)	670	10
JSC (Texas)	310	17
KSC (Florida)	104	6
MSFC, SSC (Alabama, Mississippi)	402	19
TOTAL U.S.	2,389	19

SOURCE: National Aeronautics and Space Administration, *Commercial Metrics* database.

external marketing as commercialization assistance, which brand technologies with the NASA imprimatur, as being of value to SBIR contractors.

At the center level, NASA centers with specific technology needs put out solicitations and evaluate subsequent SBIR applications. Because NASA centers generally lack knowledge of business and commercialization, they have relied on external organizations—such as Regional Technology Transfer Centers (RTTC) or state advanced technology programs—to facilitate commercialization.

Assisting commercialization effectively requires intimate knowledge of a region's companies and industries and frequent contact between the intermediary and the firm. Because roughly 80 percent of most centers' awards go to firms in other states (see Table 5-2), the centers' management of commercialization involves very little face-to-face contact and the centers often do not have a deep understanding of the regions in which their awardees operate. One result is that NASA centers are not heavily involved in SBIR commercialization.

5.6.1 NASBO and Technology Incubators

NASA's commitment to commercialization has been strong from the beginning, as evidenced by its support of an extensive regional technology transfer network. The network includes the National Technology Transfer Center (NTTC), Innovation Partnership Program offices in each of ten NASA Centers, six Regional Technology Transfer Centers (RTTC) (currently being phased out), seven regional NASA incubators, the Research Triangle Institute (RTI), and the NASA Alliance for Small Business Opportunities (NASBO).

NASA has in the past co-invested with regional stakeholders in nine business incubators, each located near one of the agency's ten field centers, in conjunction with NASA's Innovative Partnership Program. These incubators offer physical resources and limited technical assistance from management consultants to resident small businesses to promote successful NASA infusion or private-sector commercialization of their technologies.

NASBO's first chapter, the "NASA Commercialization Center" (near the Jet

Propulsion Laboratory) is one such incubator. It is a collaboration with the California State Polytechnic University—Pomona and Southern California Edison, a public utility that invests heavily in advanced technology entrepreneurship.

A second NASBO chapter (near the Johnson Space Center in Texas) is a nonincubator collaboration with the Technology Tree Group (TTG), an angel investor network. It was created using a nonfunded Space Act Agreement with TTG. TTG invests directly in SBIR firms of its choosing to meet the SBIR firm's strategic and operational needs, leveraging TTG's close ties to the National Seed and Venture Capital Fund Association and the Angel Capital Association. Unlike the NASA Commercialization Center, with its regional information technology focus, the TTG chapter is national in scope and has a medical technology focus. Here, assistance to SBIR firms includes market and technology assessments, and help in readying SBIR client firms for presentations at investor events, including the "World's Best Technology Show" (April, 2005). According to current TTG management, this effort is now largely independent of NASA, and NASBO has been of declining significance, largely because resources are lacking.

A third chapter is planned in collaboration with the Georgia Institute of Technology (Georgia Tech), with which NASA has multiple mission-driven partnerships. This chapter could link seven incubators in southern five states to cull NASA and other SBIR Phase II inventories for technologies that respond to defined needs in NASA and DoD acquisition programs. At present, chapter partners are still examining the feasibility of a Southeastern NASBO chapter, due to the small number of SBIR awardees in these states.

Each NASBO incubation chapter initiative is tasked with following NASA "ideation preparation guidelines."[41] These include two principal activities: a competing technologies contrast grid, and a market/customer availability assessment. In the first exercise, a grid is populated with significant technical-performance features on one axis, and direct plus indirect competing technologies on the other axis. In the second exercise, the grid is populated with top products under consideration in varied market segments on one axis, and dominant product features plus benefits on the other axis (these include product cost, market share, technology used, and strength/weakness points). Both "spin-in" and "spin-out" technologies are encouraged. These guidelines were designed to generate customer-focused discussions by SBIR firms, and to orient NASBO incubator tenants to the framework of an infusion/commercialization culture. Regarding outcome metrics, NASBO incubator chapters are asked to track the results of these ideation activities, as well as all post-SBIR contractual activity by incubator tenants.

NASBO's pilot chapter, the *NASA Commercialization Center*, has helped eight incubated SBIR firms since 2003. Three of these firms have sold products or services into federal markets. Two firms have yet to report infusion/commer-

[41] National Aeronautics and Space Administration, *Technology Innovation* 11(4):36, 2004.

BOX 5-2
NASA Sponsored Business Incubators

NASA sponsors nine small business incubators in different regions of the country. Their purpose is to provide assistance in creating new businesses based on NASA technology.

- Business Technology Development Center.
- Emerging Technology Center.
- Florida/NASA Business Incubation Center.
- Hampton Roads Technology Incubator.
- Lewis Incubator for Technology.
- Mississippi Enterprise for Technology.
- NASA Commercialization Center/California State Polytechnic University.
- University of Houston/NASA Technology Commercialization Incubator.
- NASA Illinois Commercialization Center.

cialization revenues but are pursuing Phase III strategies. Three firms are still maturing technologies.

The *NASA/Technology Tree Group* collaboration, created in 2003, results in "about five investments a year" made in NASA SBIR Phase II projects.[42] TTG does not reveal details of these investments. Its SBIR clients are not yet marketing products based on NASA-funded technology.

The *NASA/Georgia Tech* collaboration has no outcome information because the initiative is still in a formative stage. According to NASA's SBIR Program Executive, NASA incubators are significantly underfunded in comparison with physical plant and tenant support needs.

5.6.2 Center-level Activities and Practices

SBIR contracts are supervised with Mission Directorate assistance to ensure that SBIR awards are aligned with Mission Directorate needs. SBIR represents about 500 new contracts a year for NASA, representing almost half of the agency's total for for-profit contractors.

As described earlier, this alignment begins at the topic/subtopic development phase, when taxonomic descriptions of SBIR projects are designed to parallel the taxonomies of Mission Directorate technology roadmaps. The process continues through the awards process. Finally, during Phase II, the program emphasizes infusion opportunities for awardees.

[42] Interview with TTG Chief Executive Officer Michael Fitzgerald, March 7, 2005.

During SBIR Phase I, the interface between SBIR awardees and NASA SBIR project monitors, or COTRs, is limited and technical. During Phase II, the selection process includes outside peer evaluation of infusion/commercialization potential, and internal evaluation of the same by Mission Directorate personnel and other staff. SBIR firms also submit Phase II quarterly progress reports. These reports must include statements on mission program application. In the second year of Phase II, NASA expects its SBIR firms to develop infusion/commercialization plans with assistance from the project monitor.

Administratively, NASA SBIR activities for Levels 1 and 2—including infusion/commercialization issues—are discussed in a weekly teleconference of Level 1 and 2 principals, deputies and associates, and a monthly video conference that includes NASA field center SBIR Program Managers. A semi-annual meeting of SBIR Level 1 and 2 personnel with all ten NASA field center SBIR Program Managers is also held. At this meeting, infusion/commercialization practices are discussed, and the field centers make recommendations on prospective improvements to the program.

5.6.3 Access of SBIR Firms to Prime Contractors

One key to successful Phase III contract activity is careful management of the relationship between SBIR firms and prime contractors performing platform or system work for federal customers. NASA's SBIR infusion strategy focuses on developing "market pull" from Mission Directorate project offices for SBIR technologies.

Prime contractors who create mission hardware and software are generally not involved directly or indirectly in the NASA SBIR process. Nor are NASA SBIR firms trained to interact with the primes or other subtier suppliers who are logical customers for SBIR technologies when they have contracts with the same project offices that generated the relevant SBIR topics/subtopics.

There is growing awareness of this gap, especially at the field center level, and at least one center—Langley Research Center—has supported a pilot program to address it. However, the issue has not yet been formally raised at higher management levels for resolution.

Prime contractors, such as Raytheon, Lockheed Martin, and Alliant-Thiokol, have now begun to advocate for SBIR technologies in Department of Defense programs. Similar, "market pull" from NASA primes for SBIR technologies can be expected to increase the commercialization of NASA's SBIR-funded technologies.[43]

[43]See presentations by senior representatives of Boeing, Raytheon and other Prime Contractors on market pull in National Research Council, *SBIR and the Phase III Challenge of Commercialization*, op. cit. See pages 75-94.

5.7 SUPPORT FOR AGENCY MISSION ALIGNMENT[44]

With the appointment of NASA Administrator Michael D. Griffin in 2005, NASA made "spin-in"—the use of SBIR technology by NASA for mission needs—the SBIR program's main priority. This shift to mission-purpose uses is being accompanied by other fundamental changes underway at NASA:

- A new Moon-Mars mission, which is altering the relative position of NASA's ten Centers;
- A redesign of NASA's Innovation Partnership Program (IPP) to reduce fragmentation and to emphasize spin-in[45];
- A new budget model that employs full-cost accounting and incorporates competition for funding among NASA centers; and
- Movement of the Innovation Partnership Program to NASA Headquarters, giving it higher priority status within the agency.

Interviews with Mission Directorate staff stress that this shift in emphasis toward much improved alignment between Mission Directorate needs and SBIR program operations has been driven by the needs of the Directorates as much as by a re-evaluation of roles. Specifically, the shifts that have taken place in NASA as a result of new missions and reordered priorities have stretched NASA resources very tightly. They have also encouraged some Mission Directorates—especially Space Operations—to shift program research dollars up the TRL readiness level indicators, away from basic research.

As a result, SBIR dollars—which are insulated from this shift—have become an increasingly important source of low-TRL research funding. In some cases, they are the only available funds.

There is no formal agency-wide SBIR policy at NASA to link SBIR contractors with prospective infusion customers in mission project offices. However, eight field centers have evolved processes that task the SBIR project monitor, or SBIR subtopic manager, with brokering such relationships, with varying degrees of specificity.

This process, at its simplest, entails identifying prospective Phase III investors among NASA mission programs and projects during Phase I and II proposal evaluation. In more complex processes, SBIR project monitors are asked to present Phase II proposals to ranking committees with a record of discussions and meetings with Phase III prospects on the subject SBIR technology. In the latter case, such infusion information is shared with the SBIR winner by the SBIR project monitor.

Like DoD, NASA contracts out most of its mission hardware/software work

[44]"Inreach" refers to technology alignment efforts between SBIR technologies and potential NASA technology users.

[45]As noted above, the SBIR program is now part of the IPP.

to prime contractors, systems integrators, and sub-tier suppliers. Although these companies are large potential customers for SBIR technology, the NASA SBIR program currently has no systematic interface with these prospective customers (with the exception of Langley's pilot program linking SBIR awardees to primes).

5.8 THE REGIONAL DIMENSION

NASA, with its ten field centers, has considerable potential for a regional technology orientation. This section examines how NASA deals with the regional aspects of its SBIR program.

5.8.1 Geography and the Regional Distribution of Awards

Three main factors influence the regional distribution of SBIR awards. First, SBIR awards are highly concentrated geographically in a few locations. Second, NASA centers operate in a national market, typically awarding four of five SBIR grants to firms located in states other than the state in which the center is located. Third, technology innovation is highly concentrated geographically.

One conclusion from these observations might be that the geography of SBIR awards simply reflects an efficient matching of NASA needs (reflected in each center's awards) with the best small, high-tech companies distributed throughout the country. If this is true, outreach programs, coupled with information made available on NASA's Web site, have created a successful SBIR program. NASA's extensive documentation of SBIR success stories lends credence to this conclusion.

Of course, the same regional pattern could also emerge from a poorly functioning SBIR program. Here, the same uneven geography could result from all regions doing a relatively ineffective job of utilizing NASA's early-stage funding to support promising companies. We would still observe the nation's top high-tech regions performing proportionately better. In such a case, reform could improve commercialization of and infusion from SBIR companies by ensuring that all regions do a better job locating and supporting the most innovative small businesses. Economic benefits could be significantly less if, for example, a NASA technology problem was not solved because the best match was not made, an outstanding Phase I did not make it to Phase II, or a technology was developed too slowly to achieve the best result.

5.8.2 Complex Management Challenges

NASA's description of its technology transfer management goal—to manage NASA technology transfer from "top-to-bottom, coast-to-coast, and cradle-to-grave"—indicates the scale of the challenge. "Top-to-bottom" refers to all levels

TABLE 5-3 NASA Phase I and Phase II Awards by State and Region, 1983-2003

Region and State	NASA Center	Number of Phase I Awards	Phase I Dollars	Number of Phase II Awards	Phase II Dollars	Total Number of Awards	Total Dollars
Far West		1,433	83,404	596	301,863	2,029	385,268
Alaska		2	100	1	500	3	600
Arizona		109	6,530	37	19,250	146	25,781
California	ARC, JPL, DFRC	1,116	64,822	460	231,629	1,576	296,450
Hawaii		10	528	7	3,710	17	4,239
Idaho		3	209	0	0	3	209
Nevada		15	821	5	2,357	20	3,178
Oregon		66	3,931	32	16,764	98	20,695
Washington		112	6,463	54	27,653	166	34,116
Mid-Continent		607	134,946	242	124,657	849	160,829
Arkansas		5	259	1	594	6	854
Colorado		248	14,817	93	49,068	341	63,885
Iowa		10	557	6	2,635	16	3,193
Kansas		5	324	2	1,195	7	1,519
Missouri		10	658	4	2,286	14	2,944
Montana		16	1,029	5	2,536	21	3,565
Nebraska		4	220	2	732	6	952
New Mexico		77	4,709	24	12,503	101	17,211
North Dakota		1	70	0	0	1	70
Oklahoma		2	98,874	1	311	3	410
South Dakota		1	69	0	0	1	69
Texas	JSC	188	11,008	88	44,434	276	55,442
Utah		37	2,161	14	7,366	51	9,527
Wyoming		3	191	2	997	5	1,188
Midwest		315	18,857	117	60,993	432	79,851
Illinois		44	2,494	16	7,843	60	10,337
Indiana		34	1,912	15	8,167	49	10,079
Michigan		68	4,011	27	13,655	95	17,666
Minnesota		52	3,217	20	10,596	72	13,814
Ohio	GRC	117	7,223	39	20,732	156	27,955
New England		1,256	73,318	529	276,133	1,785	349,451
Connecticut		125	7,312	50	26,168	175	33,481
Maine		6	336	2	1,071	8	1,406
Massachusetts		724	41,883	292	150,328	1,016	192,211
New Hampshire		94	5,612	47	25,103	141	30,715
New Jersey		118	6,942	49	25,995	167	32,937
New York		177	10,434	85	45,080	262	55,514
Vermont		12	799	4	2,388	16	3,187

TABLE 5-3 Continued

Region and State	NASA Center	Number of Phase I Awards	Phase I Dollars	Number of Phase II Awards	Phase II Dollars	Total Number of Awards	Total Dollars
Mid-Atlantic		565	33,649	216	109,508	781	143,155
Delaware		7	450	2	1,051	9	1501
Maryland	GFSC	202	11,720	69	36,091	271	47,811
Pennsylvania		119	6,777	49	22,457	168	29,234
Virginia	LaRC	234	14,512	95	49,419	329	63,930
West Virginia		3	190	1	490	4	679
Southeast		466	26,617	186	95,265	652	121,884
Alabama	MSFC	209	12,127	93	49,304	302	61,431
Florida	KSC	116	6,737	44	21,619	160	28,357
Georgia		29	1,650	11	5,396	40	7,046
Kentucky		1	50	0	0	1	50
Louisiana		6	239	1	231	7	470
Mississippi	SSC	20	1,014	7	3,867	27	4,881
North Carolina		26	1,525	8	4,198	34	5,723
South Carolina		1	69	0	0	1	69
Tennessee		58	3,206	22	10,650	80	13,857

SOURCE: National Aeronautics and Space Administration.

of management; "coast-to-coast" highlights the importance of the ten NASA centers and NASA's regional infrastructure, and "cradle-to-grave" points out the difficulty of managing SBIR from solicitation through Phase III.

The management challenge is even more complex because the SBIR program is a component of NASA's Innovation Partnership Program (IPP).[46] Although often overlooked, each of IPP's components interacts with state and local science and technology infrastructures. As suggested by Table 5-4, the number of distinct technology development programs within and related to NASA raises an obvious question: How do these combine to determine innovation supported by the SBIR program?

5.8.3 The Limits of the Traditional External Network

While the rationale for NASA's traditional external network—geographic proximity linking NASA technology where firms using the technology increase the rate of innovation in the private sector—was clear, the performance of this network remains in doubt.

In the traditional network, specialized intermediaries, like the Regional

[46]Until recently, SBIR was able to operate somewhat independently of IPP's other programs.

TABLE 5-4 NASA and Non-NASA Programs

NASA	Non-NASA
NASA Headquarters Web site (e.g., EHB)	*Local University
NTTC (National Technology Transfer Program)	*Corporate R&D Labs
NASA Center Research Lab/Branch	*Nonprofit R&D Centers (e.g., hospital)
NASA Center SBIR/STTR Program Management Office	*STTI (State Science & Technology Institute)
NASA Center Patent Office	*State S&T Program
*RTTC Program (6 RTTCs)	*State DoD (e.g., early-stage funding)
*Regional Affiliates of RTTCs (each of six regions)	Angel Funders
*Rural State SBIR Outreach (RSSO) Program	Venture Capital Firms
*NASBO	Prime Contractor
*NASA Incubator	
*NASA Ames Research Park	
*FAST (Federal and State Technology Partnerships)	

NOTE: The items with an asterisk are regionally oriented.
SOURCE: National Aeronautics and Space Administration.

Technology Transfer Centers, provided an essential component to bridge the gap between NASA technology and adoption of the technology by private industry. The intermediary brought knowledge of business, the investment community, regional economies, and the ability to provide a base for sustained interactions between sources of NASA technology and firms.[47]

Although the rationale was clear, the evidence supporting the network's performance was weak and mostly anecdotal. For instance, despite documentation by NASA of numerous individual success stories, there were no compelling studies substantiating the contribution of the regional infrastructure to innovation and technological change—either to spin-out or spin-in uses. Without a new evaluation methodology and much better data it remains impossible to know whether, for example, an RTTC or NASA incubator helped to create a success, much less differentiate a spin-out success from a spin-in or dual-purpose success. This disappointing outcome largely stems from a fragmented NASA infrastructure that has been documented by a recent report from the National Academy of Public Administration (NAPA) and reinforced by NRC interviews.[48]

The NAPA report asserted that the numerous components of NASA's technology transfer program have not functioned in a coordinated way.[49] For exam-

[47]NASBO has the potential to fill these needs, but does not yet have the required scale of operation and the need for cross-regional cooperation to meet this challenge.

[48]Access information on the NAPA study at <*http://www.napawash.org/pc_management_studies/ongoing_nasattf.html*>.

[49]Recent steps are being taken to create more coordination among RTTCs and NASA centers. SBIR/STTR headquarters has implemented monthly conference calls with NASA Centers and RTTC directors. In addition, headquarters has held several national network meetings.

ple, even though SBIR is a component of the Innovation Partnership Program and reports to the same person, NAPA found that there was very little coordination among technology transfer programs. Its findings have been accepted by NASA and some of the recommended changes are already taking place; others are being discussed.[50]

NAPA concluded, in general, that the Innovation Partnership Program has been successful with administrative functions. However, the network is fragmented, in part because roles and responsibilities are unclear. Several other factors also contributed to fragmentation: there was little direction from NASA headquarters; RTTCs reported to centers rather than to headquarters (see below); and NTTC operated under cooperative agreements rather than arrangements based on performance.

An RTTC focused on its region is not well-matched with each NASA center's use of SBIR because their mission-based topics and subtopics should draw applicants from across the country. Moreover, this disconnect between the regional focus of the RTTCs and the broad mission needs of NASA also means that technologies located in another region potentially beneficial to the RTTC's region will be missed or substantially delayed. RTTCs have primarily worked independently, not as a NASA-wide and nationwide system. This should not be a surprise because each RTTC reports to a specific NASA center in their region and the RTTCs' contracts state that 85 percent of their activities are to be allocated to their region's companies and technologies.

Moreover, Innovation Partnership Program personnel's professional backgrounds are often not well matched with the requirements of technology transfer. For example, because of skill mix called for by the Innovation Partnership Program, staff frequently has difficulty communicating with NASA researchers and potential external partners (e.g., universities and companies) about technologies.

Corroborating the NAPA report, NRC interviews also found that NASA personnel had strongly held views that the RTTCs have performed poorly. NASA personnel gave various reasons for this disappointing performance, including: poor management; lack of clear objectives and metrics; too little emphasis on SBIR; and a geography that does not reflect the economics of regions. As a result, much of the Innovation Partnership Program's infrastructure is now being reorganized to focus on its mission of leveraging technology for NASA's Mission Directorates, programs, and projects.

Whatever structure emerges from the rethinking and reorganization of the Innovation Partnership Program (IPP), NASA continues to have a major stake in regions. The nation's major sources of advanced technology are highly geographically concentrated and are derived from the constantly evolving network

[50]See Leonard Yarbrough, "Initial Responses to the NAPA Recommendations" (preliminary), November 16, 2004.

of regional innovation systems that form the nation's innovation system. These dominant regions are both the primary sources (spin-in) and users (spin-out) of innovation and new technology. Spin-in and spin-out are really two sides of the same coin, with the primary difference being the direction of technology flow. Because SBIR is dual-purpose, NASA has a stake in an infrastructure that supports both spin-in and spin-out. Whatever reorganization takes place, both spin-in and spin-out need to be incorporated and a new relationship to regions clearly specified.

5.8.4 Spin-in Challenges

NASA's challenge in creating an effective regional infrastructure has become even more difficult with this increased emphasis on using SBIR for gaining technology for NASA's mission needs. The dilemma NASA faces is that, with a dual-purpose program, both infrastructures are important and should be linked. A program focused primarily on spin-in requires an infrastructure that differs from the original regional infrastructure described above.

There are two reasons why it may be difficult to create an orientation towards infusion. First, the pre-2005 program created an infrastructure that emphasized commercialization—and commercialization (not infusion) is what the regional infrastructure was designed to do. Second, organizing the infrastructure to accomplish spin-in will require greater coordination and focus by NASA personnel. Most likely, more resources will be necessary because more planning and management will be needed to ensure that SBIR projects research technology useful to NASA. Some at NASA think that SBIR will be marginalized by the shift to a spin-in approach to technology transfer. This was also the conclusion of NAPA in its recent report on NASA technology transfer.

A spin-in focus, like a spin-out focus, requires specialized and frequent contact with awardee firms. Moreover, it requires a specialized knowledge of how the relevant technology meshes with NASA's specific mission needs. Interestingly, a detailed knowledge of the region's firms and industries is also necessary.

It seems clear that NASA's new emphasis on spin-in raises the stakes on the use of the SBIR program. With tight budgets, the restructuring of NASA centers' technology capabilities, and a competitive approach to funding centers, centers that figure out how to best utilize SBIR to garner mission-use technology will have an advantage.

Several steps in this direction may be necessary.

- **Greater Role for Centers.** First, rather than turning to regional organizations established to commercialize federally funded research for regional benefit, individual NASA centers (and their researchers) will need to take greater responsibility for identifying companies best matched to the Center's specific technology needs. While the extent to which the pool of firms selected this way will overlap with the pool selected pre-2005 is unknown, significant differences will likely exist. For example, many firms that have sought NASA SBIR funds in the past had commercialization, not NASA mission needs, as their top priority. If NASA centers emphasize short-term NASA needs over more long-term commercialization potential, it may divert the nation's most innovative small companies away from NASA-oriented research areas entirely.

The emphasis on spin-in does not eliminate the need for a regional intermediary with deep knowledge of a region's companies and industries. It is not likely that a NASA center can fill this gap. However, NIST's Manufacturing Extension Programs (MEPs) might meet the need for local industry information. The MEPs may be the appropriate entities with the most knowledge of each state and local area's manufacturing companies.

- **New Resources and Approaches.** Second, with spin-in, NASA centers will need to find new resources and new approaches to managing SBIR from solicitation to Phase III. Under the previous spin-out emphasis, there was insufficient incentive for individual NASA centers to devote the resources to track an SBIR firm's progress carefully while it develops a technology over several years. As NASA centers are evaluated more carefully and systematically based on their success in gaining mission-purpose technology from the SBIR program, new structures will need to emerge to improve transitions throughout the several phases and to increase NASA benefits over the long run.
- **Collaboration among NASA Centers and National Laboratories.** Third, since the bulk of each Center's awards are distributed throughout the country (and not just in the local area), managing the spin-in approach will require far more collaboration across all NASA Centers and perhaps other federal labs. Whether the goal is spin-in or spin-out, getting the most out of the SBIR program will take much more frequent and direct contact between NASA and SBIR companies. All NASA Centers must work system-wide on their core technologies. For example, information on firms and technologies developed by NASA Ames should be shared with all NASA Centers and possibly a new, centralized RTTC (CRTTC) with responsibility for assuring the systemwide cooperation of RTTCs. The RTTCs and SBIR programs of each NASA Center should also exchange both commercialization and spin-in information with other federal agencies to maximize the joint (multiagency) benefits. For example, a NASA technology of potential use to DoD should be shared with DoD.

The difference between a spin-in and spin-out systemwide approach is basic. Spin-in requires much greater involvement of NASA centers while spin-out involves much greater involvement of a commercialization intermediary. A well functioning and scaled up system of NASBO chapters could potentially take on this role effectively.

- **Identify National Technology Capabilities.** Fourth, spin-in will also create a need for a new NASA capability for identifying and analyzing the specific R&D and technology capabilities of firms, corporate R&D labs, universities, research hospitals, and other federal labs. Presumably this analytical function would take place at NASA headquarters, although it is also a logical candidate for shared responsibility across all federal agencies—not just all SBIR programs. In addition to accurately describing regional technology capabilities, NASA Headquarters would also take responsibility for drawing on advisers inside and outside NASA with the greatest expertise on NASA's high priority technology needs. Regarding SBIR, one outcome would be superb technology intelligence that can be used to identify the best firms, universities, etc., working on key technologies. This approach to developing and using technology intelligence has a parallel in private industry, which has increasingly turned to external sources of technology over the past ten years.

- **Partnerships.** Fifth, implicit in NASA's current efforts to use its technology transfer programs to obtain external sources of technology is a more strategic, long-term approach to meeting NASA's technology needs. The implication would seem to be that each NASA center will be responsible for developing and implementing a long-run strategy for creating critical partnerships with universities, other federal labs, small high-tech firms, etc., that build NASA's high-priority technology capabilities. This requires deeper knowledge of regional innovation systems.
- **Evaluation.** Finally, NASA centers would need to be responsible for working closely with each other (or the new CRTTC) in measuring long-term, indirect benefits and developing new metrics to support spin-in. The methodology would be developed to be consistent for both spin-in/infusion and commercialization applications.

The gains from restructuring NASA's technology transfer network will take the form of better technology, lower costs, and a higher rate of innovation in support of NASA's space missions. In specific terms, this implies:

- A higher percentage of Phase I companies achieving Phase III;
- A faster rate of development of high priority NASA technologies from R&D in Phase I to use of technology by NASA in Phase II and Phase III for space missions; and
- A larger fraction of SBIR technology used by NASA to advance its own capabilities.

TABLE 5-5 Dual Purpose Uses of SBIR

	Spin-in (Mission Purpose)	Spin-out (Commercialization)
Significance of Region	Because advanced technology is highly-geographically concentrated, regions are important as the primary sources of technology.	Because commercialization requires extensive face-to-face contact, regions are important as places with infrastructure supporting commercialization.
Requirements/ Capabilities	Requires high level knowledge of specific technologies as well as knowledge of NASA needs and organization.	Requires knowledge of regional industries, business, early-stage funders, and state & local programs.
Organizational Responsibility	NASA Centers takes primary responsibility for 1) evaluating proposals, 2) monitoring technology, 3) ensuring PI-PIII transitions with spin-in potential, and ensuring cross-center sharing. NASA centers could work closely with NIST's Manufacturing Extension Program (MEP) network.	States take primary responsibility for funding a new RTTC-like intermediary with responsibility for outreach to identify new PRINCIPAL INVESTIGATOR candidates, evaluate proposals for commercialization potential, and evaluate the state's PII successes for commercialization opportunities, and assisting businesses in commercialization.
New Organizational Structures	NASA Headquarters will need to create or augment its capabilities for identifying external sources of its high priority technologies for mission purposes. NASA may also want to create a new structure for funding highly promising mission-purpose technologies that develop in Phase II. NASA centers could also work with each state's RTTC-like intermediary to link successful PII firms with NASA's prime contractors.	A new, centralized cross-agency intermediary may be required to ensure that SBIR/STTR technology available in one region is connected with commercialization opportunities in other regions. Like the NTTC, the new organization could be funded by all federal agencies. The new intermediary could work closely with NIST's Manufacturing Extension Program (MEP) network.
Evaluation and Metrics	NASA would fund the development of an evaluation methodology and metrics following a model similar to that used by the ATP. The methodology would serve as a guide to developing metrics that are consistent with SBIR/STTR's long-term mission objectives.	Working across all federal agencies, NASA would also fund development of an evaluation methodology that incorporates private-sector commercialization benefits using an approach that dovetails with evaluation of spin-in benefits and metrics.

SOURCE: National Aeronautics and Space Administration.

Annex to Chapter 5
SBIR at the NASA Centers

Until the most recent reorganization, basic SBIR processes were common to all ten field centers. Other processes affecting infusion/commercialization opportunity reflect the missions of NASA's various field centers. As a result, the centers have had differing definitions of what constitutes successful infusion/commercialization of SBIR Phase II technologies, making it difficult to compare infusion/commercialization outcomes with accuracy. Below, we examine how SBIR was administered at each of the NASA centers.

5.9 AMES RESEARCH CENTER (ARC)—SAN JOSE, CA

The Ames SBIR Program Office primary interface is with the three research directorates at Ames, whose technology foci are not closely aligned with agency Mission Directorates. These research directorates govern the SBIR topic development process, although Exploration Systems Mission Directorate does participate in subtopic development.

SBIR Phase I activity by the Ames Program Office includes a cursory evaluation of infusion/commercialization opportunity in the proposal review process, although the Program Office is planning a preparatory workshop for the 2006 Phase I proposals ranking committee that will have an infusion/commercialization appraisal component.

In both Phase I and Phase II proposal review processes, the research directorates make proposal ranking recommendations to a ranking committee. During Phase II proposal evaluation, outside peer reviews of infusion/commercialization opportunity are considered, but are not decisive in ranking committee funding recommendations. During a Phase II contract, little or no emphasis is placed by SBIR project monitors on identification of infusion/commercialization opportunities by the SBIR awardees.

The Ames SBIR Program Office does not monitor either infusion or commercialization outcomes of SBIR projects, but evidence of "success stories"—usually obtained anecdotally, and then verified with the SBIR firm—is passed on to NASA SBIR Level 1 and 2 principals. Although the aggregate of such success stories is ". . . a small number," according to Ames SBIR Program Manager Geoffrey Lee, ". . . some of NASA's largest Phase III contracts come from Ames SBIR contracts, whose technology was infused into Space Life Sciences Payloads programs."[51] Among the 18 Phase III contracts from Ames documented since 1983, Ames claims the largest Phase III dollar aggregate from SBIR projects among the ten NASA field centers. Its Phase III contracts have totaled approxi-

[51]Interview with Geoffrey Lee, February 10, 2005.

mately $123,500,000. This includes NASA's largest individual SBIR Phase III contract—$59,104,971 given to Orbital Technologies, Inc. in 1994 to develop a plant research unit.

NASA's new full-cost accounting environment for all agency functions (i.e., all funding is derived from mission programs) requires field center compliance and reorganization in many cases. Consequently, the Ames SBIR Program Office has had to explore development of an infusion/commercialization assistance component. This component will be derived from best practices of other field centers and discussions with Ames's Technology Partnerships Office.

5.10 DRYDEN FLIGHT RESEARCH CENTER (DFRC)—EDWARDS, CA

Dryden is the sole "flight research Center" among the ten NASA field centers. Its SBIR Program Office is primarily responsible for proof-of-concept aeronautics flight-test support. SBIR Phase I activity at Dryden includes a cursory evaluation of infusion/commercialization opportunity in the Phase I proposal technical review process. Phase II proposal evaluation is limited to a formal outside peer review of infusion/commercialization opportunity.

In both Phase I and Phase II proposal review processes, the research directorates make recommendations to the DFRC Ranking Committee. During a Phase II contract, SBIR program monitors (from research directorates) and the Program Office do work with awardees to help ensure that the small business aligns its SBIR technology with a NASA acquisition opportunity. This work includes assistance in assuring resonance between the SBIR firm's choice of "key words"[52] and NASA's base technology taxonomy, so that a search of the NASA SBIR Database for technologies that could be infused into NASA enterprise work would yield relevant SBIR project files.

DFRC SBIR does not formally monitor either infusion or commercialization outcomes of SBIR projects, and evidence of "success stories"—usually obtained anecdotally, and then verified with the SBIR firm—is passed on to NASA SBIR Level 1 and 2 principals. Informally, notes Dryden SBIR Program Manager Rod Bogue, ". . . we try and call our SBIRs at least every two years to ascertain Phase III success, especially NASA infusion of their technologies. To me, the business case of a SBIR project has to focus on Phase III opportunity—but our administrative resources to help SBIR projects in this regard are very limited."[53] DFRC SBIR has no estimate of its Phase III results from SBIR contracts. According to the NASA EHB Web site, DFRC has had two Phase III contracts.

Two of Dryden's current SBIR Phase II projects participate in the NASA

[52]"Key words" are self-assigned by SBIR awardees to identify their technology or technology domain. The key word chain appears on the cover sheets of most agency SBIR records, including electronic databases, and are searchable by external inquiry.

[53]Interview with Rod Bogue, February 16, 2005.

Commercialization Center incubator. Their performance as incubator tenants is not monitored by DFRC SBIR.

5.11 GLENN RESEARCH CENTER (GRC)—CLEVELAND, OH

The GRC SBIR Program Office aggressively pursues infusion opportunities for SBIR technologies. As with all field centers, SBIR Phase I activity includes evaluation of infusion/commercialization opportunity in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunities. GRC adds unique resources to these processes:

- In addition to strongly encouraging Mission Directorate program offices to participate in SBIR topic and subtopic development, the SBIR Program Office holds one-day infusion/commercialization workshops—just prior to the proposal review process—for reviewers and for the subtopic managers who are key to the review process.
- The GRC SBIR Program Office has, since 1986, noticed relevant acquisition opportunities in the Army and Air Force, and maintains ties with appropriate program offices in both service agencies.
- GRC markets its SBIR program to small business SBIR candidates at various national and state SBIR conferences, to identify candidates with infusion/commercialization potential.

To track GRC SBIR "success stories," GRC SBIR Program Manager Dean Bitler employs a five-column Excel table that notes the SBIR company and location, the NASA organizational code and COTR; the SBIR project title; the SBIR topic/subtopic number; the year of award; and finally, a succinct infusion/commercialization history.

This table, updated regularly with SBIR firms, tallies 142 projects whose technologies were successfully infused into federal acquisitions, were successfully commercialized, or were in transition to Phase III at the time of the update. GRC does not track aggregate revenues. According to the NASA Electronic Handbook Web site, there have been a cumulative 48 Phase III contracts at Glenn.

For GRC SBIR Program Office, the key venues for evaluation discussion are the semi-annual meetings of SBIR Level 1, 2, and 3 personnel, where infusion/commercialization issues are both formally and informally discussed.

5.12 GODDARD SPACE FLIGHT CENTER (GSFC)—GREENBELT, MD

The "Center-wide investment strategy" of Goddard's Technology Management Office—of which the GSFC SBIR Program Office is a component—ensures that applications needs of the resident Earth Science Enterprise Mission Directorate (ESEMD) drive all Goddard technology development.

The Center's SBIR Program Office says its role is to assist in managing a balanced technology pipeline at Goddard. "We are part of the ESEMD program offices' investment strategy, and have been for some time," says SBIR PM Dr. James Chern. "Eight years ago, we aligned our SBIR program with Goddard's needs . . . but still, it took at least three years to convince the mission program offices of SBIR benefits. In fact, SBIR technologies are essential to building mission technology portfolios."[54]

The GSFC SBIR program emphasizes maturing SBIR projects at high Technology Readiness Level (TRL), as seen in an Astra project strategic technology/systems model. GSFC deploys the agency-wide SBIR process model. SBIR Phase I activity includes evaluation of infusion/commercialization opportunities in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunities.

At Goddard, there is also serial interface with ESEMD regarding topic/subtopic development to ensure that SBIR awards help fill the Center's technology pipeline. ESEMD group leaders and branch heads play key leading roles in the SBIR process—including aggressive roles as subtopic managers. In these roles, they advocate specific infusion opportunities for SBIR technologies in ESEMD programs. GSFC's SBIR Program Office pairs subtopic managers with COTRs to promote infusion opportunities. The COTR takes the lead in Phase II, beginning with the presentation of infusion opportunities, cited in Phase II proposals, to the review committee.

GSFC's Earth Science Technology Office management strategy map illustrates Goddard's approach to meeting the technology needs of what were the Earth Science Enterprise missions, including the SBIR contribution to those missions.

GSFC SBIR Program Office also markets its resources to small business SBIR candidates at various national and state SBIR conferences, and participates in the Center's annual "Small Business Day."

Due to staff and budget constraints, GSFC SBIR Program Office does not actively track the infusion/commercialization success of its SBIR contractors. GSFC was, however, the first Center to produce and disseminate a *Success Stories* publication—a function now assumed by NASA SBIR Levels 1-2 through *Spin-off* and other publications. According to the NASA EHB Web site, Goddard has had 15 Phase III contracts over the years.

While the process is informal, evaluation of SBIR practices is continuous at Goddard through discussions with the Technology Management Office. Recommendations from these discussions are presented at the semi-annual meetings of Level 1, 2, and 3 personnel.

[54]Interview with Dr. James Chern, February 22, 2005.

Key infusion/commercialization assistance issues for GSFC SBIR include improved alignment of ESEMD element program themes and potential Phase III opportunities, improved identification of SBIR projects with high infusion potential, increased work with COTRs to improve communication with potential technology customers, and better use of the NASA technology transfer network.

5.13 JET PROPULSION LABORATORY (JPL)—PASADENA, CA

Owned by NASA and operated by the California Institute of Technology (normally known as "Caltech"), JPL has five resident Directorates: Planetary Flight Projects, Solar System Exploration, Astronomy and Physics, Earth Science Enterprise, and Interplanetary Network. Of these, the Mars mission's Technology Program Office is key to JPL's SBIR infusion focus, and is the principal contributor to SBIR topic/subtopic development.

Most JPL SBIR awards directly support the field center's Strategic Technology Plan, and the SBIR program is closely aligned with future mission needs. This alignment creates infusion opportunities for SBIR projects, but also triggers added JPL management and technical staff support for its SBIR program office. SBIR topic/subtopic managers have technical/management responsibilities at JPL and NASA Headquarters levels.

As with all field Centers, SBIR Phase I activity includes evaluation of infusion/commercialization opportunities in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunity. As a "national field center," however, the JPL SBIR proposal review process is a cross-cutting effort in which technical program office representatives from other field centers actively participate in proposal evaluation and ranking committees.

Moreover, JPL SBIR awardees in Phase I are often required to go beyond the "proof of principle" work typical of Phase I activity and perform prototyping work usually found in the final year of Phase II activity. "We want to avoid funding research that does not lead to infusion opportunity," says JPL's SBIR Program Manager Wayne Schober, ". . . in concert with our belief that the program offices should own SBIR."[55]

At JPL, the lead for SBIR infusion/commercialization activity is the project Technical Monitor (often a technical program office representative) charged with advocating for SBIR awardees to project managers in mission program offices. The Technical Monitor is tasked with ensuring that an SBIR project observes NASA program requirements. During Phase II, the Technical Monitor also serves as a liaison between SBIR contractors and appropriate project managers, and arranges for project representative participation in meetings with the SBIR contractor. In turn, the small business is required to provide status reports to its Technical

[55]Interview with Wayne Schober, February 28, 2005.

Monitor on the interface with mission projects. This information is then pushed back up to center technology management personnel for evaluation.

JPL SBIR Program Office both tracks and documents its Phase II awards for infusion/commercialization success, using a stringent dollar threshold of $100k for defining Phase III success.[56]

By its definition, of 228 JPL Phase II projects since 1983, 41 have been infused into NASA mission programs (technology and flight hardware), and 66 have found commercial success, with some projects having both infusion and commercialization success. Aggregate revenues are not available.[57]

While JPL SBIR Program Office uses the agency *Success Stories* Quad format to record and market its SBIR projects, it has also created a mission-specific format to document infusion of SBIR technologies.

Evaluation of SBIR practices is informal and continuous at JPL through discussions within the Technology Management Office and various project offices. This evaluation is informed in part by status reports provided by the SBIR firms as well as input from Technical Monitors. Some recommendations, filtered from these discussions, are presented at the semi-annual meetings of SBIR Level 1, 2, and 3 personnel.

5.14 JOHNSON SPACE CENTER (JSC)—HOUSTON, TX

JSC has the largest mission program-based research budget of the field centers. JSC's SBIR program has a complex interaction with multiple Mission Directorates. ESMD and Space Operations are the principal customers and drivers of SBIR topic/subtopic development, with the Explorations and Aeronautics directorates also playing substantive roles. Discussions with directorate program leads and technology element managers align JSC's SBIR program with the center's mission priorities. SBIR Program Manager Dr. Kumar Krishen also reviews agency Broad Area Announcements (BAAs) and Intramural Calls for Proposals (ICPs) to parse them for information that can inform the topic/subtopic development process.[58]

As with other field centers, SBIR Phase I activity includes evaluation of infusion/commercialization opportunities in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunities.

JSC's unique practice focuses on interaction between SBIR principals and mission program principals. When subtopic managers brief the ranking committee on Phase II proposals, they must cite evidence of infusion opportunities, including summaries of specific discussions and meetings with directorate technology element leads on SBIR technology viability.

[56] Some other field centers reportedly use a lower dollar threshold to determine Phase III success.

[57] It should be noted that there is only one Phase III contract cited on the NASA EHB Web site.

[58] Interview with Dr. Kumar Krishen, February 24, 2005.

Dr. Krishen reaches beyond NASA in the greater Houston area to advocate for SBIR commercialization and investment in SBIR firms with federal program infusion opportunities. At the time of his interview with NAS program staff in early 2005, his most recent SBIR marketing pitch, for example, had been made to the Houston Area Economic Alliance.

JSC SBIR Program Office actively promotes its Phase III successes through its annual Johnson Space Center Spin-Off Awards (which also reward "spin-in" technologies infused into NASA mission directorate programs) and *Success Stories*. In addition, it annually nominates SBIR candidates for NASA's *Space Technology Hall of Fame*—with two inductees in both 2004 and 2005.

JSC uses NASA's *Success Stories* Quad format of one-page summaries of SBIR projects, for use in infusion/commercialization marketing and Phase III recordation work.

Although JSC SBIR Program Office does actively monitor its SBIR portfolio of companies to assess Phase III success, tracking statistics are not available except to NASA SBIR Levels 1-2 principals for inclusion in the agency-wide *Spin-off* and other publications. According to the NASA Electronic Handbook Web site, JSC has had 44 Phase III contracts over the years.

JSC SBIR's main venues for evaluation are the semi-annual meetings of SBIR Level 1, 2, and 3 personnel, and the weekly/monthly electronic conferences. Infusion/commercialization issues—including Dr. Krishen's innovations regarding infusion/commercialization opportunity consideration in Phase I and II proposal rankings—have been reviewed by the NASA SBIR community at the semi-annual events. Internally, informal evaluation discussions of SBIR program effectiveness are held between the SBIR Program Office and local Mission Directorate personnel. In 2005, the principal emergent issue was the need for closer ESMD participation in the subtopic review process.

5.15 KENNEDY SPACE CENTER (KSC)—FLORIDA

KSC has a small mission program research budget, and a correspondingly small SBIR program. Mission project offices, especially in Human and Robotic Technology work, drive SBIR infusion/commercialization activity.

KSC SBIR shares the basic topic/subtopic development and Phase I-Phase II proposal review processes common to all NASA field centers, but includes a special emphasis on infusion opportunity and infusion planning by the SBIR contractor in both Phase I and Phase II proposal review. The responsible party is the SBIR project monitor, or COTR, who is tasked in the Phase II proposal presentation format with identifying NASA technology user community "gatekeepers." Gatekeepers include project office program managers from the Expendable Launch and Space Station mission groups who provide infusion leadership for SBIR technology once the COTR has obtained buy-in from that gatekeeper through discussions and meetings.

The KSC SBIR Program Office also monitors the participation of one of its SBIR firms resident in the NASA Commercialization Center incubator.

Citing budgetary and staff constraints, the KSC SBIR Program Office does not actively track and update information on its Phase II projects regarding Phase III activity, apart from its interest in tracking SBIR-derived intellectual property. According to the NASA EHB Web site, there have been nine Phase III contracts over the years at KSC.

As KSC SBIR is aligned with the center's Human and Robotic Technology Program and that program's Element Plan, the SBIR Program Office holds periodic evaluative discussions with the infusion "gatekeepers" from Expendable Launch and Space Station organizations.

Priority issues arising from these discussions in 2004-2005 are: closer alignment of SBIR subtopics with KSC's Human and Robotic Technology Program Element Plan; availability of demonstration venues to Phase II SBIR projects to ensure higher TRL levels upon Phase II completion; more formal infusion planning by SBIR firms; and infusion incentives for these firms. These incentives might include cost-plus, award-fee contracts where the award-fee is heavily dependent on progress with the technology infusion process. No formal KSC plans have yet been developed to deal with these issues.

5.16 LANGLEY RESEARCH CENTER (LARC)—HAMPTON, VA

Langley was founded in 1920 at the genesis of the aviation industry. The nation's first aeronautics lab, Langley is dedicated to aeronautics and engineering technologies, as well as atmospheric science, with Earth Sciences responsibilities. Its $700 million budget in 2005 marks it as the smallest field center. However, Langley is co-located with Langley Air Force Base, the Jefferson National Accelerator Laboratory, Northrop Grumman Newport News naval shipyard and the Virginia Institute of Marine Science. As these institutions have a history of partnering to pursue technologies of mutual interest, numerous small firms with advanced technology skills can be found on LaRC's perimeter. Since 2000, Virginia has averaged the nation's second-highest number of SBIR awards by state, with the Hampton Roads region surrounding LaRC as the state's second most SBIR-productive area.[59]

At LaRC, SBIR Phase I activity includes evaluation of infusion/commercialization opportunities in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunities. With LaRC's emphasis on aeronautics and engineering technologies, and atmospheric science, NASA mission directorate program offices do not appear to be solicited for participation in SBIR topic and subtopic

[59]Hampton Roads Market Alliance, *Hampton Roads: The Advanced Technology Center* (presentation), 2004.

development as frequently as with other field Centers. STTR topic development is influenced by LaRC's Center for Excellence for Structures and Materials.

The LaRC SBIR Program Office markets its resources to small business SBIR candidates at state SBIR events, its own annual "Research Development and Technology Conference" (in collaboration with Virginia's Center for Innovative Technologies), and periodic small business mentoring events. Beginning in 2004, the LaRC SBIR Program Office leveraged its ties with regional technology partners noted above, co-producing SBIR events in July and September, 2004. These two events launched the LaRC SBIR PO's *Technology Partnership Initiative*.

The "Northrop Grumman SBIR Technology Transition Conference" on 28 July, 2004, introduced a pool of 30 SBIR Phase II awardees from the NASA LaRC, Navy SBIR, and Department of Energy SBIR programs to Northrop Grumman shipyard engineers through the yard's VASCIC Technology Development Center. SBIRs were preselected according to their congruity with shipyard technology needs in 11 technology areas (e.g., data control, sensors and monitoring, power systems, etc.) for the Navy's *Virginia*-class submarine and CVN-21 aircraft carrier.

The College of William & Mary's follow-on "SBIR Mentoring Day" on September 1, 2004, gave five firms from the same SBIR Phase II pool the opportunity to present their business cases to an experienced group of technology investors, for identification and analysis of risk factors. LaRC SBIR Program Office plans to continue the *Technology Partnership Initiative* at other corporate venues.

LaRC SBIR Program Office does not appear to make available information on its Phase II projects regarding Phase III activity. However, according to the NASA EHB Web site, there have been 29 Phase III contracts over the years at Langley. As regards the *Technology Partnership Initiative*, according to Northrop Grumman Newport News sources, in December, 2004 the shipyard was pursuing discussions about further collaboration with six of the SBIR projects that presented at the July, 2004 conference. No further updates are available. Scrutiny of the NASA LaRC Web site does not reveal "Success Stories" or other awards accruing to LaRC SBIR awardees.

For LaRCs SBIR PO, the principal venue for evaluation is the semi-annual meeting of SBIR Level 1 and 2 personnel with all ten NASA field center SBIR program managers. Infusion/commercialization issues can be both formally and informally discussed among the NASA SBIR peer community at these events. No other information is available about evaluation of the LaRC SBIR program or its *Technology Partnership Initiative*.

5.17 MARSHALL SPACE FLIGHT CENTER (MSFC)—HUNTSVILLE, AL

MSFC SBIR practice observes the basic NASA field center formula. SBIR Phase I activity includes evaluation of infusion/commercialization opportunities in the Phase I proposal technical review process. Phase II proposal evaluation also includes a formal outside peer review of infusion/commercialization opportunities, as well as internal data on the alignment of candidate SBIR technologies with ESMD and/or SMD directorate needs.

At MSFC, however, these needs are expressed by MSFC's Chief Technologist and the Center Technology Council, from subtopic development prior to Phase I onwards. The SBIR proposal review Ranking Committee's Phase I recommendations are pushed back up to the Center Technology Council, which then assigns project Technical Monitors from appropriate program offices—or, in some cases, research labs. Infusion opportunity is anticipated by this direct interface in SBIR Phases I and II between the SBIR firm and an appropriate program office. Subtopic managers continue to play a role in SBIR work through the Phase II review process.

Phase III activity is tracked somewhat formally at MSFC using a six-column Excel template. The center's current tracking file cites 200 Phase IIIs (from approximately 300 SBIR Phase II projects since 1989) which have a non-SBIR revenue aggregate of $117,531,532.[60] Another ten SBIR projects are in the process of being added to this list, for an added $10,494,000. "Although we are staff and budget constrained," says MSFC PM Lynn Garrison, ". . . we have learned to rely on procurement records—in addition to direct follow-up with SBIR awardees—as an accurate and comprehensive way of getting Phase III data we otherwise might miss. This was an MSFC decision, that the SBIR Program Office needed expert support to accurately track infusion/commercialization success."[61] Among the ten NASA field centers, MSFC approach to recording Phase III results is unique.

Like other field Centers, MSFC evaluates its SBIR infusion/commercialization practices informally, and it participates in discussions at the semi-annual meetings of field center SBIR PMs with NASA SBIR Level 1 and 2 staff. In addition, MSFC SBIR Program Office has used strategic shifts at the agency-wide level—such as the recent merger of SBIR activity with ESMD—as an opportunity to reevaluate core practices. The recent decision to align center SBIR work through MSFC's Chief Technologist and the Center Technology Council, instead of directorate POCs, is one such reform, as is the decision to track Phase III occurrences through procurement sources.

5.18 STENNIS SPACE CENTER (SSC)—MISSISSIPPI

SCC's primary role is that of a test facility, and it averages six or fewer SBIR Phase II projects annually. Apart from observing the basic SBIR topic development and proposal review process, no special emphasis is placed on infusion/commercialization opportunity in the SSC SBIR program.

[60]According to the NASA EHB Web site, Marshall has had 113 (the largest by far of any of the 10 centers) Phase III contracts over the years.

[61]Interview with Lynn Garrison, February 28, 2005.

SSC has recorded four instances of Phase III infusion/commercialization. Although SBIR PM Jim Bryant believes that at least two of these four SBIR technologies has achieved multiple Phase IIIs, no detailed tracking data is available. According to the NASA EHB Web site, SCC has had eight Phase III contracts over the years.

Appendixes

Appendix A

NASA SBIR Program Data

TABLE App-A-1 Phase I Applications, 1997-2005

Program Year	Number of Proposals	Average Amount of Application ($)
1997	2,577	69,898.37
1998	2,438	69,933.18
1999	2,265	70,042.89
2000	1,836	70,150.21
2001	1,660	74,083.28
2002	2,241	69,961.88
2003	2,695	69,978.53
2004	2,127	69,585.42
2005	2,172	69,592.73

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-2 Phase I Awards, 1983-2005

Program Year	Number of Awards	Average Award Size ($)
1983	102	48,776.49
1984	127	49,267.02
1985	150	49,489.08
1986	172	49,343.22
1987	204	48,992.75
1988	228	49,224.90
1989	249	49,219.71
1990	280	49,456.59
1991	301	49,361.17
1992	346	49,473.62
1993	384	86,468.80
1994	413	69,014.55
1995	309	69,206.82
1996	349	69,186.33
1997	339	69,227.41
1998	344	69,526.44
1999	290	70,334.99
2000	287	70,960.91
2001	307	92,079.00
2002	267	69,680.05
2003	312	69,814.51
2004	291	69,627.99
2005	297	69,621.99

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-3 Phase I Success Rates, 1997-2005

Program Year	Number of Applications	Number of Awards	Success Rate (%)
1997	2,577	339	13.2
1998	2,438	344	14.1
1999	2,265	290	12.8
2000	1,836	287	15.6
2001	1,660	307	18.5
2002	2,241	267	11.9
2003	2,695	312	11.6
2004	2,127	291	13.7
2005	2,172	297	13.7

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-4 First-time Applicants to NASA SBIR Program, 1997-2005

Program Year	Number of First-time Applicants
1997	355
1998	324
1999	285
2000	259
2001	232
2002	499
2003	962
2004	465
2005	497

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-5 Phase I Applications by State, 1992-2005

State	Number of Phase I Applications	Number of Phase I Awards	Success Rate (%)	State	Number of Phase I Applications	Number of Phase I Awards	Success Rate (%)
MS	69	13	18.8	MD	1,074	141	13.1
AR	54	10	18.5	KY	16	2	12.5
VT	39	7	17.9	NY	571	69	12.1
NH	234	41	17.5	TX	1,062	128	12.1
WY	29	5	17.2	DE	86	10	11.6
MT	123	21	17.1	MN	246	28	11.4
CO	1,123	188	16.7	FL	659	73	11.1
LA	30	5	16.7	MI	380	42	11.1
WA	306	51	16.7	WV	37	4	10.8
AL	694	111	16.0	AZ	704	75	10.7
NM	402	64	15.9	ID	67	7	10.4
OR	259	41	15.8	HI	44	4	9.1
IA	38	6	15.8	GA	208	18	8.7
MA	2,395	376	15.7	NV	72	6	8.3
WI	320	50	15.6	IL	279	23	8.2
PA	426	66	15.5	KS	56	4	7.1
UT	155	23	14.8	ME	29	2	6.9
CT	334	49	14.7	DC	36	2	5.6
OH	744	106	14.2	SC	36	2	5.6
NJ	503	71	14.1	OK	49	1	2.0
				AK	13		0.0
MO	66	9	13.6	ND	4		0.0
IN	126	17	13.5	NE	4		0.0
VA	1,196	159	13.3	PR	2		0.0
TN	204	27	13.2	RI	19		0.0
NC	91	12	13.2	SD	10		0.0
CA	4,285	565	13.2	VI	2		0.0
				ALL	20,010	2,734	13.7

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-6 Phase I Applications by Demographic Group, 1997-2005

Program Year	Number of Applications					
	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	2,577	285	456	74	667	1,910
1998	2,438	306	467	83	690	1,748
1999	2,265	277	374	65	586	1,679
2000	1,836	219	295	38	476	1,360
2001	1,660	236	259	53	442	1,218
2002	2,241	269	363	52	580	1,661
2003	2,695	350	457	58	749	1,946
2004	2,127	260	360	64	556	1,571
2005	2,172	281	350	60	571	1,601

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-7 Phase I Applications by Demographic Group as a Percentage of All Applications, 1997-2005

Program Year	Percent of All Phase I Applications					
	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	100.0	11.1	17.7	2.9	25.9	74.1
1998	100.0	12.6	19.2	3.4	28.3	71.7
1999	100.0	12.2	16.5	2.9	25.9	74.1
2000	100.0	11.9	16.1	2.1	25.9	74.1
2001	100.0	14.2	15.6	3.2	26.6	73.4
2002	100.0	12.0	16.2	2.3	25.9	74.1
2003	100.0	13.0	17.0	2.2	27.8	72.2
2004	100.0	12.2	16.9	3.0	26.1	73.9
2005	100.0	12.9	16.1	2.8	26.3	73.7

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-8 Phase I Awards by Demographic Group, 1992-2005

Program Year	Number of Awards: All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1992	346	25	52	12	65	281
1993	384	31	61	6	86	297
1994	413	45	58	6	97	312
1995	309	29	47	12	64	240
1996	349	38	50	12	76	272
1997	339	25	48	6	67	272
1998	344	39	52	10	81	263
1999	290	32	41	9	64	222
2000	287	30	32	2	60	227
2001	307	27	35	5	57	250
2002	267	29	34	5	58	209
2003	312	27	44	6	65	247
2004	291	25	38	5	58	233
2005	297	36	40	4	72	225

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-9 Phase I Awards by Demographic Group as a Percentage of All Phase I Awards, 1992-2005

Program Year	Percent of All Phase I Awards: All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1992	100.0	7.2	15.0	3.5	18.8	81.2
1993	100.0	8.1	15.9	1.6	22.4	77.3
1994	100.0	10.9	14.0	1.5	23.5	75.5
1995	100.0	9.4	15.2	3.9	20.7	77.7
1996	100.0	10.9	14.3	3.4	21.8	77.9
1997	100.0	7.4	14.2	1.8	19.8	80.2
1998	100.0	11.3	15.1	2.9	23.5	76.5
1999	100.0	11.0	14.1	3.1	22.1	76.6
2000	100.0	10.5	11.1	0.7	20.9	79.1
2001	100.0	8.8	11.4	1.6	18.6	81.4
2002	100.0	10.9	12.7	1.9	21.7	78.3
2003	100.0	8.7	14.1	1.9	20.8	79.2
2004	100.0	8.6	13.1	1.7	19.9	80.1
2005	100.0	12.1	13.5	1.3	24.2	75.8

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-10 Phase I Success Rates by Demographic Group, 1997-2005

	Success Rate (%)					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	13.2	8.8	10.5	8.1	10.0	14.2
1998	14.1	12.7	11.1	12.0	11.7	15.0
1999	12.8	11.6	11.0	13.8	10.9	13.2
2000	15.6	13.7	10.8	5.3	12.6	16.7
2001	18.5	11.4	13.5	9.4	12.9	20.5
2002	11.9	10.8	9.4	9.6	10.0	12.6
2003	11.6	7.7	9.6	10.3	8.7	12.7
2004	13.7	9.6	10.6	7.8	10.4	14.8
2005	13.7	12.8	11.4	6.7	12.6	14.1

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-11 Phase I Awards by Company, Top 20 Firms, 1997-2005

Company Name	Number of Phase I Awards
Orbital Technologies Corporation	40
Intelligent Automation, Inc.	37
Physical Optics Corporation	32
Creare, Inc.	31
Foster-Miller, Inc.	29
Lynntech, Inc.	27
Physical Sciences, Inc.	26
Pioneer Astronautics	25
Los Gatos Research	20
American GNC Corporation	19
Luna Innovations, Inc.	19
TDA Research, Inc.	19
MER Corporation	18
Umpqua Research Company	18
Southwest Sciences, Inc.	17
Ultramet	15
Stottler Henke Associates, Inc.	15
Eltron Research, Inc.	15
Triton Systems, Inc.	15
Continuum Dynamics, Inc.	15
Total (Top 20 Winners)	452
Percent of all Phase I Awards	16.5

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-12 Phase II Awards, Number and Average Size, 1983-2001; 2003-2004

Program Year	Number of Phase II Awards	Average Award Size ($)
1983	58	414,277
1984	71	457,534
1985	84	470,125
1986	86	466,097
1987	98	475,084
1988	112	472,915
1989	122	501,477
1990	138	487,701
1991	151	508,848
1992	171	491,135
1993	194	575,104
1994	157	593,210
1995	183	586,886
1996	102	592,271
1997	125	595,877
1998	130	607,084
1999	139	599,072
2000	139	596,119
2001	146	596,804
2002	155	
2003	142	597,287
2004	141	498,754

NOTE: 2002 average award size unavailable.
SOURCE: National Aeronautics and Space Administration.

TABLE App-A-13 Phase II Applications by Demographic Group, 1997-2005

	Number of Applications					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	330	25	49	6	74	256
1998	345	39	52	10	81	264
1999	290	32	41	9	64	226
2000	259	27	30	2	55	204
2001	291	27	31	3	55	236
2002	251	26	35	5	57	194
2003	298	29	47	7	69	229
2004	273	30	36	6	60	213
2005	280	36	35	3	68	212

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-14 Phase II Applications by Demographic Group as a Percentage of All Phase II Applications, 1997-2005

	Percent of All Phase II Applications					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	100.0	7.6	14.8	1.8	22.4	77.6
1998	100.0	11.3	15.1	2.9	23.5	76.5
1999	100.0	11.0	14.1	3.1	22.1	77.9
2000	100.0	10.4	11.6	0.8	21.2	78.8
2001	100.0	9.3	10.7	1.0	18.9	81.1
2002	100.0	10.4	13.9	2.0	22.7	77.3
2003	100.0	9.7	15.8	2.3	23.2	76.8
2004	100.0	11.0	13.2	2.2	22.0	78.0
2005	100.0	12.9	12.5	1.1	24.3	75.7

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-15 Phase II Awards by Demographic Group, 1997-2004

	Number of Awards					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	125	9	16	2	23	102
1998	130	20	16	5	31	99
1999	139	17	12	1	28	111
2000	139	11	19	2	28	111
2001	146	16	16	3	29	117
2002	155	13	19	4	28	127
2003	142	13	20	3	30	112
2004	141	12	18	1	29	112

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-16 Phase II Awards by Demographic Group as a Percentage of All Phase II Awards, 1997-2004

	Percent of All Phase II Awards					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	100.0	7.2	12.8	1.6	18.4	81.6
1998	100.0	15.4	12.3	3.8	23.8	76.2
1999	100.0	12.2	8.6	0.7	20.1	79.9
2000	100.0	7.9	13.7	1.4	20.1	79.9
2001	100.0	11.0	11.0	2.1	19.9	80.1
2002	100.0	8.4	12.3	2.6	18.1	81.9
2003	100.0	9.2	14.1	2.1	21.1	78.9
2004	100.0	8.5	12.8	0.7	20.6	79.4

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-17 Phase II Success Rates by Demographic Group, 1997-2004

	Success Rate (%)					
Program Year	All Firms	Woman-owned Firms	Minority-owned Firms	Both Woman- and Minority-owned	Firm Either Woman- or Minority-owned	Firm Neither Woman- nor Minority-owned
1997	37.9	36.0	32.7	33.3	31.1	39.8
1998	37.7	51.3	30.8	50.0	38.3	37.5
1999	47.9	53.1	29.3	11.1	43.8	49.1
2000	53.7	40.7	63.3	100.0	50.9	54.4
2001	50.2	59.3	51.6	100.0	52.7	49.6
2002	61.8	50.0	54.3	80.0	49.1	65.5
2003	47.7	44.8	42.6	42.9	43.5	48.9
2004	51.6	40.0	50.0	16.7	48.3	52.6

SOURCE: National Aeronautics and Space Administration.

TABLE App-A-18 Phase II Conversion Rates

	Number of Phase I Awards, 1997-2005	Number of Phase II Awards, 1997-2004	Conversion Rate (%)		Number of Phase I Awards, 1997-2005	Number of Phase II Awards, 1997-2004	Conversion Rate (%)
AL	111	45	40.5	ND			NA
AR	10	4	40.0	NE			NA
AZ	75	28	37.3	NH	41	24	58.5
CA	565	237	41.9	NJ	71	30	42.3
CO	188	78	41.5	NM	64	28	43.8
CT	49	24	49.0	NV	6	2	33.3
DC	2		0.0	NY	69	24	34.8
DE	10	3	30.0	OH	106	34	32.1
FL	73	26	35.6	OK	1	1	100.0
GA	18	4	22.2	OR	41	18	43.9
HI	4	3	75.0	PA	66	29	43.9
IA	6	4	66.7	PR			NA
ID	7	3	42.9	RI			NA
IL	23	9	39.1	SC	2		0.0
IN	17	8	47.1	SD			NA
KS	4	3	75.0	TN	27	10	37.0
KY	2	1	50.0	TX	128	50	39.1
LA	5	2	40.0	UT	23	9	39.1
MA	376	150	39.9	VA	159	65	40.9
MD	141	58	41.1	VI			NA
ME	2	1	50.0	VT	7	5	71.4
MI	42	15	35.7	WA	51	24	47.1
MN	28	10	35.7	WI	50	20	40.0
MO	9	3	33.3	WV	4	3	75.0
MS	13	6	46.2	WY	5	3	60.0
MT	21	11	52.4		1,813	738	40.7
NC	12	2	16.7				

NOTE: NA denotes "not applicable."
SOURCE: National Aeronautics and Space Administration.

TABLE App-A-19 Phase II Awards by Company, Top 20 Firms, 1997-2004

Company Name	Number of Phase II Awards
Creare, Inc.	36
Orbital Technologies Corporation	26
Foster-Miller, Inc.	23
Physical Optics Corporation	21
Lynntech, Inc.	21
Intelligent Automation, Inc.	21
Ultramet	19
Physical Sciences, Inc.	18
Triton Systems, Inc.	15
CFD Research Corp	14
TDA Research, Inc.	14
Materials & Electrochemical Research	12
Stottler Henke Associates, Inc.	12
Coherent Technologies, Inc.	12
Nielsen Engineering & Research, Inc.	11
Umpqua Research Company	11
Composite Optics, Incorporated	11
Accurate Automation Corporation	10
Los Gatos Research	10
Eltron Research, Inc.	10
Total (Top 20)	327
Percent of all NASA Phase II Awards	17.0
Total Number of Firms with Phase Awards	903
Total Number of Phase II Awards (all firms)	1,924

SOURCE: National Aeronautics and Space Administration.

Appendix B

NRC Phase II Survey and NRC Firm Survey

The first section of this appendix describes the methodology used to survey Phase II SBIR awards (also referred to as projects). The second part presents the results—first of the awards, or project, survey (NRC Phase II Survey), and then of the NRC Firm Survey. (Appendix C presents the NRC Phase I Survey.)

ABOUT THE SURVEYS

Starting Date and Coverage

The survey of SBIR Phase II awards was administered in 2005, and included awards made through 2001. This allowed most of the Phase II awarded projects (nominally two years) to be completed, and provided some time for commercialization. The selection of the end date of 2001 was consistent with a GAO study, which in 1991, surveyed awards made through 1987.

A start date of 1992 was selected. The year 1992 for the earliest Phase II project was considered a realistic starting date for the coverage, allowing inclusion of the same (1992) projects as the DoD 1996 survey, and of the 1992, and 1993 projects surveyed in 1998 for SBA. This adds to the longitudinal capacities of the study. The 10 years of Phase II coverage spanned the period of increased funding set-asides and the impact of the 1992 reauthorization. This time frame allowed for extended periods of commercialization and for a robust spectrum of economic conditions. Establishing 1992 as the cutoff date for starting the survey helped to avoid the problem that older awards suffer from several problems, including meager early data collection as well as potentially irredeemable data loss; the fact that some firms and Principal Investigators (PIs) are no longer in place; and fading memories.

Award Numbers

While adding the annual awards numbers of the five agencies would seem to define the larger sample, the process was more complicated. Agency reports usually involve some estimating and anticipation of successful negotiation of selected proposals. Agencies rarely correct reports after the fact. Setting limitations on the number of projects to be surveyed from each firm required knowing how many awards each firm had received from all five agencies. Thus the first step was to obtain all of the award databases from each agency and combine them into a single database. Defining the database was further complicated by variations in firm identification, location, phone numbers, and points of contact within individual agency databases. Ultimately we determined that 4,085 firms had been awarded 11,214 Phase II awards (an average of 2.7 Phase II awards per firm) by the five agencies during the 1992-2001 timeframe. Using the most recent awards, the firm information was updated to the most current contact information for each firm.

Sampling Approaches and Issues

The Phase II survey used an array of sampling techniques, to ensure adequate coverage of projects to address a wide range of both outcomes and potential explanatory variables, and also to address the existence of a skew in the distribution of outcomes. That is, a relatively small percentage of funded projects typically account for a large percentage of commercial impact in the field of advanced, high-risk technologies.

- **Random samples.** After integrating the 11,214 awards into a single database, a random sample of approximately 20 percent was sampled. Then a random sample of 20 percent was ensured for each year; e.g., 20 percent of the 1992 awards, of the 1993 awards, etc. Verifying the total sample one year at a time allowed improved ability to adapt to changes in the program over time, as otherwise the increased number of awards made in recent years might dominate the sample.
- **Random sample by agency.** Surveyed awards were grouped by agency; additional respondents were randomly selected as required to ensure that at least 20 percent of each agency's awards were included in the sample.
- **Firm surveys.** After the random selection, 100 percent of the Phase IIs that went to firms with only one or two awards were polled. These are the hardest firms to find for older awards. Address information is highly perishable, particu-

larly for earlier award years. For firms that had more than two awards, 20 percent were selected, but no less than two.

- **Top Performers.** The problem of skew was dealt with by ensuring that all Phase IIs known to meet a specific commercialization threshold (total of $10 million in the sum of sales plus additional investment) were surveyed (derived from the DoD commercialization database). Since fifty-six percent of all awards were in the random and firm samples described above, only ninety-five Phase IIs were added in this fashion.
- **Coding.** The project database tracks the survey sample, which corresponds with each response. For example, it is possible for a randomly sampled project from a firm that had only two awards to be a top performer. Thus, the response could be analyzed as a random sample for the program, a random sample for the awarding agency, a top performer, and as part of the sample of single or double winners. In addition, the database allows examination of the responses for the array of potential explanatory or demographic variables.
- **Total number of surveys.** The approach described above generated a sample of 6,410 projects, and 4,085 firm surveys—an average of 1.6 award surveys per firm. Each firm receiving at least one project survey also received a firm survey. Although this approach sampled more than 57 percent of the awards, multiple award winners, on average, were asked to respond to surveys covering about 20 percent of their projects.

Administration of the Survey

The questionnaire drew extensively from the one used in the 1999 National Research Council assessment of SBIR at the Department of Defense, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative*.[1] That questionnaire in turn built upon the questionnaire for the 1991 GAO SBIR study. Twenty-four of the 29 questions on the earlier NRC study were incorporated. The researchers added 24 new questions to attempt to understand both commercial and noncommercial aspects, including knowledge base impacts, of SBIR, and to gain insight into impacts of program management. Potential questions were discussed with each agency, and their input was considered. In determining questions that should be in the survey, the research team also considered which issues and questions were best examined in the case studies and other research methodologies. Many of the resultant 33 Phase II Award survey questions and 15 Firm Survey questions had multiple parts.

The surveys were administered online, using a Web server. The formatting,

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

encoding and administration of the survey was subcontracted to BRTRC, Inc. of Fairfax, VA.

There are many advantages to online surveys (including cost, speed, and possibly response rates). Response rates become clear fairly quickly, and can rapidly indicate needed follow up for nonrespondents. Hyperlinks provide amplifying information, and built-in quality checks control the internal consistency of the responses. Finally, online surveys allow dynamic branching of question sets, with some respondents answering selected subsets of questions but not others, depending on prior responses.

Prior to the survey, we recognized two significant advantages of a paper survey over an online one. For every firm (and thus every award), the agencies had provided a mailing address. Thus surveys could be addressed to the firm president or CEO at that address. That senior official could then forward the survey to the correct official within the firm for completion. For an online survey we needed to know the email address of the correct official. Also each firm needed a password to protect its answers. We had an SBIR Point of Contact (POC) and email address and password for every firm, which had submitted for a DoD SBIR 1999 survey. However, we had only limited email addresses and no passwords for the remainder of the firms. For many, the email addresses that we did have were those of Principal Investigators rather than an official of the firm. The decision to use an online survey meant that the first step of survey distribution was an outreach effort to establish contact with the firms.

Outreach by Mail

This outreach phase began with the establishing a NAS registration Web site which allowed each firm to establish a POC, email address and password. Next, the Study Director, Dr. Charles Wessner, sent a letter to those firms for which email contacts were not available. Ultimately only 150 of the 2,080[2] firms provided POC/email after receipt of this letter. Six hundred-fifty of those letters were returned by the post office as invalid addresses. Each returned letter required thorough research by calling the agency provided phone number for the firm, then using the Central Contractor Registration database, Business.com (powered by Google) and Switchboard.com to try to find correct address information. When an apparent match was found, the firm was called to verify that it was in fact the firm, which had completed the SBIR. Two hundred thirty-seven of the 650 missing firms were so located. Another ten firms were located which had gone out of business and had no POC.

Two months after the first mailing, a second letter from the Study Director went to firms whose first letter had not been returned, but which had not yet

[2]The letter was also erroneously sent to an additional 43 firms that had received only STTR awards.

registered a POC. This letter also went to 176 firms, which had a POC email, but no password, and to the 237 newly corrected addresses. The large number of letters (277) from this second mailing that were returned by the postal service, indicated that there were more bad addresses in the first mailing than indicated by its returned mail. (If the initial letter was inadvertently delivered, it may have been thrown away.) Of the 277 returned second letters, 58 firms were located using the search methodology described above. These firms were asked on the phone to go to the registration Web site to enter POC/email/password. A total of 93 firms provided POC/email/password on the registration site subsequent to the second mailing. Three additional firms were identified as out of business.

The final mailing, a week before survey, was sent to those firms that had not received either of the first two letters. It announced the study/survey and requested support of the 1,888 CEOs for which we had assumed good POC/email information from the DoD SBIR submission site. That letter asked the recipients to provide new contact information at the DoD submission site if the firm information had changed since their last submission. One hundred seventy-three of these letters were returned. We were able to find new addresses for 53 of these, and ask those firms to update their information. One hundred fifteen firms could not be found and five more were identified as out of business.

The three mailings had demonstrated that at least 1,100 (27 percent) of the mailing addresses were in error, 734 of which firms could not be found, and 18 were reported to be out of business.

Outreach by Email

We began Internet contact by emailing the 1,888 DoD Points of Contact (POCs) to verify their email and give them opportunity to identify a new POC. Four hundred ninety-four of those emails bounced. The next email went to 788 email addresses that we had received from agencies as PI emails. We asked that the PI have the correct company POC identify themselves at the NAS Update registration site. One hundred eighty-eight of these emails bounced. After more detailed search of the list used by NIH to send out their survey, we identified 83 additional PIs and sent them the PI email discussed above. Email to the POCs not on the DoD Submission site resulted in 110 more POC/email/Password being registered on the NAS registration site.

We began the survey at the end of February with an email to 100 POCs as a beta test and followed that with another email to 2,041 POCs (total of 2,141) a week later.

Survey Responses

By August 5, 2005 five months after release of the survey, 1,239 firms had begun and 1,149 firms had completed at least 14 of 15 questions on the firm

TABLE App-B-1 NRC Phase II Survey Responses by Agency, August 4, 2005

Agency	Phase II Sample Size	Awards with Good Email Addresses	Percentage of Sample Awards with Good Email Addresses	Answered Survey as of 8/04/2005	Surveys as a Percentage of Sample	Surveys as a Percentage of Awards Contacted
DoD	3,055	2,191	72	920	30	42
NIH	1,680	1,127	67	496	30	44
NASA	779	534	69	181	23	34
NSF	457	336	74	162	35	48
DoE	439	335	76	157	36	47
Total	6,408	4,523	70	1,916	30	42

survey. Project surveys were begun on 1916 Phase II awards. Of the 4,085 firms that received Phase II SBIR awards from DoD, NIH, NASA, NSF, or DoE from 1992 to 2001, an additional 7 firms were identified as out of business (total of 25) and no email addresses could be found for 893. For an additional 500 firms, the best email addresses that were found were also undeliverable. These 1,418 firms could not be contacted, thus had no opportunity to complete the surveys. Of these firms, 585 had mailing addresses known to be bad. The 1,418 firms that could not be contacted were responsible for 1,885 of the individual awards in the sample.

Using the same methodology as the GAO had used in the 1992 report of their 1991 survey of SBIR, undeliverables and out of business firms were eliminated prior to determining the response rate. Although 4,085 firms were surveyed, 1,418 firms were eliminated as described. This left 2,667 firms, of which 1,239 responded, representing a 46 percent response rate by firms,[3] which could respond. Similarly when the awards, which were won by firms in the undeliverable category, were eliminated (6,408 minus 1,885), this left 4,523 projects, of which 1,916 responded, representing a 42 percent response rate. Figure 1 displays by agency the number of Phase II awards in the sample, the number of those awards, which by having good email addresses had the opportunity to respond, and the number that responded.[4] Percentages displayed are the percentage of awards with good addresses, the percentage of the sample that responded and the responses as a percentage of awards with the opportunity to respond.

The NRC Methodology report had assumed a response rate of about 20 percent. Considering the length of the survey and its voluntary nature, the rate

[3]Firm information and response percentages are not displayed in Table App-B-1, which displays by agency, since many firms received awards from multiple agencies.

[4]The average firm size for awards, which responded, was 37 employees. Nonresponding awards came firms that averaged 38 employees. Since responding Phase II were more generally more recent than nonresponding, and awards have gradually grown in size, the difference in average award size ($655,525 for responding and $649,715 for nonresponding) seems minor.

achieved was relatively high and reflects both the interest of the participants in the SBIR program and the extensive follow-up efforts. At the same time, the possibility of response biases that could significantly affect the survey results must be recognized. For example, it may be possible that some of the firms that could not be found have been unsuccessful and folded. It may also be possible that unsuccessful firms were less likely to respond to the survey.

NRC Phase II Survey Results for NASA

NOTE: SURVEY RESPONSES APPEAR IN BOLD, AND EXPLANATORY NOTES ARE TYPEWRITER FONT.

Project Information 181 respondents answered the first question. Since respondents are directed to skip certain questions based on prior answers, the number that responded varies by question. Also some respondents did not complete their surveys. 161 completed all applicable questions. For computation of averages, such as average sales, the denominator used was 181, the number of respondents who answered the first question. Where appropriate, the basis for calculations is provided in red after the question.

PROPOSAL TITLE:
AGENCY: **NASA**
TOPIC NUMBER:
PHASE II CONTRACT/GRANT NUMBER:

Part I. Current status of the Project

1. What is the current status of the project funded by the referenced SBIR award? *Select the one best answer.* Percentages are based on the 181 respondents who answered this question.
   a. **3%** Project has not yet completed Phase II. *Go to question 21.*
   b. **29%** Efforts at this company have been discontinued. No sales or additional funding resulted from this project. *Go to question 2.*
   c. **13%** Efforts at this company have been discontinued. The project did result in sales, licensing of technology, or additional funding. *Go to question 2.*
   d. **23%** Project is continuing post Phase II technology development. *Go to question 3.*
   e. **11%** Commercialization is underway. *Go to question 3.*
   f. **22%** Products/Processes/Services are in use by target population/customer/consumers. *Go to question 3.*

2. Did the reasons for discontinuing this project include any of the following? *(PLEASE SELECT YES OR NO FOR EACH REASON AND NOTE THE ONE PRIMARY REASON)*
   72 projects were discontinued. The % below are the percent of the discontinued projects that responded with the indicated response.

	Yes	No	Primary Reason
a. Technical failure or difficulties	**18%**	**82%**	**10%**
b. Market demand too small	**57%**	**43%**	**26%**
c. Level of technical risk too high	**15%**	**85%**	**1%**
d. Not enough funding	**40%**	**51%**	**14%**
e. Company shifted priorities	**29%**	**71%**	**6%**
f. Principal investigator left	**19%**	**81%**	**6%**
g. Project goal was achieved (e.g. prototype delivered for federal agency use)	**69%**	**31%**	**17%**
h. Licensed to another company	**7%**	**93%**	**1%**
i. Product, process, or service not competitive	**17%**	**83%**	**3%**
j. Inadequate sales capability	**22%**	**78%**	**4%**
k. Other (please specify): ______________________________	**18%**	**82%**	**13%**

The next question to be answered depends on the answer to question 1. If c, go to question 3. If b, skip to question 16.

Part II. Commercialization activities and planning.

Questions 3-7 concern actual sales to date resulting from the technology developed during this project. **Sales** includes all sales of a product, process, or service, to federal or private sector customers resulting from the technology developed during this Phase II project. A sale also includes licensing, the sale of technology or rights etc.

3. Has your company and/or licensee had any actual sales of products, processes, services or other sales incorporating the technology developed during this project? *(Select all that apply.)* This question was not answered for those projects still in Phase II (3%) or for projects, which were discontinued without sales or additional funding (29%). The denominator for the percentages below is all projects that answered the survey. Only 66% of all projects, which answered the survey, could respond to this question.

    a. **14%** No sales to date, but sales are expected. *Skip to question 8.*
    b. **7%** No sales to date nor are sales expected. *Skip to question 11.*
    c. **33%** Sales of product(s)
    d. **6%** Sales of process(es)
    e. **20%** Sales of services(s)
    f. **4%** Other sales (e.g. rights to technology, licensing, etc.)

    From the combination of responses 1b, 3a and 3b, we can conclude that 36% had no sales and expect none, and that 14% had no sales but expect sales.

4. For your company and/or your licensee(s), when did the first sale occur, and what is the approximate amount of total sales resulting from the technology developed during this project? If multiple SBIR awards contributed to the ultimate commercial outcome, report only the share of total sales appropriate to this SBIR project. *(Enter the requested information for your company in the first column and, if applicable and if known, for your licensee(s) in the second column. Enter approximate dollars. If none, enter 0 (zero)).*

	Your Company	Licensee(s)
a. Year when first sale occurred.	☐☐☐☐	☐☐☐☐

43% reported a year of first sale. 56% of these first sales occurred in 2000 or later. 10% reported a licensee year of first sale. 47% of these first sales occurred in 2002 or later.

b. Total Sales Dollars of Product(s), Process(es) or Service(s) to date. (Average of 181 survey respondents)	**$471,865**	**$2,104**

Although 78 reported a year of first sale, only 74 reported sales >0. Their average sales were $1,154,156. Over half of the total sales dollars were due to 7 projects, each of which had $3,200,000 or more in sales. The highest reporting project had $15,000,000 in sales. Similarly of the 19 projects that reported a year of first licensee sale, only 3 reported actual licensee sales >0. Their average sales were $127,000. 99% of the total sales dollars was due to 1 project, which had $300,00 or more licensee sales.

c. Other Total Sales Dollars (e.g., Rights to technology, Sale of spin-off company, etc.) to date. (Average of 181 survey respondents)	**$111,607**	**$2,026**

Combining the responses for b and c, the average for each of the 181 projects that responded to the survey is thus sales of over $580,000 by the SBIR company, but only four thousand dollars in sales by licensees.

Display this box for Q 4 & 5 if project commercialization is known.

Your company reported sales information to DoD as a part of an SBIR proposal or to NAS as a result of an earlier NAS request. This information may be useful in answering the prior question or the next question. You reported as of *(date)*: DoD sales *($ amount)*, Other Federal Sales *($ amount)*, Export Sales *($ amount)*, Private Sector sales *($ amount)*, and other sales *($ amount)*.

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5. To date, approximately what percent of total sales from the technology developed during this project have gone to the following customers? *(If none enter 0 (zero). Round percentages. Answers should add to about 100%)*[5] 181 firms responded to this question as to what percent of their sales went to each agency or sector.

Domestic private sector	**35%**
Department of Defense (DoD)	**22%**
Prime contractors for DoD or NASA	**11%**
NASA	**17%**
Agency that awarded the Phase II	**—%**
Other federal agencies *(Pull down)*	**3%**
State or local governments	**0%**
Export Markets	**11%**
Other (Specify)____________	**0%**

The following questions identify the product, process, or service resulting from the project supported by the referenced SBIR award, including its use in a fielded federal system or a federal acquisition program.

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6. Is a Federal System or Acquisition Program using the technology from this Phase II?
   If yes, please provide the name of the Federal system or acquisition program that is using the technology. **6% reported use in a Federal system or acquisition program**

7. Did a commercial product result from this Phase II project? **17% reported a commercial product**

8. If you have had no sales to date resulting from the technology developed during this project, what year do you expect the first sales for your company or its licensee? Only firms that had no sales but answered that they expected sales got this question.

   28% expected sales. The year of expected first sale is ☐☐☐☐
   72% of those expecting sales expected sales to occur before 2008

9. For your company and/or your licensee, what is the approximate amount of total sales expected between now and the end of 2006 resulting from the technology developed during this project? *(If none, enter 0 (zero).)* This

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[5]Please note: If a NASA SBIR award, the Prime contractors line will state "Prime contractors for NASA." The "Agency that awarded the Phase II" will only appear if it is not DoD or NASA. The name of the actual awarding agency will appear.

question was seen by those who already had sales and those w/o sales who reported expecting sales; however, averages are computed for all who took the survey since all could have expected sales.

a. Total sales dollars of product(s), process(es) or services(s) expected between now and the end of 2006. **$293,398**
(Average of 181 projects)

b. Other Total Sales Dollars (e.g., rights to technology, sale of spin-off company, etc.) expected between now and the end of 2006. **$48,897**
(Average of 181 projects)

c. Basis of expected sales estimate. *Select all that apply.*
   a. **12%** Market research
   b. **24%** Ongoing negotiations
   c. **37%** Projection from current sales
   d. **1%** Consultant estimate
   e. **30%** Past experience
   f. **36%** Educated guess

10. How did you (or do you expect to) commercialize your SBIR award?
    a. **1%** No commercial product, process, or service was/is planned.
    b. **22%** As software
    c. **70%** As hardware (final product, component, or intermediate hardware product)
    d. **21%** As process technology
    e. **19%** As new or improved service capability
    f. **0%** As a drug
    g. **1%** As a biologic
    h. **23%** As a research tool
    i. **5%** As educational materials
    j. **7%** Other, please explain ________________________________

11. Which of the following, if any, describes the type and status of marketing activities by your company and/or your licensee for this project? *(Select one for each marketing activity).* This question answered by 114 firms, which completed Phase II and have not discontinued the project, w/o sales or additional funding.

	Marketing activity	Planned	Need Assistance	Underway	Completed	Not Needed
a.	Preparation of marketing plan	**8%**	**3%**	**22%**	**25%**	**42%**
b.	Hiring of marketing staff	**4%**	**4%**	**7%**	**20%**	**65%**
c.	Publicity/advertising	**10%**	**3%**	**21%**	**26%**	**40%**
d.	Test marketing	**6%**	**4%**	**11%**	**16%**	**63%**
e.	Market Research	**4%**	**4%**	**22%**	**31%**	**39%**
f.	Other *(Specify)*	**3%**	**3%**	**2%**	**1%**	**41%**

Part III. Other outcomes.

12. As a result of the technology developed during this project, which of the following describes your company's activities with other companies and investors? *Select all that apply.* Percentage of 114 who answered this question.

		U.S. Companies/Investors		Foreign Companies/Investors	
	Activities	Finalized Agreements	Ongoing Negotiations	Finalized Agreements	Ongoing Negotiations
a.	Licensing Agreement(s)	**6%**	**11%**	**8%**	**5%**
b.	Sale of Company	**1%**	**3%**	**0%**	**0%**
c.	Partial sale of Company	**2%**	**1%**	**0%**	**0%**
d.	Sale of technology rights	**1%**	**7%**	**1%**	**3%**
e.	Company merger	**0%**	**0%**	**0%**	**0%**
f.	Joint Venture agreement	**1%**	**4%**	**0%**	**2%**
g.	Marketing/distribution agreement(s)	**7%**	**5%**	**6%**	**2%**
h.	Manufacturing agreement(s)	**2%**	**6%**	**2%**	**0%**
i.	R&D agreement(s)	**16%**	**10%**	**4%**	**1%**
j.	Customer alliance(s)	**11%**	**9%**	**6%**	**0%**
k.	Other *Specify*____________	**3%**	**4%**	**1%**	**1%**

13. In your opinion, in the absence of this SBIR award, would your company have undertaken this project? *(Select one.)* Percentage of the 113 who answered this question.

a. **3%** Definitely yes
b. **15%** Probably yes — *If selected a or b , Go to question 14.*
c. **14%** Uncertain
d. **36%** Probably not
e. **32%** Definitely not — *If c, d or e, skip to question 16.*

14. If you had undertaken this project in the absence of SBIR, this project would have been Questions 14 and 15 were answered only by the 19% who responded that they definitely or probably would have undertaken this project in the absence of SBIR.
    a. **10%** Broader in scope
    b. **48%** Similar in scope
    c. **43%** Narrower in scope

15. In the absence of SBIR funding, (Please provide your best estimate of the impact)
    a. The start of this project would have been delayed about **an average of 19** months.
       76% of the 21 firms expected the project would have been delayed.
       62% (13 firms) expected the delay would be at least 12 months. 48% anticipated a delay of at least 24 months.
    b. The expected duration/time to completion would have been
       1) **67%** Longer
       2) **14%** The same
       3) **0%** Shorter
       19% No response
    c. In achieving similar goals and milestones, the project would be
       1) **0%** Ahead
       2) **24%** The same place
       3) **52%** Behind
       24% No response

16. Employee information. *(Enter number of employees. You may enter fractions of full time effort (e.g., 1.2 employees). Please include both part time and full time employees, and consultants, in your calculation.)*

Number of employees (if known) when Phase II proposal was submitted	**Ave = 44** **7% report 0** **25% report 1-5** **28% report 6-20** **12% report 21-50** **12% report >100**
Current number of employees	**Ave = 60** **2% report 0** **16% report 1-5** **35% report 6-20** **16% report 21-50** **22% report >100**

Number of current employees <u>who were hired</u> as a result of the technology developed during this Phase II project.	**Ave = 1.3** **56% report 0** **41% report 1-5** **3% report 6-20** **1% report >20**
Number of current employees <u>who were retained</u> as a result of the technology developed during this Phase II project.	**Ave = 1.4** **52% report 0** **37% report 1-5** **4% report 6-20** **1% report >20**

17. The Principal Investigator for this Phase II Award was a (check all that apply)
    a. **6%** Woman
    b. **7%** Minority
    c. **88%** Neither a woman or minority

18. Please give the number of patents, copyrights, trademarks and/or scientific publications for the technology developed as a result of this project. *(Enter numbers. If none, enter 0 (zero).)* Results are for 161 respondents to this question.

Number Applied For/ Submitted		Number Received/ Published
52	Patents	**42**
9	Copyrights	**7**
12	Trademarks	**12**
225	Scientific Publications	**220**

<u>Part IV. Other SBIR funding</u>

19. How many SBIR awards did your company receive prior to the Phase I that led to this Phase II?
    a. Number of previous Phase I awards. **Average of 38. 26% had no prior Phase I and another 40% had 5 or less prior Phase I**
    b. Number of previous Phase II awards. **Average of 14. 42% had no prior Phase II and another 34% had 5 or less prior Phase II**

20. How many SBIR awards has your company received that are related to the project/technology supported by this Phase II award ?
    a. Number of related Phase I awards. **Average of one award. 52% had no prior related Phase I and another 43% had 5 or less prior related Phase I.**
    b. Number of related Phase II awards **Average of one award. 65% had no prior related Phase II and another 35% had 5 or less prior related Phase II.**

Part V. Funding and other assistance.

21. Prior to this SBIR Phase II award, did your company receive funds for research or development of the technology in this project from any of the following sources? Of 153 respondents.
    a. **22%** Prior SBIR *(Excluding the Phase I, which proceeded this Phase II.)*
    b. **10%** Prior non-SBIR federal R&D
    c. **1%** Venture Capital
    d. **10%** Other private company
    e. **3%** Private investor
    f. **28%** Internal company investment (including borrowed money)
    g. **1%** State or local government
    h. **1%** College or University
    i. **4%** Other *Specify* __________

Commercialization of the results of an SBIR project normally requires additional developmental funding. Questions 22 and 23 address additional funding. Additional Developmental Funds include non-SBIR funds from federal or private sector sources, or from your own company, used for further development and/or commercialization of the technology developed during this Phase II project.

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22. Have you received or invested any additional developmental funding in this project?
    a. **44%** Yes *Continue.*
    b. **56%** No *Skip to question 24.*

23. To date, what has been the total additional developmental funding for the technology developed during this project? Any entries in the **Reported** column are based on information previously reported by your firm to DoD or NAS. They are provided to assist you in completing the **Developmental funding** column. Previously reported information did not include investment by your company or personal investment. *Please update this information to include breaking out Private investment and Other investment by subcategory. Enter dollars provided by each of the listed sources. If none, enter 0*

(zero).) The dollars shown are determined by dividing the total funding in that category by the 181 respondents who started the survey to determine an average funding. Only 72 of these respondents reported any additional funding.

Source	Reported	Developmental Funding
a. Non-SBIR federal funds	$_ _, _ _ _, _ _ _	**$133,829**
b. Private Investment	$_ _, _ _ _, _ _ _	
(1) U.S. venture capital		**$0**
(2) Foreign investment		**$1,381**
(3) Other Private equity		**$3,825**
(4) Other domestic private company		**$24,150**
c. Other sources	$_ _, _ _ _, _ _ _	
(1) State or local governments		**$13,812**
(2) College or Universities		**$966**
d. Not previously reported		
(1) Your own company (Including money you have borrowed)		**$100,450**
(2) Personal funds		**$3,121**

Total average additional developmental funding, all sources, per award **$281,534**

24. Did this award identify matching funds or other types of cost sharing in the Phase II Proposal?[6]
   a. **87%** No matching funds/co-investment/cost sharing were identified in the proposal. *If a, skip to question 26.*
   b. **13%** Although not a DoD Fast Track, matching funds/co-investment/cost sharing were identified in the proposal.
   c. **0%** Yes. This was a DoD Fast Track proposal.

25. Regarding sources of matching or co-investment funding that were proposed for Phase II, check all that apply. The percentages below are computed for those 21 projects, which reported matching funds.
   a. **52%** Our own company provided funding (includes borrowed funds)
   b. **0%** A federal agency provided non-SBIR funds
   c. **52%** Another company provided funding
   d. **10%** An angel or other private investment source provided funding
   e. **29%** Venture Capital provided funding

[6] The words underlined appear only for DoD awards.

26. Did you experience a gap between the end of Phase I and the start of Phase II?
    a. **67%** Yes. *Continue.*
    b. **33%** No. *Skip to question 29.*
    The average gap reported by 109 respondents was 6 months. 3% of the respondents reported a gap of one or more years.

27. Project history. Please fill in for all dates that have occurred. This information is meaningless in aggregate. It has to be examined project by project in conjunction with the date of the phase I end and the date of the Phase II award to calculate the gaps.
    Date Phase I ended *Month/year* | | | | |
    Date Phase II proposal submitted *Month/year* | | | | |

28. If you experienced funding gap between Phase I and Phase II for this award, *select all answers that apply*
    a. **75%** Stopped work on this project during funding gap.
    b. **19%** Continued work at reduced pace during funding gap.
    c. **4%** Continued work at pace equal to or greater than Phase I pace during funding gap.
    d. **2%** Received bridge funding between Phase I and II.
    e. **1%** Company ceased all operations during funding gap

29. Did you receive assistance in Phase I or Phase II proposal preparation for this award? Of 161 respondents.
    a. **1%** State agency provided assistance
    b. **1%** Mentor company provided assistance
    c. **0%** Regional association provided assistance
    d. **6%** University provided assistance
    e. **93%** We received no assistance in proposal preparation
    Was this assistance useful?
    a. **45%** Very Useful
    b. **55%** Somewhat Useful
    c. **0%** Not Useful

30. In executing this award, was there any involvement by universities faculty, graduate students, and/or university developed technologies? Of 161 respondents.
    29% Yes
    71% No

31. This question addresses any relationships between your firm's efforts on this

Phase II project and any University (ies) or College (s). The percentages are computed against the 161 who answered question 30, not just those who answered yes to question 30. ***Select all that apply.***

a. **2%** The Principal Investigator (PI) for this Phase II project was at the time of the project a faculty member.
b. **1%** The Principal Investigator (PI) for this Phase II project was at the time of the project an adjunct faculty member.
c. **17%** Faculty member(s) or adjunct faculty member(s) work on this Phase II project in a role other than PI, e.g., consultant.
d. **15%** Graduate students worked on this Phase II project.
e. **13%** University/College facilities and/or equipment were used on this Phase II project.
f. **2%** The technology for this project was licensed from a University or College.
g. **4%** The technology for this project was originally developed at a University or College by one of the percipients in this Phase II project.
h. **16%** A University or College was a subcontractor on this Phase II project.

In remarks enter the name of the University or College that is referred to in any blocks that are checked above. If more than one institution is referred to, briefly indicate the name and role of each.

32. Did commercialization of the results of your SBIR award require FDA approval? **Yes 1%**

In what stage of the approval process are you for commercializing this SBIR award?

a. **0%** Applied for approval
b. **0%** Review ongoing
c. **1.1%** Approved
d. **0%** Not Approved
e. **0%** IND: Clinical trials
f. **0%** Other

NRC Firm Survey Results

NOTE: ALL RESULTS APPEAR IN BOLD. RESULTS ARE REPORTED FOR ALL 5 AGENCIES (DoD, NIH, NSF, DoE, AND NASA).

1,239 firms began the survey. 1,149 completed through question 14. 1,108 completed all questions.

If your firm is registered in the DoD SBIR/STTR Submission Web site, the information filled in below is based on your latest update as of September 2004 on that site. Since you may have entered this information many months ago, you may edit this information to make it correct. In conjunction with that information, the following additional information will help us understand how the SBIR program is contributing to the formation of new small businesses active in federal R&D and how they impact the economy. Questions A-G are autofilled from Firm database, when available.

A. Company Name: ____________________
B. Street Address: ____________________
C. City: ____________________ State: ____ Zip: __________
D. Company Point of Contact: ____________________
E. Company Point of Contact Email: ____________________
F. Company Point of Contact Phone: (___) ___ - ____ Ext: __________
G. The year your company was founded: ____________

1. Was your company founded because of the SBIR Program?
   a. **79%** No
   b. **8%** Yes
   c. **13%** Yes, In part

2. Information on company founders. *Please enter zeros or the correct number in each pair of blocks.*
   a. Number of founders. [ ][ ]
      5% unknown
      40% 1
      30% 2
      13% 3
      8% 4
      2% 5
      2% >5
      Average = 2 founders/firm

b. Number of other companies started by one or more of the founders.

5% unknown
46% started no other firms
23% started 1 other firm
13% started 2 other firms
7% started 3 other firms
3% started 4 other firms
3% started 5 or more other firms
Average number of other firms founded is one.

c. Number of founders who have a business background.

5% Unknown
50% No founder known to have business background
30% One founder with business background
14% More than one founder with business background

d. Number of founders who have an academic background

5% Unknown
29% No founder known to have academic background
38% One founder with academic background
28% More than one founder with academic background

3. What was the most recent employment of the company founders prior to founding this company? *Select all that apply.* **Total >100% since many companies had more than one founder.**

a. **65%** Other private company
b. **36%** College or University
c. **9%** Government
d. **10%** Other

4. How many SBIR and/or STTR awards has your firm received from the federal government?

a. Phase I: __________ **Average number of Phase I reported was 14.**

13% **1 Phase I**
34% **2 to 5 Phase I**
24% **6 to 10 Phase I**
14% **11 to 20 Phase I**
11% **21 to 50 Phase I**
3% **51 to 100 Phase I**
2% **>100 Phase I** **Five firms reported >300 Phase I**

What year did you receive your first Phase I Award? ________
3% **reported 1983 or sooner.**
33% **reported 1984 to 1992.**
40% **reported 1993 to 1997.**
24% **reported 1998 or later.**

b. Phase II: ________ **Average number of Phase II reported was 7**
27% **1 Phase II**
44% **2 to 5 Phase II**
15% **6 to 10 Phase II**
8% **11 to 20 Phase II**
5% **21 to 50 Phase II**
1% **>50 Phase II** **Four firms reported >100 Phase II**

What year did you receive your first Phase II Award? ________
3% **reported 1983 or sooner.**
22% **reported 1984 to 1992.**
35% **reported 1993 to 1997.**
41% **reported 1998 or later.**

5. What percentage of your company's growth would you attribute to the SBIR program after receiving its first SBIR award?
a. **31%** Less than 25%
b. **25%** 25% to 50%
c. **20%** 51% to 75%
d. **24%** More than 75%

6. Number of company employees (including all affiliates):
a. At the time of your company's first Phase II Award: ____
56% **5 or less**
28% **6 to 20**
9% **21 to 50**
8% **> 50** **Fourteen firms (1.3%(had greater than 200 employees at time of first Phase II.**

b. Currently: _______
29% **5 or less**
37% **6 to 20**
17% **21 to 50**
13% **51 to 200**
5% **> 200** **Eleven firms report over 500 current employees.**

7. What Percentage of your Total R&D Effort (Man-hours of Scientists and Engineers) was devoted to SBIR activities during the most recent fiscal year?___%
   22% **0% of R&D was SBIR during most recent fiscal year.**
   16% **1% to 10% of R&D was SBIR during most recent fiscal year.**
   11% **11% to 25% of R&D was SBIR during most recent fiscal year.**
   18% **26% to 50% of R&D was SBIR during most recent fiscal year.**
   14% **51% to 75% of R&D was SBIR during most recent fiscal year.**
   19% **>75% of R&D was SBIR during most recent fiscal year.**

8. What was your company's total revenue for the last fiscal year?
   a. **10%** <$100,000
   b. **18%** $100,000 - $499,999
   c. **16%** $500,000 - $999,999
   d. **33%** $1,000,000 - $4,999,999
   e. **14%** $5,000,000 - $19,999,999
   f. **6%** $20,000,000 - $99,999,999
   g. **1%** $100,000,000 +
   h. **0.4%** Proprietary information

9. What percentage of your company's revenues during its last fiscal year is federal SBIR and/or STTR funding (Phase I and/or Phase II)? ____________
   30% **0% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   17% **1% to 10% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   11% **11% to 25% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   13% **26% to 50% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   13% **51% to 75% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   13% **76% to 99% of revenue was SBIR (Phase I or II) during most recent fiscal year.**
   4% **100% of revenue was SBIR (Phase I or II) during most recent fiscal year.**

10. **This question eliminated from the survey as redundant.**

11. Which, if any, of the following has your company experienced as a result of the SBIR Program? *Select all that apply.*

    a. **Fifteen** firms made an initial public stock offering in calendar year
    Seven reported prior to 2000; two in 2000; four in 2004; and one in both 2006 and 2007

    b. **Six** planned an initial public stock offering for 2005/2006.

    c. **14%** Established one or more spin-off companies.

    How many spin-off companies?
    242 Spin-off companies were formed.

    d. **84%** reported None of the above.

12. How many patents have resulted, at least in part, from your company's SBIR and/or STTR awards?
    43% reported no patents resulting from SBIR/STTR.
    16% reported one patent resulting from SBIR/STTR.
    27% reported 2 to 5 patents resulting from SBIR/STTR.
    13% reported 6 to 25 patents resulting from SBIR/STTR.
    1% reported >25 patents resulting from SBIR/STTR.

A total of over 3,350 patents were reported; an average of almost 3 per firm.

The remaining questions address how market analysis and sales of the commercial results of SBIR are accomplished at your company.

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13. This company normally first determines the potential commercial market for an SBIR product, process or service
    a. **66%** Prior to submitting the Phase I proposal
    b. **21%** Prior to submitting the Phase II proposal
    c. **9%** During Phase II
    d. **3%** After Phase II

14. Market research/analysis at this company is accomplished by: *(Select all that apply.)*
    a. **28%** The Director of Marketing or similar corporate position

b. **7%** One or more employees as their primary job
c. **41%** One or more employees as an additional duty
d. **23%** Consultants
e. **53%** The Principal Investigator
f. **67%** The company President or CEO
g. **1%** None of the Above

15. Sales of the product(s), process(es) or service(s) that result from commercialising an SBIR award at this company are accomplished by: *Select all that apply.*
a. **35%** An in-house sales force
b. **52%** Corporate officers
c. **30%** Other employees
d. **30%** Independent distributors or other company(ies) with which we have marketing alliances
e. **26%** Other company(ies), which incorporate our product into their own
f. **9%** Spin-off company(ies)
g. **26%** Licensing to another company
h. **11%** None of the Above

Appendix C

NRC Phase I Survey

SURVEY DESCRIPTION

This section describes a survey of Phase I SBIR awards over the period 1992-2001. The intent of the survey was to obtain information on those which did not proceed to Phase II, although most of the firms that did receive a Phase II were also surveyed.

Over that period the five agencies (DoD, DoE, NIH, NASA, and NSF) made 27,978 Phase I awards. Of the total number for the five agencies, 7,940 Phase I awards could be linked to one of the 11,214 Phase II awards made from 1992-2001. To avoid putting an unreasonable burden on the firms that had many awards, we identified all firms that had over 10 Phase I awards that apparently had not received a Phase II. For those firms, we did not survey any Phase I awards that also received a Phase II. This meant that 1,679 Phase Is were not surveyed.

We chose to survey the Principal Investigator (PI) rather than the firm to reduce the number of surveys that any one person would have to complete. In addition, if the Phase I did not result in a Phase II, the PI was more likely to have a better memory of it than firm officials. There were no PI email addresses for 5,030 Phase I awardees. This reduced the number of surveys sent since the survey was conducted by email.

Thus there were 21,269 surveys (27,978 – 1,679 – 5,030 = 21,269) emailed to 9,184 PIs). Many PIs had received multiple Phase I awards. Of these surveys, 6,770 were undeliverable. This left possible responses of 14,499. Of these, there were 2,746 responses received. The responses received represented 9.8 percent of all Phase I awards for the five agencies, or 12.9 percent of all surveys emailed, and 18.9 percent of all possible responses.

The agency breakdown, including Phase I survey results, is given in Table App-C-1.

TABLE App-C-1 Agency Breakdown for NRC Phase I Survey

Phase I Project Surveys by Agency	Phase I Awards, 1992-2001	Answered Survey (Number)	Answered Survey (%)
DoD	13,103	1,198	9
DoE	2,005	281	14
NASA	3,363	303	9
NIH	7,049	716	10
NSF	2,458	248	10
TOTAL	27,978	2,746	10

SURVEY PREFACE

This survey is an important part of a major study commissioned by the U.S. Congress to review the SBIR program as it is operated at various federal agencies. The assessment, by the National Research Council (NRC), seeks to determine both the extent to which the SBIR programs meet their mandated objectives, and to investigate ways in which the programs could be improved. Over 1,200 firms have participated earlier this year in extensive survey efforts related to firm dynamics and Phase II awards. This survey attempts to determine the impact of Phase I awards that do not go on to Phase II. We need your help in this assessment. We believe that you were the PI on the listed Phase I.

We anticipate that the survey will take about 5-10 minutes of your time. If this Phase I resulted in a Phase II, this survey has only 3 questions; if there was not a Phase II, there are 14 questions. Where $ figures are requested (sales or funding,) please give your best estimate. Responses will be aggregated for statistical analysis and not attributed to the responding firm/PI, without the subsequent explicit permission of the firm.

Since you have been the PI on more than one Phase I from 1992 to 2001, you will receive additional surveys. These are not duplicates. Please complete as many surveys for those Phase Is that did not result in a Phase II as you deem to be reasonable.

Further information on the study can be found at <*http://www7.nationalacademies.org/sbir*>. BRTRC, Inc., is administering this survey for the NRC. If you need assistance in completing the survey, call 877-270-5392. If you have questions about the assessment more broadly, please contact Dr. Charles Wessner, Study Director, NRC.

Project Information
Proposal Title:
Agency:
Firm Name:
Phase I Contract/Grant Number:

NRC Phase I Survey Results

NOTE: RESULTS APPEAR IN BOLD. RESULTS ARE REPORTED FOR ALL 5 AGENCIES (DoD, NIH, NSF, DoE, AND NASA). EXPLANATORY NOTES ARE IN TYPEWRITER FONT.

2,746 responded to the survey. Of these 1,380 received the follow on Phase II. 1,366 received only a Phase I.

1. Did you receive assistance in preparation for this Phase I proposal?

Phase I only			Received Phase II	
95%	No	*Skip to Question 3.*	**93%**	No
5%	Yes	*Go to Question 2.*	**7%**	Yes

2. If you received assistance in preparation for this Phase I proposal, put an X in the first column for any sources that assisted and in the second column for the most useful source of assistance. Check all that apply. Answered by 74 Phase I only and 91 Phase II who received assistance.

	Phase I only Assisted/Most Useful	**Received Phase II** Assisted/Most Useful
State agency provided assistance	**10/3**	**11/10**
Mentor company provided assistance	**15/9**	**21/15**
University provided assistance	**31/17**	**34/22**
Federal agency SBIR program managers or technical representatives provided assistance	**16/8**	**25/19**

3. Did you receive a Phase II award as a sequential direct follow-on to this Phase I award? *If yes, please check yes. Your survey would have been automatically submitted with the HTML format. Using this Word format, you are done after answering this question. Please email this as an attachment to jcahill@brtrc.com, or fax to Joe Cahill 703 204 9447. Thank you for you participation.* 2,746 responses

50% No. We did not receive a follow-on Phase II after this Phase I.
50% Yes. We did receive the follow-on Phase II after this Phase I.

4. Which statement correctly describes why you did not receive the Phase II award after completion of your Phase I effort. *Select best answer*. All questions which follow were answered by those 1,366 who did not receive the follow-on Phase II. % based on 1,366 responses.

33% The company did not apply for a Phase II. *Go to question 5.*
63% The company applied, but was not selected for a Phase II. *Skip to question 6.*
1% The company was selected for a Phase II, but negotiations with the government failed to result in a grant or contract. *Skip to question 6.*
3% Did not respond to question 4.

5. The company did not apply for a Phase II because: Select all that apply. % based on 446 who answered "The company did not apply for a Phase II" in question 4.

38% Phase I did not demonstrate sufficient technical promise.
11% Phase II was not expected to have sufficient commercial promise.
6% The research goals were met by Phase I. No Phase II was required.
34% The agency did not invite a Phase II proposal.
3% Preparation of a Phase II proposal was considered too difficult to be cost effective.
1% The company did not want to undergo the audit process.
8% The company shifted priorities.
5% The PI was no longer available.
6% The government indicated it was not interested in a Phase II.
13% Other—explain:

6. Did this Phase I produce a noncommercial benefit? Check all responses that apply. % based on 1,366.

59% The awarding agency obtained useful information.
83% The firm improved its knowledge of this technology.
27% The firm hired or retained one or more valuable employees.
17% The public directly benefited or will benefit from the results of this Phase I. *Briefly explain benefit.*
13% This Phase I was essential to founding the firm or to keeping the firm in business.
8% No

7. Although no Phase II was awarded, did your company continue to pursue the technology examined in this Phase I? *Select all that apply.* % based on 1,366.

46% The company did not pursue this effort further.
22% The company received at least one subsequent Phase I SBIR award in this technology.
14% Although the company did not receive the direct follow-on Phase II to the this Phase I, the company did receive at least one other subsequent Phase II SBIR award in this technology.
12% The company received subsequent federal non-SBIR contracts or grants in this technology.
9% The company commercialized the technology from this Phase I.
2% The company licensed or sold its rights in the technology developed in this Phase I.
16% The company pursued the technology after Phase I, but it did not result in subsequent grants, contracts, licensing or sales.

Part II. Commercialization

8. How did you, or do you, expect to commercialize your SBIR award? *Select all that apply.* % based on 1,366.

33% No commercial product, process, or service was/is planned.
16% As software
32% As hardware (final product component or intermediate hardware product)
20% As process technology
11% As new or improved service capability
15% As a research tool
4% As a drug or biologic
3% As educational materials

9. Has your company had any actual sales of products, processes, services or other sales incorporating the technology developed during this Phase I? *Select all that apply.* % based on 1,366.

5% Although there are no sales to date, the outcome of this Phase I is in use by the intended target population.
65% No sales to date, nor are sales expected. *Go to question 11.*
15% No sales to date, but sales are expected. *Go to question 11.*
9% Sales of product(s)
1% Sales of process(es)

6% Sales of services(s)
2% Other sales (e.g., rights to technology, sale of spin-off company, etc.)
2% Licensing fees

10. For you company and/or your licensee(s), when did the first sale occur, and what is the approximate amount of total sales resulting from the technology developed during this Phase I? If other SBIR awards contributed to the ultimate commercial outcome, estimate only the share of total sales appropriate to this Phase I project. (Enter the requested information for your company in the first column and, if applicable and if known, for your licensee(s) in the second column. Enter dollars. If none, enter 0 (zero); leave blank if unknown.)

	Your Company	Licensee(s)
a. Year when first sale occurred	**89 of 147 after 1999**	**11 of 13 after 1999**
b. Total Sales Dollars of Product(s), Process(es), or Service(s) to date		
(Sale Averages)	**$84,735**	**$3,947**
Top 5 Sales Accounts for 43% of all sales	1. **$20,000,000**	
	2. **$15,000,000**	
	3. **$5,600,000**	
	4. **$5,000,000**	
	5. **$4,200,000**	
c. Other Total Sales Dollars (e.g., Rights to technology, Sale of spin-off company, etc.) to date		
(Sale Averages)	**$1,878**	**$0**

Sale averages determined by dividing totals by 1,366 responders.

11. If applicable, please give the number of patents, copyrights, trademarks and/or scientific publications for the technology developed as a result of Phase I. (Enter numbers. If none, enter 0 [zero]; leave blank if unknown.)

# Applied For or Submitted	# Received/Published	
319	**251**	Patent(s)
50	**42**	Copyright(s)
52	**47**	Trademark(s)
521	**472**	Scientific Publication(s)

12. In your opinion, in the absence of this Phase I award, would your company have undertaken this Phase I research? Select only one lettered response. If you select c, and the research, absent the SBIR award, would have been different in scope or duration, check all appopriate boxes. Unless otherwise stated, % are based on 1,366.

5% Definitely yes
7% Probably yes, similiar scope and duration
16% Probably yes, but the research would have been different in the following way
% based on 218 who responded probably yes, but research would have . . .
- **75%** Reduced scope
- **4%** Increased scope
- **21%** No Response to scope
- **5%** Faster completion
- **51%** Slower completion
- **44%** No Response to completion rate

14% Uncertain
40% Probably not
16% Definitely not
4% No Response to question 12

Part III. Funding and other assistance

Commercialization of the results of an SBIR project normally requires additional developmental funding. Questions 13 and 14 address additional funding. Additional Developmental Funds include non-SBIR funds from federal or private sector sources, or from your own company, used for further development and/or commercialization of the technology developed during this Phase I project.

13. Have you received or invested any additional developmental funding in this Phase I? % based on 1,366.

25% Yes. Go to question 14.
72% No. Skip question 14 and submit the survey.
3% No response to question 13.

14. To date, what has been the approximate total additional developmental funding for the technology developed during this Phase I? (Enter numbers. If none, enter 0 [zero]; leave blank if unknown).

	Source	# Reporting that source	Developmental Funding (Average Funding)
a.	Non-SBIR federal funds	**79**	**$72,697**
b.	Private Investment		
	(1) U.S. Venture Capital	**13**	**$4,114**
	(2) Foreign investment	**8**	**$4,288**
	(3) Other private equity	**20**	**$7,605**
	(4) Other domestic private company	**39**	**$8,522**
c.	Other sources		
	(1) State or local governments	**20**	**$1,672**
	(2) College or Universities	**6**	**$293**
d.	Your own company (Including money you have borrowed)	**149**	**$21,548**
e.	Personal funds of company owners	**54**	**$4,955**

Average funding determined by dividing totals by 1,366 responders.

Appendix D

NRC Project Manager Survey

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February 7, 2007

INTRODUCTION

Federal agency R&D programs are increasingly assessed in terms of their quality, relevance and efficiency. One means of gauging the performance of the SBIR program in light of these criteria is to obtain assessments by agency project managers who manage contracted SBIR programs. The survey findings reported here represent the first systematic effort to obtain such data from SBIR project managers. The survey questions were constructed to correspond to the three criteria above. Also, in an effort to address the ever present assessment question of "compared to what," the survey was designed to obtain respondent assessments of a comparison set of agency externally funded R&D projects.

Program performance of the SBIR program is very complex. Therefore, it is important to get as many perspectives on the SBIR program performance as possible. One group of participants in the process is agency project managers who manage contracted SBIR projects. This role only exists at agencies that contract SBIR awards (e.g., Department of Defense-DoD, Department of Energy-DoE, and the National Aeronautics and Space Administration-NASA) as opposed to administering awards as grants (e.g., National Institutes of Health-NIH and the National Science Foundation-NSF). Project managers take on different names and roles at the three agencies in question. At DoD, they are called Technical Points of Contact (TPOCs); at DoE, they are called Technical Project Managers (TPMs); and at NASA they are called Contract Officer's Technical Representatives (COTRs).

This paper gives two perspectives of project managers based primarily on an electronic survey that was administered as part of the National Research Council (NRC) assessment of the SBIR program. First, the report examines the role of the project manager in the SBIR project from topic selection to Phase III funding. Second, the report documents how project managers at these three agencies view the relative quality, usefulness and value to the agency of SBIR projects in comparison to other research at the agency.

Using the same time period of the NRC Phase II Survey of projects and firms completed as part of the NRC study as the reference point (1992-2001), we generated a list of Phase II SBIR projects for the three contracting agencies. We then requested from the SBIR program offices a list of project managers names and email addresses for as many of these individuals as possible. Naturally, there was significant attrition (absence of email addresses, absence of name for project manager, project manager having left the agency and/or was deceased, simply an error in the identified project manager). Given the constraints on collection of contact information and the time since many of the identified projects were implemented, the sample is a critical minimum size. A survey instrument was developed (based on Archibald-Finifter, 2000[1]) to determine quality and usefulness of research and mission benefits of the SBIR Phase II projects as seen by the project managers and is provided as Annex A of this paper.

General Background

The sample of project managers was first based on the original database provided by Peter Cahill of BRTRC of 11,684 SBIR Phase II projects in the five SBIR agencies (the three listed above plus NSF and NIH, which award grants, not contracts, and hence do not have contract officers as such). For the sample of the three agencies in question (DoD, DoE, and NASA), there is an estimated n=7,945 based on the BRTRC sample since 68 percent of the total sample was for these three agencies). The 7,945 represents an estimate of the potential number of project managers that could receive surveys. The number is actually far less than that because many project managers have done more that one Phase II project and therefore received a modified questionnaire for multiple projects. In a similar study by Archibald-Finifter for the DoD Fast Track study, 51.5 percent of the full sample responded and 78.9 percent of the successful contacts responded.[2] These were all recent relative to the survey data so the response rate was fairly high.

For the current survey, the actual sample of project managers/projects with known names was—5,650 for DoD, 1,488 for NASA, and 808 for DoE. These projects represent the requests for names and email addresses sent to the three agencies. In response, the agencies were able to locate names and email addresses

[1]Robert B. Archibald and David H. Finifter, "Evaluation of the Department of Defense Small Business Innovation Research Program and 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., National Academy Press, Washington, DC, 2000.

[2]Ibid.

for a limited subset of project managers—1,757 for DoD, 555 for DoE, and 272 for NASA. Finally, the actual responses we received for the survey amounted to a total of 513 (19.8 percent rate) including—347 (19.7 percent rate) for DoD, 84 (15.1 percent rate) for DoE, and 82 (30.1 percent rate) for NASA. The NASA sample was based on projects since 1997 only (the only project managers for which they had email information). The higher response rate is probably due in part to the fact that the sample is based on more recent projects. We were thus more likely to have respondents who were still available and who were more likely to have recalled the SBIR project about which they were being asked.

THE ROLE OF THE PROJECT MANAGER

Project Manager's Role in Selection

Question 2 asked if the Project Manager was involved in generating the topic that led to this particular SBIR project.

In Question 2 of the questionnaire, the respondent was asked if he or she was involved in generating the topic that led to this particular Phase II award. Table App-D-1 provides the response to this question for the total sample of project managers and results broken down by agency. Nearly 70 percent of the total respondents were involved in generating the SBIR project. This was apparently the case for DoD and DoE. However, NASA COTR respondents were less likely to have been involved in generating the topic that led to the SBIR project (only 57 percent).

Question 3 asked the Project Manager when he or she became involved in the particular SBIR project.

Another dimension of the role of project manager in the SBIR process relates to when he or she became involved in the project. As seen in Table App-D-2, for the total sample of project managers, 23 percent became involved after Phase I but before Phase II. Another 10 percent became involved after Phase II started but before Phase II was completed. Nearly two percent became involved after Phase II was completed. Over 65 percent were involved before Phase I started

TABLE App-D-1 Involvement in Generating Topic

Involved in Generating the Topic that Led to this Particular SBIR Project?	Total Sample	DoD	DoE	NASA
Yes	357 (69.59%)	251 (72.33%)	59 (70.24%)	47 (57.32%)
No	156 (30.41%)	96 (27.67%)	25 (29.76%)	35 (42.68%)
TOTAL	513	347	84	82

TABLE App-D-2 When Project Manager Became Involved in Project?

When Involved in SBIR Project?	Total Sample	DoD	DoE	NASA
After Phase I, Before Phase II	118 (23%)	56 (16.14%)	25 (29.76%)	37 (45.12%)
After Phase II Started, Before Phase II Completed	53 (10.33%)	32 (9.22%)	10 (11.90%)	11 (13.41%)
After Phase II Completed	8 (1.56%)	8 (2.31%)	— —	— —
Before Phase I	334 (65.11%)	251 (72.33%)	49 (58.33%)	34 (41.46%)
TOTAL	513	347	84	82

(consistent with the previous question relating to involvement in project generation). This varied by agency as seen in Table App-D-2.

For example, around 45 percent of the NASA respondents became involved in the project after Phase I, but before Phase II. Also, for DoD respondents, over 72 percent became involved before Phase I compared to 58 percent for DoE and 41 percent for NASA respondents. The degree to which a project manager is attached to the SBIR project by helping to come up with the topic to timing of involvement will have a likely impact on the knowledge and "ownership" of the project and may affect the respondents' view of the quality and usefulness of the project. This is analyzed further below.

Actual Role in Project

Question 10. What has your role been with respect to this SBIR project? List as many as apply.

The actual role of the project manager may vary from project-to-project, project manager-to-project manager (perhaps depending on skills and expertise of the project manager), and agency-to-agency. Question 10 of the survey asked about the project managers' role(s) with respect to the particular SBIR project in question. The results are summarized in Table App-D-3. The respondents were to respond to as many of the roles as applied. For the total sample, over 96 percent

TABLE App-D-3 Role of Project Manager with Respect to This SBIR Project

Role of Project Manager	Total Sample	DoD	DoE	NASA
Technical	493 (96.10%)	331 (95.39%)	82 (97.62%)	80 (97.56%)
Financial	109 (21.25%)	86 (24.78%)	19 (22.62%)	4 (4.88%)
Commercialization Assistance	84 (16.37%)	68 (19.60%)	6 (7.14%)	10 (12.19%)
Other	55 (10.72%)	44 (12.68%)	6 (7.14%)	5 (6.10%)
TOTAL SAMPLE SIZE	513	347	84	82

NOTE: Multiple responses permitted.

TABLE App-D-4 Played a Role in Any Phase III Funding for This Project

Who Played a Role in Any Phase III Funding for this Project	Total Sample	DoD	DoE	NASA
Respondent Played that Role	60 (11.72%)	50 (14.45%)	4 (4.76%)	6 (7.32%)
Someone Else Has Played that Role	77 (15.04%)	59 (17.05%)	12 (14.29%)	6 (7.32%)
Unknown	375 (73.24%)	237 (68.50%)	68 (80.95%)	70 (85.37%)
TOTAL	512	346	84	82

of the respondents claimed a "technical" role, with around 21 percent claiming a "financial" role and around 16 percent claiming a "commercialization assistance" role. The "commercialization assistance" role was a bit higher for those in DoD (around 20 percent) and lower for DoE and NASA (only around 7 and 12 percent, respectively). Clearly, the "technical" role dominates in all agencies. It is notable that for NASA, only around 5 percent had a "financial" role.

Project Manager's Role in Phase III Funding

Question 12. Have you or others played a role in any Phase III funding for this project?

The survey examined the role of the project manager in Phase III funding for the various projects listed (Question 12). Table App-D-4 summarizes the findings about the role. The overwhelming finding is that 73 percent of the respondents did not know who played such a role in Phase III funding efforts. The result was slightly lower for DoD respondents (68 percent) and higher for DoE and NASA (81 and 85 percent, respectively). Nearly 12 percent of the respondents in the overall sample said they played that role, ranging from 14 percent for DoD, to 7 percent for NASA, to 5 percent for DoE respondents. Overall, project managers seem to have a relatively minor role in Phase III funding for the agencies and projects studied. This is an important finding since project managers would be knowledgeable natural advocates for the project within the agency.

THE QUALITY, USEFULNESS, AND VALUE TO THE AGENCY OF THE SBIR PROJECT AS SEEN BY THE PROJECT MANAGER

As seen above, project managers tend to be fairly involved with the SBIR Phase II projects to which they are assigned, although the degree varies somewhat by agency. This involvement gives them a unique basis for evaluating the quality, usefulness, and value to the agency of each project. We used the survey of project managers to develop measures of these dimensions of program outcomes.

TABLE App-D-5 Ratings for SBIR Projects

Measure of Quality of SBIR Project	Total Sample	DoD	DoE	NASA
Mean Score	6.93	6.95	6.80	6.98
Standard Deviation	2.072	2.202	1.706	1.846
Median Score	7	8	7	8
Sample Size	513	347	84	82

Project Quality

Question 4. On a 1 to 10 scale, where 10 represents the best research ever produced in your research unit/office or for your research unit/office and 1 represents the worst research ever produced in your research unit/office or for your research unit/office, rate the quality of the research in this particular SBIR contract.

First, we use Questions 4 and 5 to arrive at a rating of the quality of SBIR Phase II projects from our sample as seen by the project managers. Question 4 asks the respondent to, on a scale of 1 to 10, where 10 represents the best research ever produced in their research unit/office or for their research unit/office and 1 represents the worst research ever produced in their research unit/office or for their research unit/office, rate the quality of the particular SBIR contract listed. The results for Question 4 are given in Table App-D-5 for the total sample of project managers and by each agency. The mean score for the total sample of 513 project managers/projects was 6.93 (with a standard deviation of 2.072) and the median score was 7. There were similar scores by agency as seen in Table App-D-5.

Question 5. On the same scale rate the average quality of the research projects conducted for your research unit/office from contracts other than SBIR contracts for the last two years.

The problem with this measure is that it does not adjust for "toughness of the grader." To compensate for the fact that different project managers have different standards in mind when evaluating a research project, we asked Question 5—On the same scale (1 to 10) rate the average quality of the research projects conducted for their research unit/office from contracts other than SBIR contracts for the last two years. A summary of those scores is given in Table App-D-6. It shows for example that the mean score for non-SBIR projects was 7.29 (standard deviation of 1.594) and a median of 8.

A comparison of the scores for the SBIR projects and the average quality of relevant non-SBIR contracts allows us to gauge the relative quality of the SBIR projects. The differences in means between the average score for the sample of SBIR projects and the average non-SBIR project are given in Table App-D-7. For the total sample of SBIR projects, the SBIR projects were on average lower by

TABLE App-D-6 Ratings for Non-SBIR Research Projects

Measure of Average Quality of Research (non-SBIR)	Total Sample	DoD	DoE	NASA
Mean Score	7.29	7.27	7.24	7.45
Standard Deviation	1.594	1.635	1.712	1.268
Median Score	8	8	7	7
Sample Size	513	347	84	82

TABLE App-D-7 Mean Difference in Scores SBIR Quality Minus Average Non-SBIR Project Quality

Measure of Difference in Scores of Project Quality	Total Sample	DoD	DoE	NASA
Mean Difference in Score—SBIR Quality Minus Average Non-SBIR Project Quality	–.364*	–.320*	–.440**	–.476**
Standard Deviation	2.15	2.19	2.03	2.10

NOTES: *Statistically significant at the .01 level; **Statistically significant at the .05 level.

.364. Similar differences are shown for the DoD, DoE, and NASA subsamples. Using a t-test, these differences are statistically significantly different from zero. The average quality score is slightly lower for SBIR projects than for non-SBIR research projects (although the differences are statistically significant). This result differs from the result found in Archibald-Finifter[3] which shows no statistical difference between the two scores for a sample of DoD projects.

Further examination of the results of the current survey shed some light on the slightly lower rating for SBIR projects. In looking at the distribution of scores for Question 3 (SBIR scores) and Question 4 (non-SBIR scores), we find that 7.4 percent of the respondents rank SBIR projects at a score of 3 or below compared to 1.9 percent for non-SBIR projects. The remainder of the distribution is much more similar. For example, around 49 percent of the SBIR sample ranked score above seven, compared to around 52 percent for the non-SBIR sample. This same skewed pattern of a few very low scores held for the three subsamples as well. Thus, the result seeming to favor non-SBIR research quality over SBIR quality is driven by a few outliers scoring the SBIR projects extremely low. The small difference in means and other evidence tends to show SBIR in a reasonably favorable light in terms of its quality and other dimensions of usefulness compared to non-SBIR research projects at the same agency.

[3]Ibid.

TABLE App-D-8 Distribution of Scores: SBIR Quality and Average Non-SBIR Project Quality (Total Sample)

	Quality of Research (SBIR)		Average Quality of Research (Non-SBIR)	
Score of Project Quality	Number of Responses	Percent	Number of Responses	Percent
1	8	1.56	7	1.36
2	12	2.34	2	0.39
3	18	3.51	1	0.19
4	32	6.24	11	2.14
5	56	10.92	50	9.75
6	48	9.36	50	9.75
7	90	17.54	126	24.56
8	129	25.15	162	31.58
9	89	17.35	84	16.37
10	31	6.04	20	3.90
TOTAL	513	100.00	513	100.00

Linkage to Research Mission

Question 6. Has the research conducted for this SBIR contract affected the way that your research unit/office conducts research or the type of research your research unit/office obtains in other contracts? (List as many as apply.)

The next question we raised in the survey dealt more with usefulness of the research for the research unit/office. In particular, we asked Question 6—Has the

TABLE App-D-9 Distribution of Scores: SBIR Quality and Average Non-SBIR Project Quality (DoD)

	Quality of Research (SBIR)		Average Quality of Research (Non-SBIR)	
Score of Project Quality	Number of Responses	Percent	Number of Responses	Percent
1	8	2.31	7	2.02
2	9	2.59	0	0.00
3	13	3.75	1	0.29
4	22	6.34	7	2.02
5	38	10.95	35	10.09
6	26	7.49	30	8.65
7	53	15.27	88	25.36
8	85	24.50	109	31.41
9	68	19.60	58	16.71
10	25	7.20	12	3.46
TOTAL	347	100.00	347	100.00

TABLE App-D-10 Distribution of Scores: SBIR Quality and Average Non-SBIR Project Quality (DoE)

	Quality of Research (SBIR)		Average Quality of Research (Non-SBIR)	
Score of Project Quality	Number of Responses	Percent	Number of Responses	Percent
1	0	0.00	0	0.00
2	1	1.19	2	2.38
3	2	2.38	0	0.00
4	6	7.14	3	3.57
5	11	13.10	8	9.52
6	12	14.29	11	13.10
7	17	20.24	19	22.62
8	24	28.57	22	26.19
9	9	10.71	13	15.48
10	2	2.38	6	7.14
TOTAL	84	100.00	84	100.00

research conducted for this SBIR contract affected the way that your research unit/office conducts research or the type of research your research unit/office obtains in other contracts? (List as many as apply.) These results are summarized in Table App-D-12.

The responses to this question varied across agencies somewhat. Of those project managers who responded "No, this project was a separate project, and the knowledge generated by this SBIR contract has had no impact on the other

TABLE App-D-11 Distribution of Scores: SBIR Quality and Average Non-SBIR Project Quality (NASA)

	Quality of Research (SBIR)		Average Quality of Research (Non-SBIR)	
Score of Project Quality	Number of Responses	Percent	Number of Responses	Percent
1	0	0.00	0	0.00
2	2	2.44	0	0.00
3	3	3.66	0	0.00
4	4	4.88	1	1.22
5	7	8.54	7	8.54
6	10	12.20	9	10.98
7	20	24.39	19	23.17
8	20	24.39	31	37.80
9	12	14.63	13	15.85
10	4	4.88	2	2.44
TOTAL	82	100.00	82	100.00

TABLE App-D-12 Effect of SBIR Project's Research on Your Research Unit

Research Effect	Total Sample	DoD	DoE	NASA
No, this project was a separate project, and the knowledge generated by this SBIR contract has had no impact on the other research we conduct or sponsor.	166 (32.4%)	88 (25.4%)	42 (50.0%)	36 (43.9%)
Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract by encouraging the firm to apply for additional SBIR awards.	148 (28.8%)	108 (31.1%)	19 (22.6%)	21 (25.6%)
Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract in other research we conduct or sponsor.	234 (45.6%)	184 (53.0%)	24 (28.6%)	26 (31.7%)
Yes, but this project found a blind alley, so we have not followed up on this line of inquiry.	49 (9.5%)	35 (10.1%)	6 (7.1%)	8 (9.8%)
TOTAL SAMPLE	513	347	84	82

NOTE: Multiple responses permitted.

research we conduct or sponsor," 32 percent of the total sample gave this response of no linkage. However, the response was only 25 percent from DoD project managers, 50 percent from DoE project managers, and 44 percent from NASA project managers. The low percentage response for DoD is indicates relatively high linkage and usefulness and this is probably not a surprise for an agency that is so mission driven.

"Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract by encouraging the firm to apply for additional SBIR awards" yielded some positive response. For the total sample, nearly 29 percent cited this response. The breakdown by agency was not dramatic—percentages around 31, 23, and 26, respectively for DoD, DoE, and NASA.

The response category "Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract in other research we conduct or sponsor" led to some interesting results. The overall sample showed a response of around 46 percent. That ranged from the high of 53 percent for DoD to a low of around 29 and 32 percent for DoE and

NASA, respectively. This may reflect the greater size and scope within DoD, or it might suggest a greater effort by DoD in finding alternative uses for the research within the agency.

In general, the results indicate that there is a relatively high agency usage rate or attempted usage rate for SBIR projects in our sample. In some cases this lead to additional SBIR awards and in some cases it influences other non-SBIR research. In any case, potential impact is relatively high for all three agencies.

One other response on this question is notable. “Yes, but this project found a blind alley, so we have not followed up on this line of inquiry” had a response rate of 9.5 percent for the total sample (around 10, 7, and 10 percent for DoD, DoE, and NASA samples, respectively). Having a 10 percent “blind alley” rate is relatively small and can be viewed as “good forecasting” by the agencies. Alternatively, we would expect agencies to take some risks with the SBIR selections and perhaps the 10 percent rate of “blind alleys” is too low for the goals of the program. This result merits further study.

Comparative Value of SBIR Projects

Question 8. In comparison to a dollar spent in your research unit/office on other R&D projects, how did a dollar spent on this SBIR project rank?

Information on another dimension of quality and usefulness of the SBIR program was sought through Question 8—“In comparison to a dollar spent in your research unit/office on other R&D projects, how did a dollar spent on this SBIR project rank” is shown in Table App-D-13. For the total sample around 28 percent responded that the particular SBIR project had fewer benefits for their agency’s mission than the average dollar spend on other contracts they sponsor. Another 28 percent responded that the SBIR project had more benefits SBIR

TABLE App-D-13 Comparative Dollar Value of Projects

Dollar Value	Total Sample	DoD	DoE	NASA
SBIR project had fewer benefits for your agency’s mission than the average dollar spent on other contracts you sponsor	145 (28.27%)	93 (26.80%)	26 (30.95%)	26 (31.71%)
SBIR project had more benefits for your agency’s mission than the average dollar spent on other research contracts you sponsor	143 (27.88%)	114 (32.85%)	14 (16.67%)	15 (18.29%)
Same Benefits	225 (43.86%)	140 (40.35%)	44 (52.38%)	41 (50.00%)
TOTAL SAMPLE SIZE	513	347	84	82

project had more benefits for their agency's mission than the average dollar spent on other research contracts they sponsor. This response varied by agency quite a bit—The response from around 33 percent for DoD respondents, but only around 17 to 18 percent for DoE and NASA, respectively. The project managers who responded the same benefits amounted to around 44 percent for the total sample, ranging from around 40 percent for DoD respondents to 52 and 50 percent for DoE and NASA respondents respectively. Overall the conclusion is that over 71 percent of the SBIR projects had at least as high benefits for the mission of the agency as the average dollar spent on non-SBIR projects.

Abundance of Fundable SBIR Proposals

Another dimension of SBIR project and program success was approached by survey Question 9. This question asked: "In general do you find that your research unit/office has had more good SBIR proposals than you can fund?" This question gets at the value of the marginal SBIR project and the consequences of expanding the funded SBIR projects. The results are impressive. As seen in Table App-D-14, while around 24 percent of the total sample of respondents claimed that there were about the right number of SBIR proposals currently, over 63 percent responded that there were more fundable SBIR proposals than they can fund, with only 13 percent claiming that there are fewer fundable proposal than they can fund. This result is fairly consistent for DoD and DoE respondents. NASA results are somewhat less favorable with around 21 percent responding that there are fewer fundable proposals than they can fund. However, over 56 percent still responded that there are more fundable projects than they can fund.

Analysis of "Ownership Bias" of Findings

As a check on bias of responses by the project managers, we broke the sample up into project managers with a potentially strong degree of "ownership" in the project and those with less potential for "ownership." We defined

TABLE App-D-14 Relative Number of Fundable SBIR Projects

Relative Number of Fundable SBIR Projects	Total Sample	DoD	DoE	NASA
More fundable proposals than can fund	220 (63.4%)	156 (65.8%)	24 (61.5%)	40 (56.3%)
About the right number of proposals	82 (23.6%)	54 (22.8%)	12 (30.8%)	16 (22.5%)
Fewer fundable proposals than can fund	45 (13.0%)	27 (11.4%)	3 (7.7%)	15 (21.1%)
Respondents	347	237	39	71

TABLE App-D-15 Analysis of Ownership Effects—Entire Sample

Area of Interest	Ownership Group (n=391)	Remaining Project Managers (n=122)
Research Quality (Difference between Q3-Q4)	–.261	–.697
Usefulness of Research (Q5)		
a. No, not useful	113 (28.90%)	53 (43.44%)
b. Yes, more SBIR	116 (29.67%)	32 (26.23%)
c. Yes, general follow-up	189 (48.34%)	45 (36.88%)
d. Yes, but blind alley	46 (11.76%)	3 (2.46%)
Mission Benefits (Q6)		
a. More than average	29.67%	22.13%
b. Same as average	44.50%	41.80%
c. Less than average	25.83%	36.07%

"ownership" as those project managers who had a potential stake in the project as demonstrated either by being involved in defining the topic or if they were involved with the firm before the Phase I proposal. These project managers might be inclined to rate the project more highly and bias the results toward more favorable outcomes. At the same time, these same project managers could also be more knowledgeable about the project and its outcomes. There were 391 of the 513 who were in this "ownership group." Table App-D-15 through Table App-D-18 summarize the key measures of quality and usefulness of the projects by ownership group membership for the total sample and by agency. In general, the ownership group does rate the SBIR projects more highly in terms of quality and usefulness measures. Again, whether this is bias or greater knowledge or some combination is not known, but there do seem to be differences.

Project Outcomes

Question 13. Has this SBIR project been commercialized?

It is sometimes argued that there is a trade-off between the research potential (intrinsic use) of an SBIR project and its potential for commercialization.[4] Table App-D-19 shows the rate of commercialization. This commercialization rate is around 34 percent for the total sample and varies slightly across agency (around 35 percent for DoD, 30 percent for DoE, and 35 percent for NASA). These rates reflect the knowledge base of the project managers.

[4]Robert Archibald and David Finifter, "Evaluating the NASA Small Business Innovation Research Program: Preliminary Evidence of a Tradeoff Between Commercialization and Basic Research," *Research Policy* 32:605-619, 2003.

TABLE App-D-16 Analysis of Ownership Effects—DoD

Area of Interest	Ownership Group (n=271)	Remaining Project Managers (n=76)
Research Quality (Difference between Q3-Q4)	–.229	–.645
Usefulness of Research (Q5)		
a. No, not useful	63 (23.25%)	25 (32.89%)
b. Yes, more SBIR	86 (31.73%)	22 (28.95%)
c. Yes, general follow-up	148 (54.61%)	36 (47.37%)
d. Yes, but blind alley	33 (12.18%)	2 (2.63%)
Mission Benefits (Q6)		
a. More than average	35.06%	25.00%
b. Same as average	40.96%	38.16%
c. Less than average	23.99%	36.84%

TABLE App-D-17 Analysis of Ownership Effects—DoE

Area of Interest	Ownership Group (n=65)	Remaining Project Managers (n=19)
Research Quality (Difference between Q3-Q4)	–.415	–.526
Usefulness of Research (Q5)		
a. No, not useful	34 (52.31%)	8 (42.10%)
b. Yes, more SBIR	14 (21.54%)	5 (26.32%)
c. Yes, general follow-up	18 (27.69%)	6 (31.58%)
d. Yes, but blind alley	5 (7.69%)	1 (5.26%)
Mission Benefits (Q6)		
a. More than average	15.38%	21.05%
b. Same as average	52.31%	52.63%
c. Less than average	32.31%	26.32%

TABLE App-D-18 Analysis of Ownership Effects—NASA

Area of Interest	Ownership Group (n=55)	Remaining Project Managers (n=27)
Research Quality (Difference between Q3-Q4)	–.236	–.963
Usefulness of Research (Q5)		
a. No, not useful	16 (29.09%)	20 (74.07%)
b. Yes, more SBIR	16 (29.09%)	5 (18.52%)
c. Yes, general follow-up	23 (41.82%)	3 (11.11%)
d. Yes, but blind alley	8 (14.54%)	0 (0.00%)
Mission Benefits (Q6)		
a. More than average	20.00%	14.81%
b. Same as average	52.73%	44.44%
c. Less than average	27.27%	40.74%

TABLE App-D-19 Project Commercialized?

Has this SBIR Project Been Commercialized?	Total Sample	DoD	DoE	NASA
Yes	175 (34.45%)	123 (35.55%)	24 (29.63%)	28 (34.57%)
No	333 (65.55%)	223 (64.45%)	57 (70.37%)	53 (65.43%)
TOTAL	508	346	81	81

Question 14. Does this SBIR project have noncommercial/intrinsic use (perhaps in research)? (Elaborate—see annex).

Table App-D-20 shows how respondents evaluated the noncommercial/intrinsic use (perhaps research) for these same SBIR projects. The intrinsic use rate for the total sample is around 66 percent. This rate varies somewhat across agencies (69 percent for DoD, 54 percent for DoE, and 63 percent for NASA).

Table App-D-21 shows the relationship between whether the projects in our survey were commercialized and/or their intrinsic research potential. Table App-D-22 through Table App-D-24 show the same results by agency. Overall, the results show that SBIR projects are highly successful in producing either commercial and/or noncommercial/intrinsic use outcomes.

The results from Table App-D-21 are compelling. Based on the responses of the project managers, nearly 74 percent of the SBIR projects showed a commercial or intrinsic use or both. In fact, over 26 percent (134 projects) were reported to have both a commercial and an intrinsic use. Thus, while there might be some trade-off between research and commercial potential, there may also be some degree of complementarity. The results differ somewhat by agency and these are shown in Table App-D-22 through Table App-D-24.

How Project Managers Relate to Phase III

One final dimension of outcome of an SBIR project that was covered by the project manager survey relates to Phase III funding. Question 11 probed this issue as follows: "This SBIR project received Phase III funding from your agency in

TABLE App-D-20 Does SBIR Project Have Non-commercial/Intrinsic Use (Perhaps in Research)?

Does SBIR Project Have Non-commercial/Intrinsic Use (Perhaps in Research)?	Total Sample	DoD	DoE	NASA
Yes	336 (65.75%)	239 (69.08%)	45 (54.22%)	52 (63.41%)
No	175 (34.25%)	107 (30.92%)	38 (45.78%)	30 (36.59%)
TOTAL	511	346	83	82

TABLE App-D-21 Relationship Between Commercial and Non-commercial Outcomes (Total Sample)

	Intrinsic Use (Research)		
Commercialized	No	Yes	Total
No	132	200	332 (65.48%)
Yes	41	134	175 (34.52%)
Total	173 (34.12%)	334 (65.88%)	507

TABLE App-D-22 Relationship Between Commercial and Non-commercial Outcomes (DoD Sample)

	Intrinsic Use (Research)		
Commercialized	No	Yes	Total
No	80	142	222 (64.35%)
Yes	26	97	123 (35.65%)
Total	106 (30.72%)	239 (69.28%)	345

TABLE App-D-23 Relationship Between Commercial and Non-commercial Outcomes (DoE Sample)

	Intrinsic Use (Research)		
Commercialized	No	Yes	Total
No	33	24	57 (70.37%)
Yes	5	19	24 (29.63%)
Total	38 (46.91%)	43 (53.09%)	81

TABLE App-D-24 Relationship Between Commercial and Non-commercial Outcomes (NASA Sample)

	Intrinsic Use (Research)		
Commercialized	No	Yes	Total
No	19	34	53 (65.43%)
Yes	10	18	28 (34.57%)
Total	29 (35.80%)	52 (64.20%)	81

the form of: Further non-SBIR R&D funding; Direct procurement of the product of this SBIR Procurement through incorporation of the result of this project into a system; No Phase III from agency; Unknown." Results of this question are shown in Table App-D-25. The result which stands out the most is that for the total sample, around 58 percent of the projects were known to have not received

TABLE App-D-25 SBIR Project Received Phase III Funding from Your Agency

Phase III Funding from Your Agency—Form	Total Sample	DoD	DoE	NASA
Direct Procurement of the Product of this SBIR	15 (2.9%)	10 (2.9%)	0 (0.0%)	5 (6.1%)
Procurement through Incorporation of the Result of this Project into System	18 (3.5%)	11 (3.2%)	4 (4.8%)	3 (3.7%)
No Phase III from Agency	299 (58.3%)	214 (61.7%)	39 (46.4%)	46 (56.1%)
Further non-SBIR R&D funding	53 (10.3%)	41 (11.8%)	7 (8.3%)	5 (6.1%)
Unknown	128 (24.9%)	71 (20.5%)	34 (40.5%)	23 (28.0%)
TOTAL	513	347	84	82

Phase III funding from the agency and another 25 percent were unknown. As seen in the table, the results vary somewhat by agency. Phase III direct procurement of the product of the SBIR project occurred in only 2.9 percent of the time for the total sample. That same percentage was the case for DoD respondents, but the results for the other two agencies varied greatly from zero cases for DoE to just above six percent for NASA. Procurement of the SBIR project through incorporation of the result of the project into the system was also relatively low, with a rate of 3.5 percent for the total sample with a range from 3.2 to 4.8 percent across the agencies. For the total sample, there were over ten percent of the respondents who said the projects were supported further by non-SBIR R&D funding.

CONCLUSIONS

The SBIR project managers in our sample appear to be a rather engaged group with respect to the SBIR Program. They were engaged in the projects early and often. In general, the project managers ranked the quality of the SBIR research as close to the quality of research undertaken at their respective research units. The projects seemed to be useful to the mission at the various agencies and affected the subsequent research program (both SBIR and non-SBIR projects.) The project managers valued the projects highly compared to non-SBIR projects. Most agreed that there is a relative abundance of fundable SBIR proposals that do not get funded. Surprisingly, SBIR project managers seem to have little involvement in what is already a relatively low rate of Phase III activity. Finally, as viewed by the project managers, the SBIR projects under examination had a very high combined commercialization and intrinsic (research) use rate.

REMAINING SECTIONS OF THE REPORT

The remaining parts of the report are in annexes. Annex A contains the base survey. Annex B contains three parts that are responses to the open-ended questions in the survey.

Annex A
The Base Questionnaire

1. Please name your research unit/office.

2. Were you involved in defining or generating the topic, which led to this particular SBIR project?
   - Yes
   - No

3. When did you first become involved with this SBIR Phase II project?
   - Before the Phase I proposal
   - After the Phase I proposal but before the Phase II proposal
   - After the Phase II proposal, but before the Phase II project was completed
   - After the Phase II project was completed

4. On a 1 to 10 scale, where 10 represents the best research ever produced in your research unit/office or for your research unit/office and 1 represents the worst research ever produced in your research unit/office or for your research unit/office, rate the quality of the research in this particular SBIR contract.
   1 2 3 4 5 6 7 8 9 10

5. On the same scale rate the average quality of the research projects conducted for your research unit/office from contracts other than SBIR contracts for the last two years.
   1 2 3 4 5 6 7 8 9 10

6. Has the research conducted for this SBIR contract affected the way that your research unit/office conducts research or the type of research your research unit/office obtains in other contracts? List as many as apply.
   - No, this project was a separate project, and the knowledge generated by this SBIR contract has had no impact on the other research we conduct or sponsor.
   - Yes, this project produced results that have been useful to us, and we have tried to follow up on the ideas initiated in this SBIR contract by encouraging the firm to apply for additional SBIR awards.
   - Yes, this project produced results that have been useful to us, and we

have tried to follow up on the ideas initiated in this SBIR contract in other research we conduct or sponsor.
- Yes, but this project found a blind alley, so we have not followed up on this line of inquiry.

7. Please describe how this SBIR project may have had an impact on your agency's mission. (Optional)

8. In comparison to a dollar spent in your research unit/office on other R&D projects, did a dollar spent on this SBIR project:
   - Yield more benefits for your agency's mission that the average dollar spent on other contracts sponsored by your research unit/office.
   - Yield the same level of benefits from your agency's mission as the average dollar spent on other contracts sponsored by your research unit/office.
   - Yield fewer benefits for your agency's mission than that average dollar spent on other contracts sponsored by your research unit/office.

9. In general do you find that your research unit/office has had more good SBIR proposals than you can fund?
   - Yes
   - No
   - About the right number of good proposals

10. What has your role been with respect to this SBIR project? List as many as apply.
    - Technical
    - Financial
    - Commercialization assistance
    - Other (please specify)

11. This SBIR project received Phase III funding from your agency in the form of:
    - Further non-SBIR R&D funding
    - Direct procurement of the product of this SBIR
    - Procurement through incorporation of the result of this project into a system
    - No Phase III from agency
    - Unknown

12. Have you or others played a role in any Phase III funding for this project?
    - I have played that role
    - Someone else has played that role
    - Unknown

13. Has this SBIR project been commercialized?
    - Yes
    - No

14. Does this SBIR project have non-commercial/intrinsic use (perhaps in research)? Elaborate.
    - Yes
    - No

15. If you have any comments that you think would help us evaluate the effectiveness of the SBIR Program in producing useful research for your agency, please feel free to comment. (Optional)

Annex B1

QUESTION 15. If you have any comments that you think would help us evaluate the effectiveness of the SBIR Program in producing useful research for your agency, please feel free to comment. (Optional)

Annex B2

QUESTION 7. Please describe how this SBIR project may have had an impact on your agency's mission (Optional)

Annex B3

QUESTION 14. Does this SBIR project have noncommercial/intrinsic use (perhaps in research)? Elaborate.

Appendix E

Case Studies

TABLE App-E-1 SBIR Case Study Firms: Principal Technology and Business

Firm	Principal Technology	Principal Business
AeroSoft, Inc.	GASP—an engineering analysis tool (computer software) to predict aerodynamics/gas dynamics with respect to any aircraft or spacecraft.	Engineering research and development.
ARACOR	X-ray computed tomography technology for several CT applications.	Develops and manufactures x-ray test and inspection systems.
Creare, Inc.	Variety of technologies in Biomedical applications, cryogenics, fluid dynamics and heat transfer, manufacturing technology, sensors and controls, and software and data systems.	An engineering R&D services company.
Deformation Control Technology, Inc. (DCT)	Developed simulation software to solve thermo-mechanical problems for the heat treatment industry. Developed DANTE™, as simulation software—Distortion Analysis for Thermal Engineering.	Computer simulation of forging processes. Providing engineering services to the metalworking community specializing in process simulation and computer-based analysis of thermal and mechanical processes such as heat treatment, forging, rolling, extrusion, and powder consolidation.
Essential Research, Inc. (ERI)	Developed a semiconductor—Light emitting technology (LED)—Quantum Dots	PIN diodes which are photodetectors, laser diodes

TABLE App-E-1 Continued

Firm	Principal Technology	Principal Business
Luna Innovations, Inc.	Core technologies are in fiber optics, wireless, and ultrasonic sensing, biotechnology, advanced materials, nondestructive evaluation, and integrated systems.	Manufacturing process control, next-generation cancer drug development, analytical instrumentation, novel nanomaterials, advanced petroleum monitoring system, and wireless remote asset management.
Mainstream Engineering Corporation	Thermal control, energy conversion, turbomachinery-based technologies and nanotechnology.	HVAC products, A/C certifications, recreational boating, environmental control units, generators/engines, M9ACE crew cooling, oil-less compressors, heat transfer fluids.
Space Photonics, Inc. (SPI)	Core Technologies: Micro Electronics Photonics Packaging; Ultra-High-Speed Fiber Optic Transceivers; Optical Network Components; and Free Space Optical Transceivers.	Innovative avionics and space optical communications components, networks, services and support. Products include: SPI's LaserFire® (Free-Space Communications Transceivers); MEMSpot® (beam steering devices currently under development); Micro-Electo-Mechanical Systems (MEMS); SPI's FireFibre® (4-Channel transmitters and receivers); and SPI's FireRing® (High Speed Real-Time Fiber Optic Networks).
Technology Management, Inc. (TMI)	Solid Oxide Fuel Cell System (SOFC).	Fuel cell systems integrator. A compact, multifuel, modular, kilowatt class system, which can be delivered overnight.
TiNi Alloy Company	MEMS (Microelectronic-Mechanical Systems) and nanotechnology. Thin film microfabrication and materials science. The result is micro-miniature valves and micro-switches with potential applications to consumer products and manufacturing. Their technologies have applications in four areas: Biotech, Aerospace, Energy, and Medicine.	Heat engines that run on hot and cold water, with application to aerospace devices; microdevices and nanodevices made of TiNi thin film.

TABLE App-E-2 Strengths of the NASA SBIR Program as Identified by Firms Interviewed for the Case Studies

1. SBIR program is a cost-effective model for small business to obtain government funded projects—eliminates the intimidation factor for small business.
2. Generally there are good topics to apply to over time.
3. Requires the development of a new technology.
4. The program is a great resource for companies to develop technologies, in particular technologies that would not be developed by larger companies.
5. Allows for government to do some key research.
6. Nice complement between NASA and DoD programs (broad and narrow scope, respectively).
7. The range of ideas that get to see the light of day—ideas grow out of it.
8. Policy on Intellectual Property is an important plus.
9. Innovativeness is encouraged.
10. Provides opportunities to work with government research labs and equipment which some small firms could not do without SBIR.
11. Not a lot of strings attached like with VCs.
12. Freedom to pursue technology they want within confines of solicitation.
13. Data rights.
14. SBIR allows high risk/high payoff ideas to get funding at the seed level which is difficult to do through private industry.
15. SBIR promotes working with other companies and universities combining ideas with others to emphasize a team approach. This helps to ensure that the applicant has the right team to get a reliable, solid solution to a problem.
16. SBIR is a merit-based competition. Size of company does not matter so it levels the playing field relative to large companies.

TABLE App-E-3 Weaknesses of the NASA SBIR Program, as Identified by Firms Interviewed for the Case Studies

1. Agencies opt for lower risk projects too often.
2. Inconsistency of topics.
3. Inadequate feedback on losing Phase Is.
4. There is often only a market for one unit purchased by the agency, thus a limited market for the product. This makes the SBIR program technology driven rather than market driven.
5. Need to increase funding levels of Phase I and Phase II awards.
6. Need more structured process for transitioning to Phase III.
7. Requires small companies to develop an accounting capability and this might discourage some companies from applying for the program.
8. Need to be more flexible with no-cost extensions.
9. Time lags in program is primary weakness.
10. Insider's knowledge is needed to compete.
11. Not all awardees that are good at Phase I and Phase II projects are necessarily good at commercializing.
12. For SBIRs, there is 3 ½ years from writing a proposal to finalizing a Phase II. Over that time, technology changes. That is the real time lag problem. It would be helpful if firms can change direction of the contract as information changes.
13. There should be a yearly technical conference (instead of having to contact topic authors during the solicitation process). Currently, conferences are geared more to application/contractual issues rather than technological issues. Agencies would then get fewer proposals because they would be able to more clearly define their technical needs.
14. Need more opportunities to talk to primes (such as opportunity that Dawnbreaker provides).
15. Concern with growing emphasis on short-term technology objectives. This trend moves against SBIR's original purpose and is causing less innovation.

AeroSoft, Inc.

David H. Finifter
The College of William and Mary

April 10, 2006

SUMMARY

AeroSoft, Inc., is located in Blacksburg, Virginia. The company was founded and incorporated in 1988 by Dr. Robert Walters. It was set up to develop, license, market and support software for computational fluid dynamics (CFD) applications, utilizing novel algorithms which expand the capabilities of its users. AeroSoft also provides customized solutions for aerospace and military clients which wish to hire the expertise needed to solve individual problems, but with no interest in purchasing CFD software. The company should be categorized as a "lifestyle company" not a "growth company." In 1993, the company had five employees and it currently has eight.

The company has three related technologies (GASP, GUST, and SENSE)—engineering software packages—that have been developed and in each case, SBIR funding played an important role. Currently, about 50 percent of the company's revenue comes from SBIR/STTR and other government contracts (with the Air Force currently) and 50 percent of the revenue comes from licenses sales that have been a commercial success. The firm was initially woman-owned but is not currently.

In 1990, AeroSoft developed GASP v1 (structured code). GASP v2 was released in 1992 and in 1995, the company released GASP v3 (parallel CFD solver with GUI). In 1996, AeroSoft's focus shifted from CFD analysis to CFD analysis and design. Dr. Walters sold the company to Dr. William McGrory in 1998. In 1998, the company released GUST v1 (unstructured flow solver and grid generator). Also, in 1998, the company released SENSE v1 as a sensitivity analysis tool. In 2001, the company released both GASP v4 and GUST v2.

GASP is AeroSoft's most important innovation. It is an engineering analysis tool (computer software) to predict aerodynamics/gas dynamics with regard to any aircraft or spacecraft. It involves computational fluid dynamics and is a structured solver. A second technology, GUST, is similar to GASP in that it is set up to predict aerodynamics. It is an unstructured solver. AeroSoft's third technology is SENSE. This is a designer tool as opposed to an analysis tool. It is for the same applications as GUST and GASP. It provides design sensitivities and determines how performance will change as a property of the vehicle or the flow varies. SENSE is used in the design phase. The impact that AeroSoft's technologies have on its customers includes: reduced cost, additional capability, higher quality, and increased ability to achieve agency mission.

The SBIR program was critical to the formation of the firm. AeroSoft would not have existed without SBIR. For the first four years, AeroSoft, Inc. was a paper company to bid on SBIRs and it had no employees. Its first Phase I, through NSF, did not turn into a Phase II. Then the company won two NASA Phase Is that became Phase II awards. The growth of the company is completely attributable to SBIR (it was 90 percent of the revenue). It took seven years for the technology to get commercialized and then gradually the firm got up to the fifty/fifty ratio that it now has with SBIRs and other revenue. It currently has an Air Force SBIR Phase II. Of its Air Force contracts, now two-thirds are SBIRs with the Air Force and the other one-third are non-SBIR Air Force contracts. AeroSoft still sells licenses to NASA but does not currently have a NASA SBIR award. It has licenses for its software with NASA Glenn, Langley, Johnson, Ames, and Marshall.

The SBIR awards may or may not have had an effect on securing other financing. It may have been mildly beneficial with banks. The company is not in search of VC funding or other private investors. SBIR did help the company get Air Force non-SBIR contracts. The SBIR funding gave core engineering technologies to the company. There are fundamental algorithms and physical modeling directly attributable to SBIR.

SBIR not only helped the company survive, but more recently it helped to maintain some of its critical employees. It has also helped with growth, too.

The company became aware of SBIR from the solicitation from NSF. AeroSoft's CEO was in the academic community with university connections. There was no geographical connection to SBIR agencies. To determine which agency it would apply to, the basis was the research topics and agencies where the company had applicable strengths. Basically it was looking for key words of "high speed aerodynamics."

AeroSoft's strategy is limited by the topics available. In the past it has had a good success rate. It has gotten more difficult as the number of companies competing increases. AeroSoft's strategy is basically to pick the number of proposals on which it has time to do a good job.

In other experience, it finds that Air Force contracts are more relaxed and allow for establishment of longer term relationships. It has proven itself as an Air Force contractor. While Phase I is a short rushed time frame, Phase II is more like a regular Air Force contract. It is able to establish a relationship and get good closure on a research topic.

How Would It Change the SBIR Process?—It is hard to get good two-way communication. This is not uniform across Technical Point of Contact (TPOCs) and depends on who you talk with to get different quality of information. The company wants to be sure it is worthwhile to propose the topics.

In terms of debriefings, most of the debriefs simply state that "you did a great job technically but we didn't pick you," with no indication of whether you should come back. The company must use its own judgment about whether to go back. It should be noted that SENSE did a couple of Phase Is before it went into Phase II.

AeroSoft has had very little success in getting third-party private investment via Phase IIB. It basically plows back the licensing revenue into the firm. This is more a function of the software aspect of the product. There are not many third parties who want to commit money. It can get letters of support from third parties but not funding. The company would like to see more flexibility in government funding Phase III or IIB. In its case, the firm is technically top heavy and its sales and marketing are weak.

Selection Process: The company sees that fairness of the program selection process varies. Politics play a role. How strongly a champion fights for you matters. But it has won its share and lost its share, so it is not complaining.

The feedback the company gets is not always helpful. There needs to be more candor. The company never knows anything about winners or other losers. It would be good to know from the debriefing that with certain changes it would want to resubmit the proposal.

Funding Lags: With regard to funding delays and time lags between Phases I and II, the owner has had to take out loans to keep staff on board. So the program should try to improve the continuity of topics.

Size and Number of Awards: In regard to the size and number of awards, it prefers more opportunities for the company. It would add more contracts at current levels of funding per award. Note that computer equipment costs have actually gone down, so for its case, it is still able to fund the same number of man-hours with the relatively fixed level of awards.

Strengths of SBIR Program: The company cited two program strengths. First, the SBIR program is a cost-effective model for small business to obtain government funded projects. Small companies are intimidated by the requirements for large contracts and the SBIR program eliminates the intimidation factor. Second, there are generally good topics to apply to over time.

Weaknesses of SBIR Program: There were a few weakness cited by AeroSoft. First, the people writing the tasks and research topics are potential high risk takers but opt for lower risk projects. Second, there is an inconsistency of topics. It is either feast or famine on some topics. Finally, there is inadequate feedback on losing Phase Is.

BACKGROUND ON THE COMPANY

Introduction: This case is based heavily on an interview with AeroSoft, Inc. President William D. McGrory, Ph.D., on December 21, 2004 and on the company's Web site. AeroSoft, Inc. is located at 1872 Pratt Drive, Suite 1275, Blacksburg, VA 24060-6363 (phone 540-557-1900; fax 540-557-1919). The Web site is <*http://www.aerosft.com*>.

The company was founded and incorporated in 1988 by Dr. Robert Walters.

It was set up to develop, license, market and support software for computational fluid dynamics (CFD) applications, utilizing novel algorithms which expand the capabilities of its users. AeroSoft also provides customized solutions for aerospace and military clients which wish to hire the expertise needed to solve individual problems, but with no interest in purchasing CFD software.

Company History: As described on AeroSoft's Web site, the company history is as follows. AeroSoft was founded in 1988 by Dr. Robert Walters. In 1990, AeroSoft developed GASP v1 (structured code). GASP v2 was released in 1992 and in 1995, the company released GASP v3 (parallel CFD solver with GUI). In 1996, AeroSoft's focus shifted from CFD analysis to CFD analysis and design. Dr. Walters sold the company to Dr. William McGrory in 1998. In 1998, the company released GUST v1 (unstructured flow solver and grid generator). Also, in 1998, the company released SENSE v1 as a sensitivity analysis tool. In 2001, the company released both GASP v4 and GUST v2.

Principal Business: The principal business is engineering research and development. It is a government contractor and engineering service provider in the aerospace and defense industries.

AeroSoft had total revenue of $1.1 Million in 2005. For AeroSoft, SBIR/STTR funding as a percentage of revenue was 36 percent last year. The company has had no patents or IPOs as a result of SBIRs. It has had 15 Phase I and eight Phase II awards, with five Phase Is and two Phase II awards from NASA The initial Phase II came through NASA Langley, in 1993 with a second one in 1996 from MSFC. More recently, SBIR Phase II awards have come through the Air Force and Navy. The company had no funding at the time of the first SBIR award except for a few small consulting contracts. The faculty member who owned the company at the time funneled the contracts through the company.

In 1993, the company had five employees and it currently has eight. The company should be categorized as a "lifestyle company" not a "growth company." Dr. William McGrory became president of the company in 1998.

AeroSoft is committed to accelerating the rate at which it brings new CFD capabilities to the aerospace and military markets. Since its inception, the company has strategically utilized the SBIR program to fund innovative research and development and then teamed with strategic allies and/or utilized internal funding to complete the latter stages of product development. The first commercially available product, GASP v2.2 was released in the spring of 1994. In 1994, AeroSoft completed two Phase II SBIR awards sponsored by NASA which provided support for the development of GASPv3 and its unstructured CFD software, GUST. GASPv3 became commercially available in June 1995. AeroSoft has completed the development work on both GUSTv1 (released in December, 1998) and SENSE (released in December, 1998). GASPv4 was released in mid-1999.

All of AeroSoft's contracts have been completed in a timely fashion and on budget. In addition, various commercial licenses to use AeroSoft software are held by 47 organizations including 9 universities, 14 government facilities, 20 commercial entities, and 4 overseas organizations. AeroSoft has been engaged in general consulting and contracting work for some of the major aircraft companies including The Boeing Company, McDonnell Douglas Corporation, General Dynamics, Pratt & Whitney, and General Electric. It has also been team members of the Aero-Thermal Technology Development Program sponsored by the U.S. Army Strategic Defense Command.

The company has three related technologies—engineering software packages—that have been developed and in each case, SBIR funding played an important role. Currently, about 50 percent of the revenue comes from SBIR/STTR and other government contracts (with the Air Force currently) and 50 percent of the revenue comes from licenses sales that have been a commercial success. The firm was initially woman-owned but is not currently.

Linkage to University—AeroSoft has a strong linkage to Virginia Tech. Several members of the firm's technical staff were Ph.D.s from Virginia Tech including its CEO.

TECHNOLOGY OF THE COMPANY

GASP is AeroSoft's most important innovation. It is an engineering analysis tool (computer software) to predict aerodynamics/gas dynamics with regard to any aircraft or spacecraft. It involves computational fluid dynamics and is a structured solver.

The Web site description of GASP is as follows: GASP is a structured, multiblock CFD flow solver which solves the Reynolds Averaged Navier-Stokes (RANS) equations. It is applicable to compressible flow fields approximately Mach 0.1 and greater. This would include flows with finite-rate or equilibrium chemistry, such as combustion problems or reentry type flows. GASP can perform both steady and time accurate simulations. The code has a six degree of freedom (6-dof) motion modeling capability and uses a Chimera overlapping grid system for moving body simulations. Overlapping grids may also be used for complex steady state simulations. GASP is the firm's most stable, and validated product.

A second technology, GUST, is similar to GASP in that it is set up to predict aerodynamics. It is an unstructured solver.

The Web site description of GUST is as follows: GUST, in a nutshell is an unstructured version of GASP. It too is a compressible CFD flow solver for anything from perfect gas calculations up to finite-rate chemistry, with non-equilibrium thermodynamics (like GASP). However, GUST operates on unstructured or arbitrary control volumes. Currently the grid generators that interface with GUST generate tetrahedral, pyramids, prisms, and hexahedra (brick element). So, one can run on a GASP type structured grid, but also more grid types.

AeroSoft's third technology is SENSE. This is a designer tool as opposed to an analysis tool. It is for the same applications as GUST and GASP. It provides design sensitivities and determines how performance will change as you vary the property of the vehicle or the flow. SENSE is used in the design phase.

The Web site description of SENSE is as follows: SENSE takes a user supplied structured multiblock cfd solution, and will predict the variation about that solution with respect to one or more design variables. For example, it will tell one how the entire solution at a point will vary as one changes the angle of attack. SENSE in not meant to replace a CFD solver, but to augment it.

The government determines "Grand Challenge Problems"—that is, the government decides what uses there are for supercomputers in predicting turbulence. GASP is used for some of these applications. NASA and the Air Force uses GASP on the supercomputer and it is licensed from AeroSoft. An important aspect of the product's success is that anyone using the supercomputer can use GASP.

There are licenses with government as well as with Northrup Grumman, some large aerospace firms, and some small aerospace firms. AeroSoft also exports to Japan (to the space industry, i.e., the NASA equivalent and also Japanese contractors), Israel (military applications), and France (military applications). Also, several U.S. universities use GASP. Occasionally AeroSoft will use the software to do engineering analysis but mostly it licenses it. It has not done much to market the product. It is sometimes paid to add features to GASP. This is all a very small part of its activities.

COMMERCIALIZATION

The impact that AeroSoft's technologies have on its customers includes reduced cost, additional capability, higher quality, and increased ability to achieve agency mission.

Potential software applications (as listed on the company's Web site) include the following:

- Configuration analysis.
- General aeronautical education.
- Expendable launch vehicles.
- Aero-thermodynamic analysis.
- Experimental validation.
- Basic algorithm research.
- Re-entry heating problems.
- Waverider design.
- Propulsion.
- Space shuttle analysis.
- Chemical deposition lasers.
- Civil transport analysis and design.

- Shock-boundary layer interactions.
- X-33 analysis.
- Rocket analysis.
- Internal flow analysis.
- Missile defense.

IMPORTANCE OF SBIR

The SBIR program was critical to the formation of the firm. AeroSoft would not have existed without SBIR. For the first four years, AeroSoft, Inc. was a paper company to bid on SBIRs and it had no employees. Its first Phase I, through NSF, did not turn into a Phase II. Then the company won two NASA Phase I awards that became Phase II awards. The growth of the company is completely attributable to SBIR (it was 90 percent of the revenue). It took seven years for the technology to get commercialized and then gradually the firm got up to the 50/50 ratio that it now has with SBIRs and other revenue. The firm does STTRs as well as SBIRs. It does not really distinguish between the two since it often teams with universities on SBIR awards. It finds the research goals are about the same for SBIR and STTR.

AeroSoft currently has an Air Force SBIR Phase II. Of its Air Force contracts, now two-thirds are SBIRs with the Air Force and the other one third are other non-SBIR Air Force contracts. AeroSoft still sells licenses to NASA but does not currently have a NASA SBIR award. It has licenses for its software with NASA Glenn, Langley, and Johnson. NASA Ames uses a copy of the software but it does not currently support the firm. The company has received SBIR awards from NASA Langley, Ames, and Marshall. NASA and the Air Force use GASP on HPC MSRC facilities.(High Performance Computing Major Shared Resource Center) Anyone who uses these supercomputer facilities can use GASP due to the licensing arrangement. This is a clear positive spillover effect of the firm's research output.

The SBIR awards may or may not have had an effect on securing other financing. It may have been mildly beneficial with banks. The company is not in search of VC funding or other private investors. SBIR did help the company get Air Force non-SBIR contracts. The SBIR gave core engineering technologies to the company. There are fundamental algorithms and physical modeling directly attributable to SBIR.

SBIR not only helped the company survive, but more recently, it helped to maintain some of its critical employees. It has also helped with growth, too. In the future, AeroSoft is planning to go with the model it currently has. If it were to expand at all, it would do some applications.

AeroSoft has no patents from SBIR project. There are many research publications that came out of the company's SBIRs. Most are customers. There were approximately 30 publications authored by researchers from AeroSoft.

NASA Phase II Projects: The following summarizes the two NASA Phase II projects that AeroSoft has had:

1. Year of Award: 1993.
   Project Title: Computational Fluid Dynamics Enhancements to Reduce End-User Work Load.
   Sales to: (a) DoD/Primes: $110,000; (b) Private Sector: $16,126. Additional Investment: 0.
2. Year of Award: 1993.
   Project Title: A Generalized Computational Fluid Dynamics Package for All Mach Numbers.
   Sales to: (a) DoD/Primes: $1,922,462; (b) Export: $34,525; (c) Private Sector: $1,819,854.
   Additional Investment: 0.

AeroSoft has also been awarded SBIR Phase II awards from two other agencies. These are Navy and the Air Force.

ISSUES WITH CURRENT SBIR PROGRAM

The company became aware of SBIR from the solicitation from NSF. AeroSoft's CEO was in the academic community with university connections. There was no geographical connection to SBIR agencies. To determine which agency it would apply to, the basis was the research topics and agencies where the company had applicable strengths. Basically, it was looking for key words of "high speed aerodynamics."

While the firm does not see any particular differences across NASA centers, there were big differences between the SBIR programs at DoD and NASA. However, while the introductory sections of the proposals differ, the meat of the proposals is about the same.

AeroSoft's strategy is limited by the topics available. In the past, it has had a good success rate. It has gotten more difficult as the number of companies competing increases. AeroSoft's strategy is basically to pick the number of proposals on which it has time to do a good job. It does a manageable number of proposals given the staffing constraints. That strategy does pay off. It once had the entire firm working on proposals for a couple of months. Now it spends relatively little time and picks the ones it is expert in.

It has proven itself as an Air Force contractor. While Phase I is a short rushed time frame, Phase II is more like a regular Air Force contract. It is able to establish a relationship and get good closure on a research topic.

How Would It Change the SBIR Process?—It is hard to get good two-way communication. This is not uniform across Technical Points of Contact (TPOCs) and depends on who you talk with to get different quality of information. The company wants to be sure it is worthwhile to propose the topics.

In terms of debriefings, most of the debriefs simply state that "you did a great job technically but we didn't pick you," with no indication of whether you should come back. The company must use its own judgment about whether to go back. It should be noted that SENSE did a couple of Phase Is before it went into Phase II.

There is a pretty good range of topic specifications. Commercialization potential depends on the project.

In regard to frequency of solicitation, the Air Force has two rounds, but these are not always topics to which AeroSoft could submit. AeroSoft would opt for a more uniform distribution of topics as opposed to a higher frequency of announcements. It is feast or famine with regard to topics.

AeroSoft has had very little success in getting third-party private investment via Phase IIB. It basically plows back the licensing revenue into the firm. This is more a function of the software aspect of the product. There are not many third parties who want to commit money. It can get letters of support from third parties but not funding. The company would like to see more flexibility in government funding Phase III or IIB. In its case, the firm is technically top heavy and its sales and marketing are weak.

Selection Process

The company sees that fairness of the program selection process varies. Politics play a role. How strongly a champion fights for you matters. But it has won its share and lost its share, so it is not complaining.

The feedback the company gets is not too helpful. There needs to be more candor. The company never knows anything about winners or other losers. It would be good to know from the debriefing that with certain changes it would want to resubmit the proposal.

Funding Lags

With regard to funding delays and time lags between Phases I and II, the owner has had to take out loans to keep staff on board. So the program should try to improve the continuity of topics. The company liked the idea of Phase I follow on and is sorry to see it go.

Size and Number of Awards

In regard to the size and number of awards, the company would not opt for fewer larger ones. It prefers enough opportunities for the company. The dollar amounts are minimally adequate. It would add more contracts at current levels of funding per award. Note that computer equipment costs have actually gone down, so for its case, it is still able to fund the same number of man-hours with the relatively fixed level of awards.

An interesting note—The Air Force has split SBIRs. For Phase II awards, it will give one half of Phase II and then have to resubmit for new statement of work. In terms of software development, the company does this. In terms of software research, the agency wants it this way. It produces less high risk projects. This is not necessarily a good thing. The company will do either high or low risk projects. However, it is a problem that the SBIR program has it written in the "rules" that the project be high risk work. If a response is low risk, but that is what the customer really wants, then it is hard to make it through the selection process.

Strengths of SBIR Program

The company cited two program strengths. First, the SBIR program is a cost-effective model for small business to obtain government funded projects. Small companies are intimidated by the requirements for large contracts and the SBIR program eliminates the intimidation factor. Second, there are generally good topics to apply to over time.

Weaknesses of SBIR Program

There were a few weaknesses cited by AeroSoft. First, the people writing the tasks and research topics are potential high risk takers but opt for lower risk projects. Second, there is an inconsistency of topics. It is either feast or famine on some topics. Finally, there is inadequate feedback on losing Phase Is.

Suggested Changes

AeroSoft advocates for increased funding for this good program. Its perception is that the sponsors are not funding all the projects it would like.

ARACOR[1]

Michael S. Fogarty
Portland State University
and Case Western Reserve University

April 28, 2005

OVERVIEW

ARACOR (Advanced Research and Applications Corporation) was started in 1977 by Dr. Robert A. Armistead in Sunnyvale, California, a part of Silicon Valley. An ARACOR office is also located near Wright-Patterson Air Force Base's Air Force Research Laboratory in Dayton, Ohio. Armistead is the company's president. ARACOR was purchased in January 2004 by OSI Systems, Inc., a NASDAQ company, and is now known as Rapiscan Systems High Energy Inspection Corporation

ARACOR's story revolves around the early development of industrial X-ray computed tomography (CT). Over time, their development of CT technology and involvement in high energy X-ray imaging led to the development of a mobile X-ray inspection system (Eagle) which is now being used by of the Department of Homeland Security at U.S. Seaports and Borders to inspect containers and trucks. Armistead began development of the technology at SRI International; he left SRI to start ARACOR in 1977. Almost three decades later, the firm was purchased by OSI Systems. ARACOR became a public company in January 2005. Armistead continues as the company's president. From startup until purchased by OSI, the company had received 78 Phase I and 42 Phase II awards.

Armistead sees their location in the Bay Area as providing significant advantages, including the availability of complementary technology and resources and a large workforce of scientists and engineers. Also in the area are major universities and two national laboratories.

This case illustrates several important issues for the SBIR program: 1) the importance of sustained, strategic use of a large number of SBIR awards by one company over a long period of time; 2) the significance of SBIR during periods when other potential sources of early-stage funding, such as VC companies, show no interest because the technology is viewed as too risky and doesn't offer a large commercial market; 3) the founder's skill in competing for SBIR awards from several agencies while utilizing the funding to build the company sufficiently to gain contract funding from several federal agencies (i.e., the founder was able to meet the company's short-term needs while continuing to develop the technology

[1]Based on an interview with Dr. R. A. Armistead, ARACOR's president, Sunnyvale, California; Web site information; patent data from USPTO; and the DoD's SBIR database.

over a long period of time); and 4) Although the Eagle was developed to support the "war on drugs," it has become even more vital after 9-11. Most important, with increasing emphasis on using SBIR to support shorter-term mission objectives, we should ask: How will proposals from today's budding ARACORs be evaluated and what are the implications for U.S. technology innovation?

COMPANY AND FOUNDER BACKGROUND

Dr. Armistead attended the Virginia Military Institute. With his ROTC service deferred, he received an Oak Ridge National Laboratory graduate fellowship to Carnegie Mellon University in Pittsburgh, PA. He completed his doctorate research on site at the Oak Ridge National Laboratory, Tenn. After graduate work, he fulfilled his military service stationed at the Pentagon. He was assigned to DASA (Defense Atomic Support Agency), which was responsible for stockpiling and underground tests of nuclear weapons. Armistead acted as liaison with several West Coast companies, including Stanford Research Institute (SRI) and Lockheed. After completing his military commitment, he took a position with SRI, where he became manager of the radiation and solid-state physics department. During this time he obtained a master's degree in business administration from the University of Santa Clara.

The Nobel Prize in medicine was awarded to two scientists who developed the CAT scan (computed axial tomography) in the mid-1970s. While several companies focused on medical applications, Armistead saw the need and possibility of using the science for applications to inanimate objects. Importantly, industrial applications could ignore obstacles that existed in medical applications, such as the human-safe level of radiation tolerance (120kV; current ARACOR systems employ up to 15MV) and image blurring due to involuntary patient motion. This produces CT systems with significantly higher performance and enables the inspection of a wide variety of objects ranging from automobile parts to nuclear weapons. At the same time, the industrial applications of CT scanner technology create new problems, such as issues involving variation in materials and the large size of objects. It was necessary to use a higher level of energy and X-rays that are more penetrating. Industrial applications also required the development of more complex computer algorithms. Effective March 2005 ARACOR's name was changed to Rapiscan Systems High Energy Inspection Corporation.

ARACOR Was Just Purchased by OSI Systems

Bob Armistead founded ARACOR in 1977 after leaving SRI and developing a contract relationship with Aerojet Strategic Propulsion Company, which needed an application of Armistead's technology. The technology was first used to find defects in solid rocket motors. This application drew on one DSAT project, an

SBIR from the Air Force and an SBIR program from the National Science Foundation. As of January 7, 2005, ARACOR became a wholly owned subsidiary of OSI Systems, Inc. OSI Systems is a diversified global developer, manufacturer and seller of several products: medical monitoring, optoelectronic-based components and systems, and security and inspection systems. With more than 30 years of optoelectronics experience, OSI competes in three areas: Medical Devices, OEM Manufacturing, and Security and Inspection Systems.

Develops and Manufactures CT Systems for Industrial Purposes

ARACOR develops and manufactures X-ray test and inspection systems for industrial purposes. These include nondestructive evaluation and process control applications, and manufactures cargo inspection systems. ARACOR is a leading manufacturer of digital radiographic (DR) and computed tomography (CT) systems. They also provide research services in related areas.

ARACOR's SBIR-Supported Technology Supports Homeland Security

One Homeland Security example is the Eagle, which is a mobile and relocatable high-energy X-ray system for inspecting vehicles and cargo containers. In less than 30 seconds, the Eagle can scan a densely-loaded 20-foot container using full penetration and resolution. The resulting high quality X-ray images are immediately available to an inspector on the Eagle or can be wirelessly transmitted to a remote facility. Major competitors are large firms in the security business, such as SAIC and AS&E. ARACOR's Eagle received a 2004 R&D 100 award for their technology. The Eagle also got the "Best of the Best" award from R&D Magazine in 2004.

ARACOR TECHNOLOGY

ARACOR utilizes X-ray computed tomography technology for several CT applications. CT is a digital X-ray inspection technology used to produce images of an object's internal features, including information characterizing the object's materials and geometry. The CT data can be processed and used for various purposes: reverse engineering, metrology, and two and three-dimensional visualization.

ARACOR has developed a proprietary X-ray detector system, which is a foundation for their high-energy X-ray imaging products. This system uses advanced, solid-state linear-array detector technology. As a result, they achieve important performance advantages relative to systems based on film and fluorescent-screen technologies. Advantages include superior rejection of scattered radiation, greater dynamic range, and higher detection efficiency.

COMMERCIALIZATION

ARACOR received an early important California contract in a bid against several other large firms. Their first contract was $3 million for CT for finding defects in rocket engines.

Much later, they received a U.S. Customs $20 million contract for several Eagle systems to search for drugs.

ARACOR has had $25 million sales of the Eagle, which is used for inspection of sea containers, and trucks to detect contraband.

According to Armistead, the primary indication of the company's commercial value occurred with its acquisition by OSI Systems, Inc. After U.S. Customs gave them $20 million for the Eagle, which was about two years ago, they got inquiries from VC and private equity capital firms. There were eight suitors. They finally went with one that was already involved in security and had worldwide marketing resources. This was OSI Systems.

IMPORTANCE OF SBIR

ARACOR Founded Prior to SBIR Creation

Despite the early connection to SBIR, the firm's startup was not associated with SBIR. ARACOR was founded several years prior to SBIR's creation. By the time ARACOR received its first SBIR award it employed about 20 people. When it became a public company in January 2005, the company which outsources much of its manufacturing, employed 33 people as of February 15, 2005.

Other Early-state Funding

The company's earliest funding came from Armistead and his family. There were no other investors; ARACOR did not receive either Angel or VC funding. Initially, VC funding was not an option because the VC had to see both the product and a market of major dimensions. At the time, they only had the technology.

Armistead views a Phase III activity as carrying a product developed during Phase I and II to the next level, Phase III could entail delivering additional units to the government agency that funded the program; extending the technology to other types of systems and/or applications; or developing a commercial product.

ARACOR Has Received 120 SBIR Awards Over Two Decades

Prior to its purchase, ARACOR received a large number of SBIR awards: 78 Phase I and 42 Phase I coming from NSF, DoD and NASA. Their original award was with Wright-Patterson Air Force Base in Dayton, Ohio. Armistead believes that SBIR's strength is also its weakness: The SBIR award requires the development of a new innovative technology, but only guarantees that there is a market for one unit. Thus, while the government agency may satisfy its requirement, there may not be a follow-on market for the new product. The weakness is that only one sale is guaranteed. There is no #2 guaranteed. In other words, the SBIR is primarily technology driven rather than product driven.

ARACOR had 23 employees at the time it received its first SBIR award. Although ARACOR was not founded because of an SBIR award, the Eagle is a derivative of the technology developed with the SBIR awards. As the founder pointed out, "the SBIR is a brick, not a building." A combination of SBIR awards were used to build the CT industrial inspection technology. Some of the later awards were used to demonstrate how CT technology could be used for different applications, such as the inspection of materials, nondestructive inspection of rocket motors, the quality assurance of nuclear weapons, etc.

SBIR Awards Helped to Strategically to Build and Control the Company's Growth

Although the company wasn't founded because of SBIR awards, the SBIR programs were very important in developing the company's technology and products. Therefore, SBIR both directly and indirectly contributed to the company's growth and to the current employment level. One key to their success is that ARACOR never bid on SBIR just to get an SBIR; the view is that the project must fit strategically. Armistead pointed out that some companies seek VC funding in order to develop their technology and products. However, to receive VC funding, the company must be able to demonstrate a potentially large commercial market. SBIR funding on the other hand is awarded on the basis of the value and uniqueness of the technology and enables government organizations to satisfy arising problems even when there is not a demonstrable market for the new technology system.

Their Technology Has Triggered Further Developments by Other Companies

SBIR awards were very important in supporting the development of the firm's technology capabilities. Some of ARACOR's patents and key products were based on technology that evolved from R&D supported by SBIR. ARACOR was first to offer computed tomography (CT) scanners for industrial applications. Their technology appears to have helped trigger further technology development by other companies, including GE and InVision Technologies, which later introduced their own industrial CT systems.

Several additional issues emerged. First, although the company lists three patents as resulting from SBIR projects, patenting has not been the primary tool for developing and commercializing ARACOR's technology. Second, SBIR's primary role in marketing ARACOR's capabilities was the development of the technology itself and the applications that came from the SBIR programs rather than information about the company's winning of SBIR awards. Third, the company did not participate in business/commercialization support activities provided by either SBIR agencies or states.

ISSUES WITH THE CURRENT SBIR PROGRAM

Too Much Phase I to Phase II Delay

One difficulty with SBIR is that you can have a great idea but there is too much delay. This begins with waiting for topics/subtopics. Once the proposal is written, it's necessary to wait six months to get a Phase I award to do "proof of principle" for $100,000. Then, after a successful Phase I, there is often another 6-12 month delay for the Phase II award. By this time the technical concept is two years old before getting to the Phase II program.

ARACOR prefers DoD's "Fast Track." At the completion of a Phase I proposal a Phase II proposal can be submitted. DoD provides funds to keep the project team together and focused on the technology. In other cases the company found it difficult to hold a team together with delays between Phase I and II awards. However, they pursued other projects so that the company wasn't dependent on SBIR awards.

A Preference for Larger Awards Over More SBIRs

The sense was that within limits the program could make trade-offs between the award size and the number of awards. Nevertheless, certain important products couldn't be developed with the current amounts. For example, their first CT system order with the Air Force was $3 million, which clearly can't be developed under a $50,000 SBIR award.

Armistead had no complaints concerning the fairness of the award selection process, although he wasn't familiar with the selection details.

In summary, Armistead thinks SBIR is a valuable and successful program. He believes that the awards should be used to enable the government to benefit from the innovative ideas of small businesses and strong encouragement should be provided to commercialize important new technology. He believes that some checks and balances should be established to prevent firms from just existing only to receive SBIR awards.

Creare, Inc.

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OVERVIEW

Creare, Inc., is a privately held engineering services company located in Hanover, NH. The company was founded in 1961 by Robert Dean, formerly a research director at Ingersoll Rand. It currently has a staff of 105 of whom 40 are engineers (27 PhDs) and 21 are technicians and machinists. A substantial percentage of the company's revenue is derived from the SBIR program. As of Fall 2004, Creare had received a total of 325 Phase I awards, 151 Phase II awards—more in the history of the program than all but two other firms.[2] While its focus is on engineering problem solving rather than the development of commercial products, since its founding it has been New Hampshire's version of Shockley Semiconductor, spawning a dozen spin-off firms employing over 1500 people in the immediate region, with annual revenues reportedly in excess of $250 million.[3]

Creare's initial emphasis was on fluid mechanics, thermodynamics, and heat transfer research. For its first two decades its client base concentrated in the turbo-machinery and nuclear industries. In the 1980s the company expanded to energy, aerospace, cryogenics, and materials processing. Creare expertise spans many areas of engineering. Research at Creare now bridges diverse fields such as biomedical engineering and computational fluid and thermodynamics.

At any given point in time Creare's staff is involved in approximately 50 projects. Of the 40 engineers, 10-15 are active in publishing, external relations with clients, and participation in academic conferences. The company currently employs one MBA to manage administrative matters (though the company has operated for long periods of time with no MBAs on staff). As Vice President and Principal Engineer Robert Kline Schoder states, "Those of us who are leading business development also lead the projects, and also publish. We wear a lot of hats."

The company's facilities comprise a small research campus, encompassing over 43,000 square feet of office, laboratory, shop, and library space. In addition to multipurpose labs, Creare's facilities include a chemistry lab, a materials lab with a scanning electron microscope, a clean-room, an electronics lab, cryogenic

[2]The other two firms are Foster-Miller (recently sold, and no longer eligible for the SBIR program) and Physical Science, Inc.

[3]A list is given in the annex to this case study.

test facilities, and outdoor test pads. On-site machine shops and computer facilities offer support services.

FIRM DEVELOPMENT
FOUNDING AND GROWTH

Creare's founder, Robert (Bob) Dean, earned his Ph.D. in engineering (fluid/thermal dynamics) from MIT. He joined Ingersoll Rand as a director of research. Not finding the research work in a large corporation to his liking, he took an academic position at Dartmouth's Thayer School. Soon thereafter, he and two partners founded Creare. One of the two left soon after the company's founding; the other continued with the company. But for its first decade, Robert Dean was the motive force at Creare.

Engineer Nabil Elkouh relates that the company was originally established to "invent things, license the inventions, and make a lot of money that way." Technologies that would yield lucrative licensing deals proved to be difficult to find. The need to cover payroll led to a search for contract R&D work to cover expenses until the proverbial "golden eggs" started to hatch.

The culture of the company was strongly influenced by the personality of the founder, who was highly engaged in solving research and engineering problems, but not interesting in building a commercial company—indeed, it was precisely to avoid a "bottom line" preoccupation that he had left Ingersoll Rand. Thus, even the "golden eggs" that Bob Dean was focused on discovering were innovations to be licensed to other firms, not innovations for development at Creare.

As Elkouh observes "the philosophy was—even back then—that what a product business needs isn't what an R&D business needs. You're not going to be as creative as you can be if you're doing this to support the mother ship. . . . Products go through ebbs and flows and sometimes they need a lot of resources." Furthermore, Dean was a "small organization person," much more comfortable only in companies with a few dozen people than in a large corporation. A case in point: In 1968, Hypertherm was established as a subsidiary within Creare to develop and manufacture plasma-arc metal-cutting equipment. A year later Creare spun off Hypertherm. Today, with 500 employees, it is the world leader in this field.

By 1975, an internal division had developed within Creare. Where Dean, the founder, continued to be focused on the search for ideas with significant commercial potential, others at Creare preferred to maintain the scale and focus consistent with a contract research firm. The firm split, with Dean and some engineers leaving to start Creare Innovations. Creare Innovations endured for a decade, during which time it served as an incubator to three successful companies: Spectra, Verax, Creonics.

The partners who remained at Creare, Inc., instituted "policies of stability" that would deemphasize the search for "golden eggs"—ultimately including policies, described below, to make it easy for staff members to leave and start companies based upon Creare technologies.

The nuclear power industry became the major source of support for Creare. That changed quickly following the accident at Three Mile Island. At about the same time, the procurement situation with the federal government changed. Procurement reform made contracting with the federal government a far more elaborate and onerous process than it had been previously. As research funds from the nuclear industry disappeared and federal procurement contracts became less accessible to a firm of Creare's size, the company was suddenly pressured to seek new customers for its services.

In the wake of these changes came the SBIR program. The company's president at the time, Jim Block, had worked with the New Hampshire Senator Warren Rudman, a key congressional supporter of the original SBIR legislation. As a consequence, the company knew that SBIR was on its way. Creare was among the first firms to apply for, and to receive, an SBIR award.

Elkouh notes that "early in the program, small companies hadn't figured out how to use it. Departments hadn't figured out how to run the program." The management of the project was ad hoc. The award process was far less competitive than it is today." Emphasis on commercialization was minimal. Program managers defined topics according to whether or not they would represent an interesting technical challenge. There was little intention on the part of the agency to use the information "other than just as a report on the shelf."

IMPACTS

From the earliest stages of its involvement in the SBIR program, Creare has specialized in solving agency initiated problems. Many of these problems required multiple SBIR projects, and many years, to reach resolution. In most instances, the output of the project was simply knowledge gained—both by Creare employees directly, and as conveyed to the funding agency in a report. Impacts of the work were direct and indirect. As Elkouh states: "You're a piece in the government's bigger program. The Technical Program Officer learns about what you're doing. Other people in the community learn about what you're doing—both successes and failures. That can influence development of new programs."

Notwithstanding the general emphasis within the company on engineering problem solving without an eye to the market, the company has over thirty years generated a range of innovative outputs. The firm has 21 patents resulting from SBIR-funded work.[4] Staff members have published dozens of papers. The firm has licensed technologies including high-torque threaded fasteners, an aid in breast cancer surgery, corrosion preventative coverings, an electronic regulator for firefighters, and mass vaccination devices (pending). Products and services de-

[4]Numbers as of fall 2004.

veloped at Creare include thermal-fluid modeling and testing, miniature vacuum pumps, fluid dynamics simulation software, network software for data exchange, and the NCS Cryocooler used on the Hubble Space Telescope to restore the operation of the telescope's near-infrared imaging device.

In some cases, the company has developed technical capabilities that have remained latent for years until a problem arose for which those capabilities were required. The cryogenic cooler for the Hubble telescope is an example. The technologies that were required to build that cryogenic refrigerator started being developed in the early 80s as one of Creare's first SBIR projects. Over 20 years, Creare received over a dozen SBIR projects to develop the technologies that ultimately were used in the cryogenic cooler. Additionally, Creare has been awarded "Phase III" development funds from programmatic areas that were ten times the magnitude of all of the cumulative total of SBIR funds received for fundamental cryogenic refrigerator technology development. However, until the infrared imaging device on the Hubble telescope failed due to the unexpectedly rapid depletion of the solid nitrogen used to cool it, there had been no near-term application of the technologies that Creare had developed. The company has built five cryogenic cooler prototypes, and has been contacted by DoD primes and other large corporations seeking to have Creare custom build cryogenic coolers for their needs.[5]

Cooling systems for computers provide another example. The company worked intensively for a number of years in two-phase flow for the nuclear industry. This work branched into studies of two-phase flow in space—that is, a liquid-gas flow transferring heat under microgravity conditions. In the course of this work, the company developed a design manual for cooling systems based on this technology. The manual sold fifteen copies. As Elkouh observes, "there aren't that many people interested in two-phase flow in space." A Creare-developed computer modeling program for two-phase flows under variable gravity had a similar limited market. Ten years later, Creare received a call from a large semiconductor manufacturing company seeking new approaches to cooling its equipment because fans and air simply were not working any more. This led to a sequence of large industrial projects doing feasibility studies and design work to assist the client in evaluating different possible cooling systems, including two-phase approaches. The work covered the spectrum from putting together complete design methods—based on work performed under SBIR awards—to building experimental hardware. Most recently, NASA has contacted Creare with a renewed interest in the technology. From the agency standpoint, there is a benefit to Creare's relative stability as a small firm: They don't have to go back

[5]See National Aeronautics and Space Administration, "Small Business/SBIR: NICMOS Cryocooler—Reactivating a Hubble Instrument," *Aerospace Technology Innovation* 10(4):19-21, 2002. Access at <*http://ipp.nasa.gov/innovation/innovation104/6-smallbiz1.html*>. See also <*http://www.nasatech.com/spinoff/spinoff2002/goddard.html*>.

to square one to develop the technologies if a need disappears and then arises again years later.

As academic research in the 1990s demonstrated the power of small firms as machines of job creation, the perception of the program changed. In the process, the relationship of perennial SBIR recipient firms such as Creare changed as well. These new modes of relationship, and some recommendations for the future, are described below.

SPIN-OFF COMPANIES

The success of the numerous companies that have spun off from Creare naturally leads to the question: Is fostering spin-offs an explicit part of the company's business model?

The answer is no to the extent that the company does not normally seek an equity stake in companies that it spins off. The primary reason has to do with the culture of Creare. Elkouh states that, as a rule, Creare has sought to inhibit firms as little as possible. "If you encumber them very much, they're going to fail. They are going to have a hard enough row to hoe to get themselves going. So, generally, we've tried to institute fairly minimal encumbrances on them. We've even licensed technology to companies who've spun off on relatively generous terms for them."

Does the intermittent drain of talent and technology from Creare due to the creation of spin-off firms create a challenge to the firm's partners? According to Kline-Schoder, no: "It has not happened all that often and when it has, opportunities for people who stay just expand. It's not cheap [to build a company] starting from scratch. So there's a barrier to people leaving and doing that. The other thing—in some sense, is that Creare is a lifestyle firm. Engineers are given a lot of freedom—a lot of autonomy in terms of things to work on. We think that Creare is a rather attractive place to work. So there's that barrier too."

ROLE OF THE SBIR PROGRAM

The founding of Creare pre-dated the start of the SBIR program by 20 years. However, SBIR came into being at an extremely opportune moment for the firm. It is very difficult to say whether or not the firm would have continued to exist without the program, but it is plain that the streamlined government procurement process for small business contracting ushered in by the SBIR program facilitated its sustainability and growth. In the intervening years, the SBIR program and technologies developed under the program have become the primary sources of revenue for the firm.

What accounts for the company's consistent success in winning SBIR awards? Kline-Schoder relates that "I've come across companies that have spun-out of a university or a larger organization. I routinely receive calls—five years or more after I met these startups—calling us and asking 'We were wondering, how you guys have been so successful? Can you tell us how do you do it?'"

As reported by the firm's staff members, Creare's rate of success in competitions where it has no prior experience with the technology or no prior relationship with the sponsor—"cold" proposals—is about the same as the overall average for the program. However, in domains where it has done prior work, the company's success rate is higher than that of the program overall. In some of these cases the author of the technical topic familiar with Creare's work may contact the firm to make them aware of the topic (this phenomenon is not unique to Creare).

Where the company has success with "cold proposals," it is often because the company successfully bridges disciplinary boundaries. In these instances, as Elkouh states, "we may have done something in one field. Someone in a different field needs something that's related to our previous work and we carry that experience over."

IMPROVING THE ADMINISTRATION OF THE SBIR PROGRAM

According to Creare's current staff members, the single most significant determinant of the Phase III potential of a project is the engagement of the author of the technical topic. Kline-Schoder states: "If your goal is to, at the end, have something that transitions (either commercially or to the government) having well written topics with authors who are energetic enough and know how to make that process happen. Oftentimes we see that you develop something, it works—it's great—and then the person on the other side doesn't know what to do. Even if you sat it on a table, the government wouldn't know how to buy it. There's no mechanism for them to actually buy it."

It is something of an irony that today, forty years after its founding, Creare is increasingly fulfilling the original ambitions of its founder: earning an increasing share of its revenue from the licensing of its technologies. Here, also, the active engagement of the topic author is critical. In one instance Elkouh worked with a Navy technical topic manager who saw the potential in a covering that had been developed at Creare with SBIR funds. This individual introduced him to over 300 people, and helped set up 100 presentations. That process led to Creare making a connection with a champion within a program area in the Navy who had the funds and was willing to seek a mechanism to buy the technology from Creare for the Navy's use.

However, even in this instance, concluding the license was not a simple matter. The appropriation made it into the budget—but that funding was still two years away. Elkouh: "The government funded the development of the technology because there was a need. Corrosion is the most pervasive thing that the Navy actually fights—a ship is a piece of metal sitting in salt water. There were reports from the fleet of people saying 'We want to cover our whole ship in this.' So now you have the people who use it say they want it, but who buys it? There is this vacuum right there—*who buys it*?"

With regard to contracting challenges, the SBIR program has largely solved the problem of a small business receiving R&D funds. From the standpoint of the staff interviewed at Creare, the contracting process directly related to the award is straightforward. What the SBIR program has not solved is the challenge of taking a technology developed under the SBIR program and finding the place within the agency, or the government, that could potentially purchase the technology.

Large corporations are no more willing to fund technology development than are government agencies. Kline-Schoder reports being approached by a large multinational interested in a technology that had been developed at Creare. The company offered to assist Creare with marketing and distribution once the technology had been fully developed into a product. However, the company was unwilling to offer any of the development funds required to get from a prototype to production.

Further obstacles to the commercial development of SBIR-funded technology are clauses within the enabling legislation pertaining to technology transfer. Kline-Schoder: "FAR clauses were in existence before the SBIR program. They were inherited by the SBIR program, but they don't fit. For instance, they state that the government is entitled to a royalty-free license to any technology developed under SBIR. But there has never been a clear definition of what that means." In one instance Creare developed a coating of interest to a private company for use in a specific product. The federal government was perceived ultimately to be the major potential market for the product in question. The issue arose: Could the company pay a royalty to Creare for its technology, given that it would be prohibited from passing on the cost to the federal buyer? Contracting challenges related to the FAR clauses created a significant obstacle to the commercialization of the technology, even when two private entities were in agreement on its potential value. "We could potentially be sitting here now looking at fairly substantial licensing revenues from that product as would [the corporate partner] and it's not happening because of that IP issue."

A second issue pertaining to the intellectual property pertains to timing. As the clause is written, a company that invents something under an SBIR is obliged to disclose the invention to the government. Two years from the day that the company discloses, it must state whether or not it will seek a patent for the invention. However, the gap between the start of Phase I and the end of Phase II is most often longer than two years. So the SBIR-funded company is placed in the awkward position of being compelled to state whether or not it intends to seek a patent on a technology essentially before it is clear if the technology works. Pressure to disclose inventions have increased over time, as the commercial focus of the program has intensified. The time pressure is even more severe when Creare seeks to find the specific corporate partner who wants to use the technology in a product. The requirement also, importantly, precludes the SBIR-funded company from employing trade secrets as an approach to protecting its intellectual property—in certain contexts, a significant constraint. Kline-Schoder: "Patenting is not the only way to protect intellectual property. The way things are structured now, you don't have that choice. No matter what invention you disclose, you have to decide within two years whether or not to patent. If you don't patent, then the rights revert to the government." In this context, Creare has a much longer time horizon that most small companies.

The view expressed by the Creare staff members interviewed was that the size of awards is adequate for the scope of tasks expected. The variation in program administration among agencies is a strength of the program—although creating uniform reporting requirements for SBIR Phase III and commercialization data would significantly reduce the burdens on the company.

Finally, from an institutional standpoint, no substitutes exist for the SBIR program. Private firms often will not pay for the kind of development work funded by SBIR. Once the scale of a proposed project grows over $100,000, a private company will question the value of outsourcing the project. Lack of control is also a concern.

CONCLUSION

Creare appears to occupy a singular niche among SBIR-funded companies. The company's forty-year history as a small research firm is one characteristic that sets it apart from other SBIR-funded firms. The many spin-offs it has produced are a second. However, from the standpoint of its ongoing success in the SBIR program and in providing corporate consulting services, Creare's most significant differentiating characteristic may be its range of expertise. The scope of the SBIR-funded work at Creare is very broad. The reports of staff members suggest that the firm's competitive advantage relative to other small research firms is based to a significant extent on that breadth. "A lot of companies compartmentalize people," as Elkouh observes. "Everybody here is free to work on a variety of projects. At the end of the day, the companies I work with think that is where we bring the value." The same factor may account for the longevity of the firm. "We diversified internally by hiring people in different areas. That is when the cross-pollination happened." Areas come and go. Small product companies or small startup companies focused in one area will struggle when the money disappears for whatever reason. Having evolved into a diversified research firm, Creare has endured.

CREARE—ANNEX: SAMPLE OF INDEPENDENT COMPANIES WITH ORIGINS LINKED TO CREARE

- Hypertherm, now the world's largest manufacturer of plasma cutting tools, was founded in 1968 to advance and market technology first developed at

Creare. Hypertherm is consistently recognized as one of the most innovative and employee-friendly companies in New Hampshire.

- Creonics, founded in 1982, is now part of the Allen-Bradley division of Rockwell International. It develops and manufactures motion control systems for a wide variety of industrial processes.
- Spectra, a manufacturer of high-speed ink jet print heads and ink deposition systems (now a subsidiary of Markem Corporation) was formed in 1984 using sophisticated deposition technology originally developed at Creare.
- Creare's longstanding expertise in computational fluid dynamics (CFD) gave birth to a uniquely comprehensive suite of CFD software that is now marketed by Fluent (a subsidiary of Aavid Thermal Technologies, Inc.), a Creare spin-off company that was started in 1988.
- Mikros, founded in 1991, is a provider of precision micromachining services using advanced electric discharge machining technology initially developed at Creare.

Deformation Control Technology, Inc. (DCT)[6]

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May 5, 2005

OVERVIEW

The Deformation Control Technology, Inc., (DCT) case illustrates SBIR's support of a small existing software company whose Midwest market was dramatically changing with an increasingly important role of technology in the region's anchor industries. The SBIR program provided an important source of funding for the company's R&D, permitting them to respond to new market needs. SBIR has played a particularly important role for DCT by contributing 95 percent of the company's R&D funding. The company was awarded four Phase I and three Phase II awards from 1993 to 2005. SBIR awards also helped give better access to the larger defense contractors. DCT continues to operate at a small size, with three employees and annual sales about $600,000.

The industrial changes involved a major technology shift that combined a switch to casting and thermal process of materials and performance of engineering components at high temperature, with the decline of forging in Northeast Ohio as more high-tech companies were gaining ground. The technological change involved a shift to thermal type analyses. The Midwest location is clearly a major factor shaping DCT's experience in commercializing their software.

SBIR awards supported the company's R&D that, for example, created a capability for simulating the causes for material failure and the interrelationship among the various coatings, materials, and how they interact to affect failure rates.

DCT views NASA as increasingly focusing the SBIR program over the last five years specific space-related needs with very little commercial significance for Northeast Ohio, and on interactions with minority companies. Their view is that narrowly focused topics with specific mission objectives significantly limits opportunities for commercialization, which they see as conflicting with SBIR's original purpose. One result is much less incentive to write SBIR proposals. Given the significance of earlier awards in funding nearly 100 percent of its R&D, the implication is that DCT will be increasingly unable to continue making software advances. In particular, they see themselves less able to compete

[6]Based on an interview with Andrew Freborg, April 12, 2005, Cleveland, Ohio, and follow-up communications.

with European companies where governments support research and technical implementation.

COMPANY AND FOUNDER BACKGROUND

The company's founder and president is B. Lynn Ferguson. Ferguson has a doctorate in Materials Engineering from Drexel University. The company was founded by two partners in 1982, but not as a result of SBIR. DCT's president is originally from Philadelphia. Prior to DCT, he worked for TRW in Beechwood, a Cleveland suburb, where he did research on forging and powder metals.

DCT began as a scientific company linked to forging and powder metals. During the 1980s one of the two partners left but the company continued. At the time it was focused on industrial process consulting, which then shifted to forging design process and analysis. Today's company results from the background of the remaining individuals in computer simulation of forging processes. This was DCT's strength in the late 1980s and early 1990s.

DCT Developed in Response to Changes in the Midwest's Forging Industry

DCT describes their capabilities as providing engineering services to the metalworking community, specializing in process simulation and computer-based analysis of thermal and mechanical processes such as heat treatment, forging, rolling, extrusion and powder consolidation.

The marketplace evolved toward more and more emphasis on thermal stress, casting and thermal process of materials and performance of engineering components at high temperature. The shift occurred because the forging industry in Northeast Ohio was declining and more high-tech companies were gaining ground. There shift was toward thermal type analyses. SBIR became key asset for doing the R&D necessary to adjust to the changing market.

ESSENTIAL RESEARCH TECHNOLOGY

DCT Collaborated with the National Center for Manufacturing Sciences in Developing Simulation Software to Solve Thermo-Mechanical Problems for the Heat Treatment Industry

Deformation Control Technology (DTC) has developed simulation software to solve thermo-mechanical problems for the heat treatment industry. The problems include distortion and stress due to casting, mold performance, and phase distribution and distortion in heat treated components. The firm specializes in applying simulation methods to thermo-mechanical problems by combing several disciplines: mechanics, metallurgy, process simulation and optimization.

DCT's involvement in the National Center for Manufacturing Science's

(NCMS) project resulted in DANTE(TM), a simulation software that is commercially available exclusively through the company. (DANTE stands for Distortion Analysis for Thermal Engineering.) The project was a university-government-industry collaboration. Sandia National Laboratories in California developed the materials model, and owns the model. The Colorado School of Mines developed the phase transformation kinetics models under contract to NCMS (NCMS is the owner). The software is licensed through DCT. The software's importance is that it permits manufacturers to simulate conditions rather than rely exclusively on trial and error.[7]

Dimensional changes occur during heat treatment due to several factors: thermal expansion and contraction, phase transformation, and internal stress. While these changes cannot be prevented during heat treatment, they can be accounted for during design. Distortion (unanticipated dimensional change) is a significant problem, costing industry millions annually. The phases and distribution of phases, internal stress state, and the steel part's final hardness is predicted by DANTE.

NASA issued a second call in a related technology on characterization of more complex shapes and complex operating conditions—still in their aerospace work. Along with this there was a DoE collaborative project. DoD issued an SBIR call, which resulted in DCT getting a Phase I to demonstrate that it was possible to adapt heat treat simulation to aerospace applications: military aircraft, primarily attach helicopters (U.S. Army). While the basic principle was similar, the modeling of materials is very different, involving a melding of metallurgy and computational physics.

The Technology Continues to Change

The simulation technology is continuing to change significantly. They have two main competitors: Scientific Forming Technologies Corporation in Columbus, Ohio and CRC Research Institute in Japan. In addition, they see themselves as competing with government-sponsored research in Germany, France and Korea, where governments support research and technical implementation.

COMMERCIALIZATION

Commercial Sales Have Grown Slowly

The percent of DCT's revenue that is public versus private varies year by year. During the period 1995-1998, the split was probably 60 percent federal/40 percent commercial; then 1999-2002 it became about 70 percent federal/30 percent commercial; and 2003-2004 private sources increased significantly, resulting

[7]See *Gear Technology*, November/December 2002, p. 24.

in 80 percent commercial/20 percent federal; and in 2005 the split is equal at 50 percent/50 percent.

DCT experienced steady growth over most of its life until the economic downturn in 2001, which hit them very hard. At the time they added an additional person to help move the technology to the next level. They have begun to see a very positive return from this decision.

The Region's Struggling Industries Are Slow to Adopt DCT's Software

Reflecting adverse conditions in Midwest manufacturing, DCT believes that either manufacturing will become more innovative or they will die. A lot of manufacturing capacity was lost. But, the market has picked up again because "the price of steel went up fast [with the] growth in purchases by the Chinese, causing steel to become profitable again."

Despite this, the market for their software shows slow growth, according to Freborg. He believes it to be the reluctance of U.S. industrial companies to invest in technology, largely stemming from a weak regional economy and a cultural attitude embedded in the region's manufacturing industries. Freborg refers to this as a "sink or swim" attitude.

Most of DCT's sales are to automotive companies in Michigan and to research institutions. It currently employs three people and have annual sales of $600,000. They estimate that SBIR has contributed approximately $200,000 in sales.

Their Dante software is trademarked as a result of SBIR. DCT has no patents and has no current plans to patent. The software is held by a firm that provides a general commercial software. So DCT's proprietary software makes the general software useful for their applications.

Most Customers Are Located in the Midwest

Commercial customers are mostly located in Northeast Ohio and in Detroit's auto industry. They also have some Pittsburgh customers in specialized manufacturing. Also, some aerospace customers are located Connecticut. They have virtually nothing on the West Coast.

Publishing Technical Papers Helps Market Their Software

Freborg views DCT's technical papers as being highly important as their principal way of marketing.

DCT is here because it's a good interstate location, commute to Pittsburgh, airport, and large concentration of metals industries.

IMPORTANCE OF SBIR

DCT's SBIR Awards

1993 NASA Phase I
1995 NASA Phase II
1998 Follow-up NASA Phase I
1999 DoD Phase I
2001 DoD Phase II
2004 DoD Phase I
2005 DoD Phase II

SBIR Provided the R&D Support Needed for Developing Simulation Software

While DCT was founded because of SBIR, the funds made it possible to do the R&D that supported development of the simulation software. DCT has no other sources of external funding and no government contracts. SBIR has supported R&D that wouldn't otherwise been possible and has provided credibility which has helped get better access to the larger defense contractors. If SBIR were eliminated, DCT believes that would do very little R&D, perhaps only some specialized R&D for specific companies.

DCT received its first Phase I in 1993 with NASA Glenn. The project focused on a thermal barrier coating-related NASA aerospace turbine. At the same time, they became involved with a DoE collaborative project examining the use of simulation of steel heat treatment. (Freborg's background was chemical metallurgy & industrial process development at LTV.)

From, DCT completed a Phase II went on to a number of good software applications. Using a Phase II SBIR sponsored by NASA, DCT developed a finite element modeling technique. The technology helps design ceramic coatings for high temperature components. By allowing increasing temperatures, it also improves the efficiency of turbine and diesel engines. Part of the work supported by a NASA Glenn Phase II led NASA to identify DCT as a "success story."

The simulation models were used to quantify the relative significance of complex materials property interactions. The technology is currently available for use. For example, it has been successfully applied in the design of thermal barrier coatings for turbine applications. Its application reduces experimentation costs and helps in developing new design concepts. A 1995 Phase II award helped to advance their simulation capabilities. They can simulate, for example, why the material would fail and the interrelationship among the various coatings, materials, including how they interacted to be more or less likely to fail.

DCT learned about SBIR through word of mouth and through their president, who knew the mechanisms from his previous employment at TRW. NASA had told DCT about the simulation problem at a ASM (American Society for Metals) meeting where the company's president was participating. Freborg's view is that the networking is beneficial but a lot depends on the tenacity of the NASA program manager. DCT had the capabilities to do the work but there was no application. A Phase I was used to show that it could be simulated. A Phase II followed and was used to develop the prototype and demonstrate in a more comprehensive application.

SBIR support has also helped in publishing a lot of papers. Publishing gives them needed commercial exposure. DCT publishes 4-6 papers per year with DoD's SBIR support.

ISSUES WITH THE CURRENT SBIR PROGRAM

DCT Plans to Be Selective in Applying for Future SBIR Projects

DCT's plans to seek additional SBIR support but only selectively. They have to avoid topics that are too specific. They view responding to highly specific topics as especially difficult for a small business.

NASA's Increasingly Narrow Focus on Specific Mission Needs Limits Commercialization and Usefulness by DCT

DCT is particularly concerned that NASA increasingly turns to outsourcing for NASA technology. As a result, SBIRs are very narrowly targeted on technologies that have relatively little commercial value. Freborg believes that this trend conflicts with the purpose of SBIR. In addition, DCT believes that topics/subtopics are "wired," and NASA uses the emphasis on meeting immediate needs as an excuse.

The belief is that, while the switch to "infusion" is an excellent idea; one implications is less opportunity for private-sector commercialization and a need for greater assistance in commercializing for government. According to Freborg, DCT sees SBIR's purpose as private sector commercialization. But they see NASA funding very specific research for very strong niche needs in NASA with no needs outside NASA. The change has created an impediment writing applications. In addition, working with other companies, they've concluded that many projects are wired. Some of this appears as "repeated emphasis in certain areas, specificity of the topics/subtopics, and multiple awards (for example, six at a time)."

Government, the RTTC and Nonprofit Intermediaries Are Seen as Unresponsive to the Needs of Basic Industries

They view the Midwest's RTTC (GLITeC) as making very little contribution to the region's basic industries, paying more attention to "sexy" topics and "showcasing." As a result, DCT considers solicitations as a waste of time and effort. In general, they have not found government or nonprofit institutions to be helpful. "It's very hard to get their attention and assistance." Freborg says that DCT has had only a minor relationship with the Cleveland Advanced Manufacturing Program (CAMP). He believes that their assistance goes primarily to Cleveland State University, that manages to hoard projects and funding. CAMP is the region's Manufacturing Extension Program (MEP).

Regarding the RTTC, GLITeC provided some very basic, helpful information on a business plan, but otherwise has not very helpful. "They seem to focus on a few select companies and have a high turnover of people."

DCT concludes that there's a disconnect between NASA needs and innovation. In one example, they see GliTeC's use of people running their commercialization workshops as wanting projects that show big markets. The question is: How does someone who is developing a little sensor for mouse urine in space identify a large market? In their view, they can get a criticism of a proposal that says they're not showing a broad enough commercial application.

From a broader perspective, Freborg thinks that the older industries, such as steel and forging, are being left to die. "The economic problems with these industries only get attention when the steel mill is shut down."

DCT's view is that state and local assistance would be helpful if it focused on local basic manufacturing industries and if government agencies were more responsive.

Phase I to II Funding Delays Are a Significant Problem

Phase I to Phase II funding delays present a significant problem to DCT. They respond by curtailing development or absorbing costs internally. They consider the DoD "Fast Tract" as an excellent option, which NASA doesn't currently have.

NASA Glenn Budgets Expected Cuts Would Have Minimal Effect on DCT

Their view is that NASA Glenn's expected 30 percent budget cut in 2005-2006 would have only minimal effect on their company. The reason is that over the last five years NASA's has "increasingly used SBIR to focus on space-related needs, with very little commercial significance for Northeast Ohio, and on interactions with minority companies." DCT has not been awarded any Phase III awards. They see these as also "political and wired." In their view, they think that NASA often knows less about Phase III awards than proposal writers.

Phase I Awards Should Be Indexed to Inflation

They view Phase I award amounts are becoming increasingly limiting. The recommend indexing the awards, such as adjusting for trends in the cost of R&D. Phase II awards are seen as adequate.

The Selection Process Should Be Clearer

DCT thinks that the selection process could be made much clearer. For example, it would be helpful to get a clearer understanding of rankings, picking of categories (specificity), etc.

Experience Indicates that NASA's SBIR Program Is Less Efficient than DoD

DoD is much more efficient in their contracting, award process and management of the program than NASA. On the other hand, NASA's payment process is more efficient. Payment is more efficient with NASA.

Essential Research, Inc.[8]

Michael S. Fogarty
Portland State University
and Case Western Reserve University

April 28, 2005

OVERVIEW

Essential Research, Inc., (ERI) was founded in 1996 by three NASA subcontractors who had received a number of SBIR awards. Two years later, with growth in the company they hired C. William King to run the business. King bought the company in 2000 and has continued to develop the technology and the company using personal funds, contract sales and SBIR.

This case reflects a common theme: the original researchers' talent and enthusiasm for research, not commercialization. Most likely, the technology would not have developed to a level with significant commercialization opportunities without bringing in a new person—an entrepreneur with the technology background and substantially more business experience. Five years later, according to King, ERI is on the verge of a breakthrough and significant growth.

The Essential Research case illustrates several important SBIR issues: 1) the potential significance of SBIR for creating spin-offs from technology developed by NASA research; 2) the extent to which successful commercialization by creating a spin-off company hinges on the availability of an entrepreneur who both understands the technology and brings a high level of business experience; 3) the importance of proximity to a NASA facility with specialized testing equipment and researchers involved in the technology; and 4) the hurdle faced by such a firm in a regional environment characterized by a weaker entrepreneurial culture and banks tied to the region's older industries. The case highlights the special importance of SBIR funding to high-tech businesses in the nation's older industrial regions and SBIR's need to clarify its role in supporting high-tech business in these disadvantaged regions.

[8]This report is based on an interview with C. William King, Essential Research, Inc., April 12, 2005, Cleveland, Ohio, and information from ERI's Web site, patent data from the USPTO, and DoD's SBIR database.

COMPANY AND FOUNDER BACKGROUND

Essential Research Is a NASA Glenn Spin-off

Essential Research was founded in 1996 by three NASA researchers who were subcontractors to NASA. The group had many SBIRs. Because they had many contracts, it was necessary to hire people. They then realized that they needed someone to run the business.

In 1998 C. William King, who had just left a position as VP of Engineering for Danahur Corporation and was looking for a position. The three founders hired King as the company's general manager. Two years later he bought the company. Now he is now ERI's owner and president.

Bill King received an MBA in 1977 at the University of Pittsburgh. He had considerable business experience, including a position as technical director of R&D and director of new product development. In the R&D position, he had 33 people working in R&D for him. He brought experience with business, selling, marketing, product development, and scientific technology experience. He also brought experience in selling many products, with a market worth of about $250 million.

Bill King Bought ERI and Became the Entrepreneur to Build the Company

When King joined the company he created a business plan, and told the three researchers that they needed to borrow a couple million dollars to make this happen, and, in fact, he had already identified funders. The NASA researchers were too risk averse to borrow the money and eventually turned the business plan down. Essential Research then spent the next two years making money. However, instead of investing these funds in the company, the firm's founders withdrew the money. At the same time they had just leased the company's current 5,000 square foot space, which was bare. Moreover, they were fighting among themselves.

It was at this point on July 1, 2000, that King bought company. His first step was to update the business plan. At the time he purchased Essential Research, there were eleven employees. The four original owners quit. Since then the company has had a steady employment of seven.

He firmly believes that one key to success is governance—i.e., the board of directors, which he appoints. He has known all of them a long time before putting them on the board. His board includes, a banker, a lawyer, an accountant, a marketing person, and a technologist. Each brings a different and deeper expertise to the business. His son, William P. King, is a key member of their board. The son has a doctorate from Stanford in Nanotechnology and is currently a professor at Georgia Institute of Technology. 2003-2002 and 2004-2003 were very bad years economically, however, according to King, ERI is now poised to grow. Within 4-5 years he expects to employ 50-100 people.

ESSENTIAL RESEARCH TECHNOLOGY

One Key Is ERI's Laboratory for Making Opto-Electrical Devices

Mr. King developed three related laboratories at the new site. All three laboratories are essential for making a completed opto-electrical device. The first laboratory holds the MOCVD machine (Metal-Organic Chemical Vapor Deposition). The machine is housed in a class 1,000 clear clean room and is used to grow layers of InAs, GaAs, InGaAs, and so forth on a substrate. The chemicals are referred to as optical semiconductors and grow in the machine at a rate of two atomic layers per second, which is called an epiwafer.

A second laboratory holds a photolithography machine, a scanning electron microscope and other equipment, housed in a class 10,000 clean room. These equipment are used in a manufacturing process. Their purpose is to etch and perform quality control on very tiny complex patterns on the epiwafer to make opto-electronic devices.

ERI's third laboratory is a class 10,000 clean room containing three vacuum deposition machines. The machines are used to coat the "photo-etched" epiwafer with gold to make bond pads (electrical contacts) and optically antireflective and reflective layers. Their chief scientist is from nearby Pittsburgh. He was a Fellow scientist with the Westinghouse Research Center, located in the Pittsburgh area, which moved when Northrop-Grumman shut down. He didn't move with them.

ERI Has Made a Breakthrough Using Quantum Dot Technology

Essential Research made a breakthrough in light emitting diode (LED) technology that allows wider use of quantum dot technology to replace incandescent light. They are using this LED to satisfy a commercial need. The quantum dot LED journey started in with a sales call to a local company. They visited a possible customer and stated that they could create 900 percent more light instead of 10-15 percent more light at conventional wavelengths, but the company didn't want it. However, they said that they could really use LED's emitting light in a certain infrared wavelength. And they were willing to buy one million per year if ERI could do this. ERI solved the problem. They worked on the problem that led to quantum dots, even though given existing knowledge indicated that it was impossible. Now it was possible.

The reason they got a recent Phase I SBIR was that they could make the quantum dots. They had demonstrated growing dots and put this in the proposal to DARPA, which, according to King, is willing to take more risk and gives more dollars. Other agencies want less risk and higher probability of success.

One recent trade journal article indicated that the market is $3 billion and growing 58 percent per year. Essential Research has been quietly working on the technology for 25 months. According to King, ERI's competitors are firms with the current technology. There are approximately two dozen organizations that can make quantum dots in the world and they know who they are.

The following is a quote from Bill King describing the quantum dot technology:

> We are engaged in the development of a novel semiconductor—light-emitting diode—that emits light in the 1.7 to 2.4 micron (Near Infrared—NIR) wavelength range based on the use of quantum dots in a III-V compound semiconductor structure. These wavelengths are commercially needed but have yet to be economically produced. Substantial cost savings are expected over current technology. Conventional wisdom holds that these wavelengths cannot be produced by III-V compound semiconductor light-emitting diodes. These quantum dots are approximately 0.2 to 2 nanometers high and 2 to 10 nanometers in diameter.
>
> The name quantum dot is derived from the fact that as the size of a particle of bulk semiconductor decreases to the nanometer length scale, the electronic properties of the semiconductor change. Once the diameter becomes smaller than the bulk exciton radius, the energy levels in the particle become quantized and the transitions are locked into specific energy states, as opposed to the ordinary band structure present in bulk semiconductors. Each quantum dot behaves essentially as a potential well for electrons trapped within it (i.e. the quantum mechanical "particle in a box"). The energy levels are thus quantized, and their energies are inversely related to the size of the box. Therefore, the size of the particle will dictate the threshold energy that it may absorb or emit. The presence of an ordered array of semiconducting quantum dots within the p/n junction of a diode results in the existence of an energy band(s) within, what in an ordinary semiconductor is its band gap. These dots will allow for the creation of lower energy (longer wavelength) photons that the device could not normally produce. It is theoretically possible to develop a quantum dot junction that could be incorporated with current LED cell technology to provide energy conversion in the longer wavelength region of the spectrum.
>
> The precise emission spectra of a particular dot will vary with both dot size and spacing. Much like the energy dependence with multiple quantum wells, the energy states of the quantum dot are inversely proportional to their size. Thus, as the radius of a dot is increased, its absorption edge will shift to lower energies and longer wavelengths.[9]

COMMERCIALIZATION

King Projects Year Five Revenue of $20 Million

Mr. King's assessment is that ERI is "close to hitting pay dirt." They project revenue of $20 million in year five. He expects that they could be bought in four years. Someone offered to buy the company a couple of months ago, but he didn't

[9]Presentation by C. William King, University of Dayton, December 3, 2004.

sell because he wants to grow the company. "I have been through the hard times, now it's fun, so why sell."

ERI Has Worked Hard to Build Links and Resources Within the Midwest Region

ERI has developed important links to resources in Northeast Ohio. For example, King made a presentation to JumpStart on April 14. Jumpstart is a Cleveland economic development organization designed to help grow new businesses in Northeast Ohio. In 2004 JumpStart indicated that it plans to provide a total of $3 million a year of seed financing to ten to fifteen companies a year, with an average investment per company of $250,000. King was informed on the April 26th that JumpStart will loan ERI $125,000. Illustrating the region's heavy involvement in helping to cultivate small, high-tech businesses, JumpStart's funding will be combined with support is derived from regional foundations, corporations and the state of Ohio.

VCs Have Shown Recent Interest in ERI

King has also talked with VC firms. In fact, he had an offer from about five local VCs to invest in the company. But he turned them down because they require too much equity and/or control. "Bill King has been ERI's own angel funder."

He applied for a patent in November 2004. Support for the technology came from internal R&D funds but also a Phase I SBIR award. Although the idea had been conceived prior to the SBIR, the company needed the SBIR to help fund the technology's development. King's view is that without the SBIR the technology would have taken another two years to get to market. The reason is that the LED development project is a large one and ERI can't generate sufficient money internally to do all of the development.

NASA Glenn Continues to Be a Key Asset

King's expectation is that in the next two years ERI will need more equipment and space. Most likely he will go to a bank for funding to build ER's own building. He plans to stay in Northeast Ohio, mainly because of ERI's link to NASA Glenn, which is just a few miles west of the company. According to Mr. King, NASA is a great asset—its people and testing equipment. Specifically, it is the GRC's photovoltaic research that makes them so valuable. Although the original three NASA researchers left, King still has NASA badges for his people, from a space act agreement: this access gives ERI important moral support, conversations about technology, and use of testing equipment.

As a consequence, the expected 30 percent NASA Glenn budget cuts are very troubling. One possibility is that ERI would buy its equipment and hire some of NASA's people. However, thinking ahead, King has been working to make the NASA equipment less important.

ERI Has Early Alpha Customers

The company already has four or five alpha customers, which are some of the very first customers for a new product—usually before the product is offered for sale in the general market. These customers realize that the product may still have bugs; however, because early use gives them an advantage, they agree to be guinea pig. In most cases, the customers are quiet about any mistakes the product may have in order to prevent it from getting a bad reputation prior to its availability in the general marketplace.

ERI Has Sold a Number of Products Stemming from SBIR Awards

ERI has sold a number of products stemming from SBIR, representing 100 81 percent of 2005/2004 sales revenue. These include PIN diodes in seven different sizes (AlGaAs and InGaAs), which are photodetectors, laser diodes, 1.55 micro GaAs waveguides; thermophotovoltaic cells; solar cells; and light emitting diodes at various wavelengths. In 2005 sales are expected to be $1.4 million. Sales in 2004 were $1.05 million; 2003 was $800,000; 2002 was $600,000. There were no commercial sales in 2000.

Federal agencies are buying services now, not products. For example, ERI is helping fabricate parts for NASA and SANDIA labs. They've also sold parts to Lockheed-Martin as government contractor.

THE IMPORTANCE OF LOCATION

ERI Is Located in Northeast Ohio Because It's a Spinoff from NASA Glenn

Location is a major issue for Essential Research. Their location is primarily due to the firm's being a spinoff from NASA Glenn in Cleveland. Initially, the firm was on NASA premises. Most important, if NASA Glenn were to disappear with the re-allocations underway, ER will be forced to change its business practices. At present they are not totally independent from Glenn; however, part of their strategy is to become independent.

The Region's Old Industrial Culture Is a Significant Location Disadvantage

At the same time, King worries about their Northeast Ohio location. There are only 250 MOCVD machines in the world, mostly elsewhere. None are in

Ohio. NASA has two but they are not commercial. Even Case Western University's MEMS program doesn't have the machine.

Ohio lending institutions are unfamiliar with high-tech business and are very risk averse. Mr. King had to go to banks three times to explain the MOCVD technology. According to King, even though the bank was given everything, the environment is hostile. The loan officer said "we can't take you." He said they could lend to a low-risk, low-tech company. King's observation is: "If banks persist in funding only the pasts tried and true, they will contribute to Northeast Ohio's downfall."

The company that manufactures the MOVCD is located in the UK. However, they've only had to come to Cleveland once for repair purposes. Their machine was refurbished, which they got for half the cost of a new machine ($750,000).

ERI's experience illustrates the scope of problems with their Northeast Ohio location. One is that they can't get liability insurance locally. Second, local banks simply don't understand the technology. Their only source of external funding, other than SBIR, is a bank. The bank only wanted cash-flow projects. According to King, the SBIR awards were not important in obtaining a bank loan.

State Science and Technology Only Partially Offsets the Region's Culture

One other source of funding was a state Ohio Department of Development guaranteed loan of about $200,000-300,000, which King knew about. The loan was for capital equipment.

King also views other state and local science & technology infrastructure as a mixed bag. For example, "when money flows down from state it flows through the old corporate mindset. Money supports the institutions and not the small guy. State funds support the intermediaries but not to the creative people."

Importantly, Essential Research can rely on Ohio State University as a source of some needed talent.

Regional Partnerships Have Been an Important Asset

King has developed important partnerships with a variety of universities and the Cleveland Clinic. Has made joint proposals to government and the private sector with the University of Toledo, University of Dayton, Ohio State University, Ohio University, Notre Dame, University of Rochester, and MIT. So far he hasn't done anything with Wright-Patterson Air Force Base, but he is networking with them. They are considering Essential Research as a provider of custom wafers. He has made presentations and talked with people at all of these institutions and they are happy to partner with him. He also has submitted an STTR to the University of Michigan. Although he hasn't had one yet, he views the STTR and SBIR as the same, except one has a university collaborator.

In addition, ERI is doing BioMems with the Cleveland Clinic. ERI does work for them using two of the three labs.

Many direct competitor companies don't have all three labs. One New Hampshire company has all three.

ERI has a number of customers in the northeast Ohio region, some of which are large ones. There appears to be a large potential local customer base.

IMPORTANCE OF SBIR

Essential Research Probably Wouldn't Exist Without SBIR

Mr. King says that Essential Research would probably not exist without SBIR. SBIR was key to the company's early success. However, he believes that it's possible that VC funding would be an option. SBIRs allow the owners to keep the equity and the intellectual property. VCs require equity and the owners would likely lose control of the company. "VCs want in and out with a pile of money." In contrast, King plans to be involved for the long run.

While SBIR can only provide small dollars, it has played a key role for all ERI's personnel. But building the company requires a million dollars. In the beginning, in order to purchase and fund the company, King borrowed money on his house with the equipment as collateral. Absent VC funding, ERI raises larger sums of money by contract sales of products as the company continues to improve its technology. Through 2000 their funding was 100 percent SBIR. Now the company relies on SBIR to fund roughly one person. Despite its importance, SBIR was never used as validation for the company.

A Growing Fraction of ER's Revenue Comes from Commercial Sales

King became very effective in writing successful SBIR proposals. His success rate is about one in three, or perhaps one in four. He knows how to write a winning proposal. They continued getting SBIRs since he bought company. However, SBIRs contribute a declining percentage of revenue. They are still important because the SBIR is being used to further build advance the technology.

All of the company's income prior to 2000 was SBIR. By 2004, however, 81 percent of the company's revenue was commercial (sales revenue to non-governmental sources); 19 percent was government. The transition to commercial sales was important because the government is an unreliable source. ERI has a $600,000 Phase II that starts now and continues for 2 years. ERI's 2005 projected revenues are expected to be $1.39 million, with profits before taxes of $283,000.

ERI has three patents, all from SBIR support. Even though they have tried, none are licensed. But knowledge gained from the patented technology was 100 percent useful for their current work. The patents protect what the company's doing now.

ERI has also published dozens of papers as a vehicle for marketing and sales. The papers show what the company is doing and, according to King, legitimizes the work supported by SBIR. Although they haven't received any calls in direct response to the papers, they are important. ERI works in a small community that knows who they are.

ERI has a Phase I and a Phase II on quantum dots. So SBIR continues to play a key role allowing the technology to be further developed to meet the timeline. They couldn't have gotten to this point without the previous SBIR. And they plan to apply for more SBIRs. Currently, they are working with a University of Toledo researcher on one technology. They also have a company partner. They are waiting to hear about a joint SBIR submitted to the U.S Army.

ISSUES WITH THE CURRENT SBIR PROGRAM

ERI Expects That NASA's Budget Changes Will Make SBIR More Important

Mr. King believes that SBIR will become more important in the new NASA funding environment, especially with the emphasis on internal competition for funds in NASA's budgeting process. The reason is that, if a company receives an SBIR in a specific area of technology, the internal NASA technical representative will get funds to oversee the project. For example, Essential Research just received a Phase II SBIR from NASA Glenn in NASA's photovoltaic area. One of Glenn's scientists in this field will have part of his/her salary covered for managing the project.

Variation in Evaluators' Assessment of Risk Creates Uncertainty

One problem with proposals is the variability of evaluators—some say too risky, some say not innovative enough. What this means is that evaluators express different views concerning the riskiness of the proposed project. The first evaluator may say that it's too risky, which can cause you to rewrite the proposal as less risky; then the next set of evaluators may decide that the proposed project isn't risky enough. "The feeling is that if you left the proposal the same—and didn't listen to the first set of evaluators—that it would have won the second time around. Instead, I lose twice trying to please the first set of evaluators." King feels that risk doesn't have to be the variable. Instead, it could be factor involving a technical, business or timing issue.

Phase I to Phase II Delays Create Big Issues

King says there are big, big, big issues in delay between Phase I and II. He handles it with the 81 percent commercial—makes commercial part of strategy important. He would recommend to SBIR that they say yes/no in a timely manner.

The Midwest's RTTC Hasn't Provided Relevant Help

Regarding support services, his view is that GLITec (the region's RTTC) doesn't provide any useful support services to his business. "I've got nanotechnology, I need nano customers." King stresses an important issue: GLITeC's business model is one involving their help transferring NASA technology to an outside firm. In the case of Essential Research, the reverse exists: The company has more technology than NASA in its field.

The point is that companies will view the role differently depending on whether the RTTC emphasizes private-sector commercialization or use of technology by NASA. Marketing strategy is entirely network—talks, etc.

According to King, some SBIR firms may benefit from the RTTC's help in getting mentors, but this hasn't been an issue for ERI because they already have great mentors.

Award Size Should at Least Keep Up with Inflation

Mr. King thinks that because the cost of research is going up that awards need to be made bigger. But this shouldn't be at the expense of fewer. He would like to see SBIR's budget increase by 10-20 percent. "At a minimum, SBIR's budget should keep up with inflation."

He noted a few other issues: The SBIR paperwork doesn't present a problem because ERI has become good at doing it. Regarding, proposal selection, he thinks it is very important to get quicker yes/no turnover. The feedback hasn't been applicable because of variability among proposal readers—for some the proposed work is too theoretical; for others it's too practical. Overall, he's experienced only minor differences between agencies and none of the differences have affected ERI's performance.

Luna Innovations, Inc.

David H. Finifter
College of William and Mary

April 18, 2006

SUMMARY

This case is based heavily on an interview with Luna Innovations, Inc.'s Scott Meller, P.E.—President, Contracts Research Division, the company's 2005 Web site, and a presentation made by company CEO and Chairman Dr. Kent Murphy at a conference on SBIR Phase III issues organized by the National Academy of Sciences. Luna is headquartered in Blacksburg, Virginia.

Luna was founded in 1990. Its motto is "Ideas taking flight." Dr. Murphy and Mike Gunther (now Vice President of Operations) founded Fiber and Sensor Technologies based on an accelerometer/high performance strain gauge technology for monitoring the health of aircraft designs. The firm's initial contract was private (Dr. Kent Murphy had a patent). However, the firm would not be where it currently is without SBIR. All its successes and spin-offs are attributable to SBIR. The firm was originally Fiber and Sensor Technologies, then F&S, and now Luna. In 1993 it had five employees. It became Luna Innovations, Inc. and currently has 185 employees.

Luna Innovations has created five new companies since 2000 while opening additional branches in Charlottesville, Danville, Roanoke, Hampton Roads, and Mclean, Virginia, and Baltimore, Maryland. As described on its Web site, the company focus areas include manufacturing process control, next-generation cancer drug development, analytical instrumentation, novel nanomaterials, advanced petroleum monitoring systems and wireless remote asset management. Luna's core technologies are in fiber optic, wireless, and ultrasonic sensing, biotechnology, advanced materials and integrated systems. It has had over a decade of consecutive growth. Luna actively transitions basic research and development into cost-effective products for industry, defense, communities and the environment. Luna's mission is to identify market opportunities, develop new technologies, and fully develop commercial potential.

Luna Innovations is an employee-owned company that applies innovative science and technology to develop unique solutions for significant real world problems and then assembles the resources to develop commercial potential. The SBIR program plays a strong supporting role in allowing Luna Innovations the opportunity to investigate ideas and then move ideas with quantifiable results on to commercial viability.

According to Dr. Murphy, the keys to driving innovation to equity are the following:

- Success in building business.
- Continuous pipeline of opportunities.
- Utilization of university and federal research.
- Utilization of funding resources.
- Drive to create products.
- Accelerating the innovation process.

Luna has had several business successes that include spin-offs, for example: Luna Technologies—Optical test instrumentation; Luna Energy—Downhole oil and gas sensors (acquired by Baker Hughes); Luna iMonitoring—Wireless sensing (acquired by HIS Energy); Luna Analytics—Proteomics and clinical diagnostics.

Luna's revenues are derived from products, licenses, contracts, and spin-offs. It is a growing and profitable diversified company. It is an award-winning leader in commercializing intellectual property. It has over one hundred patents, licensed patents, and patent applications.

As described on the company's Web site, Luna has developed core technologies in the following areas: fiber optic, wireless, and ultrasonic sensing, biotechnology, advanced materials, and integrated systems.

SBIR is not so critical for survival as for growth and an ability for the firm to strengthen and get technologies further along. When Luna got its first SBIRs, they allowed expansion into other areas. There were only founder's funds, no other investors. SBIR awards helped in changing the project from an idea on paper to a feasible idea and prototype. Then they would get more specific for the agency involved.

SBIR makes Luna more competitive for Broad Agency Announcements (BAAs). These are open to everyone, but SBIR makes the firm more competitive since the technology-based idea has been proven via the SBIR.

SBIR helps develop the firm's technical capability. It allows high-risk/high-payoff ideas to get funding at the seed level which is difficult to do through private industry. In fact, if there were no SBIR, Luna probably would have survived or died based on the initial product/private contract it had. SBIR has allowed Luna to have multiple ideas or projects in the pipeline so one or more will be a "home run."

Luna is very focused. It reviews all solicitations and then chooses promising topics based on market or idea. Then it refines the topic and matches it with longer term goals of the company. It melds the technology push with the government/industry market pull. The company prefers to do fewer proposals that are market focused. It needs to be efficient with proposal expenditures.

Luna has won Phase II awards from several other agencies. These include: Air Force, Army, Navy, NSF, EPA, DoC/NIST, USDA/DoA, DNA/DSWA/DTRA, DoT, and OSD.

In regard to the application process, Luna would prefer fewer awards be given for a larger dollar amount. The government should analyze proposals more carefully and do fewer. There should be more money for Phase II awards. They should have a yearly technical conference (instead of having to contact topic authors during the solicitation process). Currently, conferences are geared more to application/contractual issues rather than technological issues. Agencies would then get fewer proposals because they would be able to more clearly define their technical needs.

In terms of the process of selection, Luna believes that there is not enough time put into reviewing Phase Is. Debriefs often do not provide detailed feedback. The process for Phase II and Phase IIB is fair and adequate.

Strengths of SBIR

According to Luna, there are several strengths of the SBIR Program. In general, the program allows business to test high-risk/high-payoff ideas. It fosters building technology areas in small business. It allows for licensing out innovations. The program solves problems of government agencies. There is some flexibility that SBIR offers that VC and other funding alternatives do not provide. SBIR promotes working with other companies and universities combining ideas with others to emphasize a team approach. This helps to ensure that the applicant has the right team to get a reliable, solid solution to a problem.

The SBIR program is reliable. The funding does not get pulled unlike some government programs. The firm knows the funding will be there. The intellectual property arrangements are good, owned by small business. When working with private partners, this is not always the case. According to Luna, small business is the backbone of the nation and SBIR gives small business more of a chance vis-à-vis large firms. The SBIR program also promotes teamwork with large organizations. Also, the SBIR program indirectly supports the intellectual base of the country by supporting student interns, keeping the nation trained and bringing in new engineers and scientists flowing into the pool.

Weaknesses of SBIR

According to Luna, SBIR has some weaknesses as well. The funding level has been fixed over time. Phase II awards should be more closely linked to the task being proposed like NIH does. It also believes that the number of Phase I awards is too large. And finally, access to agency technologists is not always easy.

Recommended Changes in the Program

Luna recommends a larger funding level for the program. It suggests that there should be more information from agencies on their needs by offering technology conferences. It wonders if there is not some way to give preferential treatment to firms that are really solving commercial problems. The program should not promote doing research for research sake. Therefore, taking company performance into account in the award process would be useful. However, that said, the program should not penalize real startups. Therefore, if the applicant had a number of previous awards, then its track record of commercialization should come into play.

Also, Phase III needs to be communicated and promoted more. That is where the process is really completed. There must be better communication within the agency about Phase III possibilities. Opportunities to sole source to next level (i.e., Phase III) is important. There is a disconnect between SBIR and other shops within the agency. This is really a weakness of SBIR. The Navy TAP program is a good start at connecting small businesses with potential Phase III customers. All agencies would benefit from implementing a program like this.

BACKGROUND ON THE COMPANY

Introduction

This case is based heavily on an interview with Luna Innovations, Inc.'s Scott Meller, P.E.—President, Contracts Research Division—done on December 22, 2004, the company's Web site, and a presentation made by company CEO and Chairman Dr. Kent Murphy on June 14, 2005, at a conference on SBIR Phase III issues organized by the National Academy of Sciences. Luna is headquartered at 2851 Commerce Street Blacksburg, VA 24060-6657. Its phone number is (540) 552-5128; fax number is (540) 951-0760. The company's Web site is <*http://www.lunainnovations.com*>.

Luna was founded in 1990. Its motto is "ideas taking flight." Dr. Murphy and Mike Gunther (now Vice President of Operations) founded Fiber and Sensor Technologies based on an accelerometer/high performance strain gauge technology for monitoring the health of aircraft designs. The firm's initial contract was private (Dr. Murphy had a patent). However, the firm would not be where it currently is without SBIR. All its successes and spin-offs are attributable to SBIR. The firm was originally Fiber and Sensor Technologies, then F&S and now Luna. In 1993 it had five employees. It became Luna Innovations, Inc. and currently has 185 employees. The total revenue for fiscal year 2005 was $16,454,000. Its SBIR/STTR funding as a percent of total revenue is 60 percent. Luna went public on June 2, 1006. Luna has had over 100 Phase I SBIR/STTR awards and over 90 Phase II SBIRs since inception in 1990. The SBIRs have come through the Air Force, NASA, NSF, the Navy, EPA, the Army, DOC/NIST, and DOT. Luna has established five spin-off companies. The company is not woman- or minority-owned.

Luna Innovations has created five new companies since 2000 while opening additional branches in Charlottesville, Danville, Roanoke, Hampton Roads, and Mclean Virginia and Baltimore Maryland. As described on its Web site, the company focus areas include manufacturing process control, next-generation cancer drug development, analytical instrumentation, novel nanomaterials, advanced petroleum monitoring systems and wireless remote asset management. Luna's core technologies are in fiber optic, wireless, and ultrasonic sensing, biotechnology, advanced materials and integrated systems. It has had over a decade of consecutive growth. Luna actively transitions basic research and development into cost-effective products for industry, defense, communities and the environment. Luna's mission is to identify market opportunities, develop new technologies, and to fully develop commercial potential.

Luna Innovations is an employee-owned company that applies innovative science and technology to develop unique solutions for significant real world problems and then assembles the resources to develop commercial potential. The SBIR Program plays a strong supporting role in allowing Luna Innovations the opportunity to investigate ideas and then move ideas with quantifiable results on to commercial viability. Luna's research projects include work for the Department of Defense, Department of Energy, National Science Foundation, National Institutes of Health, and NASA. Luna is a two time recipient of the Tibbets Award from the Small Business Administration. In 1998, Inc. 500 named Luna one of the 500 fastest growing companies in the U.S. In 2001, the High Tech Entrepreneur of the Year award went to CEO Dr. Kent Murphy from the New Century Technology Council. In 2003, Luna Technologies received the Optical Test Product of the Year from Frost & Sullivan. In 2004, Luna Technologies was awarded Emerging Company of the Year from Frost & Sullivan. In 2004, Luna won the High Technology Company of the Year award from the New Century Technology Council.

Luna's revenues are derived from products, licenses, contracts, and spin-offs. It is a growing and profitable diversified company. It is an award-winning leader in commercializing intellectual property. It has over one hundred patents, licensed patents, and patent applications.

Luna is very dedicated to skill development and having the right skill mix. Among its 185 employees are the following: electrical engineers, optical engineers, mechanical engineers, materials scientists, physicists, biochemists, software engineers, computer engineers, organizational chemists, polymer chemists, aerospace engineers, and microbiologists.

According to Dr. Murphy, the keys to driving innovation to equity are the following:

- Success in building business.
- Continuous pipeline of opportunities.
- Utilization of university and federal research.
- Utilization of funding resources.

- Drive to create products.
- Accelerating the innovation process.

The Luna Business Model

Luna Innovations' mission is to identify significant problems, apply innovative science and technology to generate unique solutions, and provide the launch pad to fully develop its commercial potential.

Luna is a next-generation, employee-owned company that has built a complete network for driving innovative technologies through the development cycle all the way to fully functioning separate companies. These spin-off companies produce and distribute products that address billion dollar markets.

Luna's corporate structure provides the framework to nurture ideas with tremendous commercial potential. The business model provides the appropriate support throughout the commercialization cycle as the typical engineer and scientist moves through the Luna network, including technology transfer from Luna Innovations, and then rebuilding a technical staff focused on the next identified commercial market.

COMPANY TECHNOLOGIES

As described on the company's Web site, Luna has developed core technologies in the following areas: fiber optic, wireless, and ultrasonic sensing, biotechnology, advanced materials, and integrated systems. The R&D includes:

- Fiber Optic Sensing (harsh environment and distributed sensing).
- Optical Devices (fiber optic sensors, photonic crystal waveguides and engineered instrumentation solutions).
- Nanotechnologies (carbonaceous nano materials).
- Nondestructive Evaluation (NDE also called nondestructive testing or NDT).
- Biotechnology.
- Advanced Materials (multifunctional thin films and composites).
- Corrosion (monitoring and prevention).
- Wireless (remote sensing and assessment management with internet accessibility).

Fiber optic sensors do the following: improve measurements; reduce costs; operate in harsh environments; produce faster measurements; allow for remote operation; and have intrinsic safety.

COMMERCIALIZATION

In terms of Luna commercialization profile and commercialization versus serving as an agency supplier, there is a mix but slanted toward commercialization. Most of this comes in the form of spin-offs from technology developed by SBIRs and some to government agencies.

The principal business is that Luna is an R&D firm that does high-risk research and filters out best ideas and brings them to market. It takes new technology to market effectively. It does that for "hot" technologies. This occurs in three areas: optical devices, advanced materials, and life sciences. Much of the sensor based work in different markets have also moved into more materials based areas.

There are numerous commercial products internal to Luna Innovations and at spin-off companies. Optical telecom occurs through Luna Technologies, which was acquired by Luna Innovations in September 2005. Petroleum downhole measurement runs through Luna Energy. Wireless measurement in oil runs through Luna iMonitoring—(companies sold now).

Sensor systems have been sold ever since the start of the company. This has been sold to infrastructure like civil engineering type customers. There are industrial applications in monitoring temperature. There are a large amount of R&D type sales from auto industry to university-based work. Also, there are sales to government programs via government R&D labs for measurement needs they have. In addition, we should expect industrial markets for wireless sensor and fiber optics sensor to move forward. Plus, spin-off companies continue to grow.

Luna has pursued various commercialization strategies. The strategy depends on the market or customer. It has pursued pure VC approaches, formed strategic partnerships, and licensed and sold technologies to other companies.

In terms of spillovers, Luna products have provided measurements that are not possible (with sensors). Other approaches are more costly. It improves a process or tests out a new scientific application.

Luna has had several business successes that include spin-offs:

- Luna Technologies—Optical test instrumentation.
- Luna Energy—Downhole oil and gas sensors (acquired by Baker Hughes).
- Luna iMonitoring—Wireless sensing (acquired by HIS Energy).
- Luna Analytics—Proteomics and clinical diagnostics.
- Luna Quest—Cancer inhibitors.

Here are more specifics about some of Luna's spin-offs.

1. Luna Technologies was established in December 2000. It is based on a technology licensed from NASA. It had $12 million raised in A&B rounds. Its market is defined as telecom at $125 million. Its product is fiber optic components

and subassemblies test equipment. Its top competitor is Agilent. The status of the spin-off is that it is VC funded. The spin-off is exceeding its revenue projections. Luna Technologies was acquired by Luna Innovations in September of 2005 and continues to operate as our Luna Technologies Division.

2. Luna Energy, LLC was established in February 2002. It is based on a sensor technology licensed from Luna Innovations. Its market is oil and gas physical sensing at $100 million. Its product is physical sensors for downhole monitoring. Its top competitor is Schlumberger. The status of the spin-off is that it has been acquired by a Fortune 100 company, Baker Hughes.

3. Luna iMonitoring was established in May 2002. It is based on a technology licensed from Luna Innovations. It is in the petroleum market, $250 million for second tier on shore wells. The product is remote asset management sensors. Its top competitor is Weatherford. The status of the spin-off is that it has been acquired by IHS Energy.

4. Luna Analytics was established in June 2001. It is based on a technology licensed from Luna Innovations and Lucent. The market is in the area of life sciences research (i.e., proteomics) at $100 million. The product is a direct detection instrument to quantify protein and small molecule interactions. Its top competitor is Biacore. The status of the spin-off is that is a joint venture product development and technology license agreement signed with the industry leader.

Luna's model for driving technologies to commercialization—Luna's technology launch pad:

- Identifies market opportunities;
- Develops technologies internally and when necessary integrates intellectual property from universities, government labs, and other industries;
- Secures initial development funds from government and industrial organizations, including internal Luna funds to demonstrate technical feasibility; and
- Builds expert entrepreneurial management teams, writes well-developed business plans, and raises private investments including angel, venture capital and large corporation strategic investors.

The Luna Group History of Success

Luna Innovations is proud of its record in commercializing the technologies evolving out of SBIR contracts and has introduced a number of products to the marketplace while establishing five spin-off companies. These companies are focused on sales of revenue generating products that include fiber optic telecommunications that power the Internet; proteomics instrumentation that provides leads for new drug discoveries and rapid in-office clinical diagnostics; high-volume production of nanomaterials and technologies that lead to enhanced contrast agents for medical diagnostics, advanced systems for down-hole petroleum monitoring, wireless sensing networks for real-time, remote asset management and next-generation cancer drug discovery. These new companies are businesses built by Luna Innovations, by identifying market potential, developing new technology, proving technical feasibility, building management teams and raising private investments.

The Luna family of companies currently employs more than 185 professionals in basic research, development, administration, and production. Drawing upon a strong team of scientists, business professionals and engineers from diverse technical backgrounds, Luna has built a unique set of core capabilities in fiber optic and ultrasonic sensing, advanced materials, biochemistry, and integrated systems.

The Luna spin-offs have enjoyed much success over the past two years.

- Luna Technologies' Optical Vector Analyzer, based on technologies from NASA, was Frost & Sullivan's 2002 Optical Test Product of the Year.
- Luna Energy has Baker Hughes, a Fortune 100 company and a leader in oilfield services, as its investment partner. The NIST ATP funded research on this technology.
- Luna iMonitoring began with an NSF adaptive vibration sensor and many wireless contracts with the Navy and Air Force. In October 2003, the company was acquired by IHS Energy and is now producing remote sensing products for the oil and gas industry.
- Luna nanoMaterials was aided by an NSF program that focused on production and separation technology. The company is making molecules that cannot be produced anywhere else on earth and has also scaled up its manufacturing of nanomaterials for bulk purchase.

The Luna team is passionate about turning ideas into useful products to improve the quality of life globally, while creating sustainable, high-value jobs in the U.S. While Luna remains a small business and a **HubZone** company, the company has experienced extensive revenue growth since 2000 accompanied by an exponential increase in nongovernment investment in the company and its divisions. In the past five years, Luna received $39.1 million in revenue from Phase I and Phase II SBIR contracts which have been augmented by $91.2 million in non-SBIR funding. For every $1 of SBIR funding awarded, Luna has generated $2 in non-SBIR funding. Luna's research continues to produce new products, technologies, and jobs—all proof that the Luna is exceeding the commercialization returns envisioned by our federal R&D partners.

IMPORTANCE OF SBIR

In addition to Phase I and Phase II awards, Luna has won three Phase IIB or Phase II enhancements projects. Luna has received over 30 NASA Phase I/II awards since inception in 1990.

SBIR is not so critical for survival as for growth and an ability for the firm to strengthen and get technologies further along. When Luna got its first SBIRs, they allowed expansion into other areas. There were only founder's funds, no other investors. SBIR awards help in changing the project from an idea on paper to a feasible idea and prototype. Then they would get more specific for the agency involved.

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SBIR helps develop the firm's technical capability. It allows high-risk/high-payoff ideas to get funding at the seed level which is difficult to do through private industry. In fact, if there were no SBIR, Luna probably would have survived or died based on the initial product/private contract it had. SBIR has allowed Luna to have multiple ideas or projects in the pipeline so one or more will be a "home run."

The most important innovation for Luna was in fiber optic sensor development. It has an exclusive license from Virginia Tech. It was critical. Other important links were EFPI, Advanced Materials, Flame Retardants, and Development of Nanomaterials. It also has licenses from VA Tech, some patents, and produces the product.

Working with government and industry partners takes some of the risk out of it. There is a technology push and a market (government and industry) pull.

There have been over 100 scientific papers attributable to SBIR.

There have been over 90 patents and patent applications awarded or in process. Of these, 75 percent are related to SBIR. It also licenses technology teaming with universities.

Luna does some work with STTR, when it fits with the business goals of the company and valuable IP exists at a university to team with.

It is not clear how Luna became aware of the SBIR program. Probably customers it was selling to suggested it. There is no geographic linkage or limit to opportunities. There is no particular agency linkage. It is the "problem" it is looking for and the agency is secondary. It looks at the technology the agency is requesting to guide the process.

Some agencies are more academic such as NSF, DoE, and NIH, which are peer reviewed and do not have a particular application in mind. This contrasts to DoD and NASA which are more specific and the solicitation is tied to specific application programs. Luna accommodates both and applies to technologies that have most promise. With DoD, an applicant can get to the customer and discuss problems and are more specific about applications, compared to NIH, where the applicant cannot know the details. However, there is less flexibility with DoD and NASA compared to the peer-review agencies.

Luna is very focused. It reviews all solicitations and then chooses promising topics based on market or idea. Then it refines the topic and matches it with longer term goals of the company. It melds the technology push with the government/industry market pull. The company prefers to do fewer proposals that are market focused. It needs to be efficient with proposal expenditures.

In regard to non-SBIR contracts, Luna participates in NASA and the Air Force and through prime contractors as subs. Some of the awards are more exploratory and similar to SBIR awards whereas others are tied to deliverables of the agency (but some SBIRs are like that too). These are more competitive since it is competing against a larger number of competitors. If the contracts are outside of the SBIR realm, they are more flexible from the agencies' point of view so they can get what is needed to do the job. Also, for larger non-SBIR awards, there are more regulatory requirements, in some ways less flexibility and more reporting requirements.

The following is a list of NASA Phase II Awards received by Luna:

1. Year of Award: 1996. Project Title: Metal-Coated Optical Fiber Temperature and Pressure Sensors. Sales to Private Sector: $1,278,045. Additional Investment from: (a) Other Federal Agencies: $17,280; (b) Private Sector: $1,599,319.

2. Year of Award: 1996. Project Title: Optical Fiber Strain Gage Using Polyimides. Sales to Private Sector: $1,312,816. Additional Investment from Private Sector: $1,642,831.

3. Year of Award: 1996. Project Title: Smart Material Products for Communications, Actuation and Sensing. Sales to Private Sector: $119,451. Additional Investment from Private Sector: $354,166.

4. Year of Award: 1998. Project Title: Micromachined Fiber Optic Accelerometers. Sales to Private Sector: $1,332,097. Additional Investment from Private Sector: $166,959.

5. Year of Award: 1999. Project Title: Fiber Optic Based NDE Systems for Space and Aircraft. Sales to Private Sector: $1,110,618. Additional Investment from Private Sector: $1,389,804.

6. Year of Award: 1999. Project Title: Multimeasure and Optical Fiber Sensors for Flight Test Applications. Sales to Private Sector: $1,717,910. Additional Investment from Private Sector: $1,667,726.

7. Year of Award: 2002. Project Title: Carbon Nanotube-Fiber Optic Skin Friction & Temperature Sensor. Sales: 0. Additional Investment from Private Sector: $1,441,275.

8. Year of Award: 2002. Project Title: SiC Fiber Optic Sensors for Turbine Engine Monitoring. Sales to Private Sector: $1,212,827. Additional Investment from Private Sector: $1,312,265.

9. Year of Award: 2002. Project Title: Rotational Molding of Thermoplastic Cryogenic Propellant Tanks. Sales: 0. Additional Investment: 0.

10. Year of Award: 2002. Project Title: Distributed Optical Fiber Sensor Demodulation System. Sales: 0. Additional Investment: 0.

11. Year of Award: 2002. Project Title: Distributed Fiber Optic Sensors for Space-Based Nuclear Reactors. Sales: 0. Additional Investment: 0.

12. Year of Award: 2003. Project Title: Advanced Monitoring System for Space Flight Applications. Sales: 0. Additional Investment: 0.

Phase II awards from other agencies include: Air Force, Army, Navy, NSF, EPA, DOC/NIST, USDA/DOA, DNA/DSWA/DTRA, DOT, and OSD.

ISSUES WITH CURRENT SBIR PROGRAM

In regard to the application process, Luna would prefer fewer awards be given for a larger amount of awards. The government should analyze proposals more carefully and do fewer. There should be more money for Phase II awards. It is hard to get a hold of the technology resources. It would be helpful to have the agency do a conference. They should have a yearly technical conference (instead of having to contact topic authors during the solicitation process). Currently, conferences are geared more to application/contractual issues rather than technological issues. Agencies would then get fewer proposals because they would be able to more clearly define their technical needs. There is of course always freedom in the technology a firm proposes, but then they need to specify parameters. Firms prefer more flexibility, but agencies have needs.

Frequency of Solicitations

In regard to frequency of solicitations, DoD has increased from two to four and that is no problem. Luna prefers fewer solicitations but with more focus. Instead of four solicitations, it prefers fewer topics and more money for awards.

Process of Selection

In terms of the process of selection, Luna believes that there is not enough time put into reviewing Phase Is. Debriefs often do not provide detailed feedback. The process for Phase II and Phase IIB is fair and adequate.

Timing

In terms of timing NASA in particular is done well. There are specific dates given and the agency meets them. In general, the award process for SBIR has reasonable time lags compared to other government programs. NIH definitely has a longer lag between application and award, but it allows the applicant to resubmit based on feedback from reviews.

Strengths of SBIR

According to Luna, there are several strengths of the SBIR Program. In general, the program allows business to test high-risk/high payoff ideas. It fosters building technology areas in small business. It allows for licensing out innovations. The program solves problems of government agencies. There is some flexibility that SBIR offers that VC and other funding alternatives do not provide. SBIR promotes working with other companies and universities combining ideas with others to emphasize a team approach. This helps to ensure that the applicant has the right team to get a reliable, solid solution to a problem.

The SBIR program is reliable. The funding does not get pulled unlike some government programs. The firm knows the funding will be there. The intellectual property arrangements are good, owned by small business. When working with private partners, this is not always the case. According to Luna, small business is the backbone of the nation and SBIR gives small business more of a chance vis-à-vis large firms. The SBIR program also promotes teamwork with large organizations. Also, the SBIR program indirectly supports the intellectual base of the country by supporting student interns, keeping the nation trained and bringing in new engineers and scientists flowing into the pool. There tends to be more flexibility and the award winner can communicate with the agency to satisfy both government and market needs.

Weaknesses of SBIR

According to Luna, SBIR has some weaknesses as well. The funding level has been fixed over time. Phase II awards should be more closely linked to the task being proposed like NIH does. It also believes that the number of Phase I awards is too large. And finally, access to agency technologists is not always easy.

Recommended Changes in the Program

Luna recommends a larger funding level for the program. It suggests that there should be more information from agencies on their needs by offering technology conferences. It wonders if there is not some way to give preferential treatment to firms that are really solving commercial problems. The program should not promote doing research for research sake. Therefore, taking company performance into account in the award process would be useful. However, that said, the program should not penalize real startups. Therefore, if the applicant had a number of previous awards, then its track record of commercialization should come into play.

Also, Phase III has not been communicated or promoted very much in general. That is where the process is really completed. There must be better communication within the agency about Phase III possibilities. Opportunities to sole source to next level (i.e., Phase III) is important. There is a disconnect between SBIR and other shops within the agency. This is really a weakness of SBIR. The Navy TAP program is a good start at connecting small businesses with potential Phase III customers. All agencies would benefit from implementing a program like this.

Mainstream Engineering Corporation

Julie Ann Elston

December 13, 2006

The SBIR program has helped Mainstream Engineering Corporation—an innovator in heating, ventilating, air conditioning and refrigeration products—build competencies, identify new technology needs, conduct research and development, and commercialize products through federal procurement and in the market.

Mainstream believes that governmental needs, as outlined in the SBIR's topic list, aid in the identification of new technology needs; in that, their general view is the United States government's needs are a microcosm to the needs of the world at large, both public and private sector. This model allows identification of topics within their area of specialization. They then conduct an analysis of the commercial potential of the end product and new technology. If the technology and product holds potential, then research and development is undertaken.

The firm's owner/director, Dr. Robert P. Scaringe, received a Ph.D. in mechanical engineering at RPI and worked in R&D at General Electric for several years. He then accepted a professorship in Mechanical Engineering at Florida Institute of Technology, and founded Mainstream Engineering Corporation in Rockledge Florida in 1986. The firm began to work with the SBIR program after the Air Force WPAFB contacted Dr. Scaringe with a thermal control problem and suggested the SBIR program as a means of funding the development of a solution to the problem.

SBIR EFFECTS ON THE FIRM

Mainstream views SBIR awards as the government as an underwriter of research and development to small business and as source of funds to help offset the cost of a project. Dr. Scaringe notes that "the awards have allowed [Mainstream] to compete with bigger corporations by offsetting the heavy costs of research and development." He added that "[we] would not have been as successful today without the assistance of the program." Dr. Scaringe measures his company's success by products and technologies that come to market and states that "100 percent of projects that were funded with Phase II monies went to market (23 Phase II awards since 1986), while most that received Phase I monies went commercial."

SBIR's has also had an impact on improving the firm's competitive capabilities. The SBIR program allows for all patents, royalties, and trademarks to be held by the company that created them. This is attractive because it allows the company to prosper from its research and development.

Mainstream has received multiple awards and multiple commercial products resulting from SBIR funding—too many to list really—the key products however are Mainstream's (HVAC/R).

COMMERCIAL OUTPUTS

Mainstream sells products and services derived from SBIR funding in the market place. Mainstream only takes on projects that have commercialization as an end. All Mainstream projects that received Phase II awards went on to commercialization. Dr. Scaringe estimated that 80 percent of products developed are for Department of Defense with the remaining 20 percent going to the Departments of Energy and Transportation and NASA.

Mainstream's heating, ventilating, air conditioning and refrigeration products (HVAC/R) are sold in more than 7,000 trade wholesalers throughout the United States. Overseas, Mainstream has distributors in Europe, Israel, South America and the Middle East. Mainstream's automotive air conditioning products are licensed and sold through Interdynamics Corporation in all major Auto parts stores as well as "Big Box" outlets such as Wal-Mart and Target. Mainstream's retail air filtration and related indoor air quality (IAQ) products are private labeled and sold through various industry leaders via "Big Box," supermarket and drug chains stores.

Mainstream licenses some of its patents but always keeps core technologies that apply to the HVAC/R and IAQ markets. These core technology products are manufactured in the United States and distributed through Mainstream's network of more than 7,000 trade distributors.

PRIVATE RETURNS AND SPILLOVER EFFECTS

Dr. Scaringe provided the following examples of technologies developed with SBIR that yielded both private return and spillover effects:

- *Mainstream 2-kilowatt diesel generator.* Whereas the standard Department of Defense 2-kilowatt generator weighs 138 lbs and requires 4-man transport, Mainstream's backpack generator weighs only 65 lbs and requires a 1-man transport. Mainstream's generator has the same power output, lighter weight, more compact, easier to transport, and quieter.
- *QwikBoost.* This air conditioning additive increases the performance of refrigerators, air conditioners, and heat pumps by 8 to 10 percent. This technology is incorporated into Mainstream's HVAC/R product line and licensed to another company for the automotive industry.
- *Mainstream Modular Lightweight Environmental Control Unit (MECU).* This field-deployable tent air conditioner heats or cools military tents in extreme temperatures. It states a 28 percent boost in performance over existing units and incorporates a weight and volume reduction by 56 percent. The second genera-

tion prototype can operate in nuclear, biological, or chemical (NBC) or non-NBC mode.

KNOWLEDGE EFFECTS

Mainstream has generated numerous papers, patents, and trademarks, which appear to indicate the presence of significant knowledge generation. As of November 2000, Mainstream had 115 papers published or presented. In addition, as of September 2003 the company claimed 51 patents, 35 trademarks, and 15 more patents pending.

Dr. Scaringe also provided examples of know-how from SBIR-funded projects that were carried over to other (civilian) endeavors of the firm. Some examples include:

- Ion-propulsion for NASA to water purification.
- Portable generator for army to same for campers and smaller marine craft.
- Thermal control for avionics, aircraft and spacecraft to HVAC/R products for the general public.
- Spacecraft air quality to Indoor Air Quality improvements for the general public.
- Non-toxic working fluids.
- Fire suppressants and coolants for the DoD and NASA are also now available as safe working fluids for the public.

FIRM PERSPECTIVES ON THE SBIR PROGRAM

According to the Dr. Scaringe, the SBIR program has been helpful to the firm, adding "I wouldn't be here today without the SBIR program." Below are the main positive features of the program, as identified by Mainstream, followed by some criticisms of the way the program is managed.

Fair Selection Processes

Dr. Scaringe finds the selection process to be extremely fair and refreshingly unpolitical in nature compared to Florida state "Plus-up" practices where certain firms may be given noncompetitive subsidies.

Patent Rights Retention and Commercialization

Importantly, SBIR allows whole retention of patents, trademarks, and intellectual property rights. "I have applied for and received the BAA awards, which are far easier to do than the SBIR if all I want is to do basic research. The SBIR awards are harder and less cost effective until you consider the payoffs from the ensuing patent rights and commercialization."

New Product Development Using SBIR

"In our view the SBIR program is funding our R&D effort to develop a new product. So if it cost $300,000 in R&D and the Phase I program gives us $100,000 than that is a $100,000 savings and not a $200,000 loss. We love to get a Phase II, but if we don't a Phase II, the government still paid for $100,000 of our R&D costs. Remember, we only take on projects that our marketing studies show would make a great product that can be protected by our patents. We do not pursue R&D just for the sake of pure research—I believe that is the role of university research, rather we pursue R&D to solve a specific problem and sell a product."

"I lose money on the Phase I proposals in that it costs what I receive from winning a Phase I and then some to complete the Phase I. I do it only because of the potential for commercialization of a product which comes out of the project, i.e., the Phase II and Phase IIB are when the real returns kick in."

Helping to Identify New Technology Needs

Mainstream believes that governmental needs, as outlined in the SBIR's topic list, aid the company identify new technology needs. They use this list to screen for potential technologies that can be commercialized within their area of specialization in HVAC/R. They then conduct an analysis of the commercial potential of the end product and new technology. If the technology and product holds potential then research and development is undertaken and SBIRs are applied for. Dr. Scaringe said that "If the topic listed has commercialization potential and was also in one of the core competencies of the firm: thermal control and energy, chemical engineering and chemistry, or mechanical design and rapid prototyping, then the company applied."

In summing up the positive contributions of SBIR, he noted that SBIR allows a small company like Mainstream to compete against larger companies in research and development. Dr. Scaringe balanced these positive views of SBIR with specific criticisms of some of the program's administrative processes. These are reviewed below.

"Vague" Solicitations

Dr. Scaringe noted that "In general, NASA's solicitations are a bit too vague for my interests, and they have also changed very little in the past two decades." "Obviously, the government does not need to know the solution to the problem, but they should be able to define the problem in very specific terms. If they can't maybe is it not a problem but just a passing fancy. Too many times, we have solved one of their problems only to find out they have no need for the solution. They have no specific application that would benefit. That is why we do a market study first. To determine if there is a commercial need; if not, we avoid the topic, because there is probably no government need either."

Solicitations Are Too Frequent

"Too many solicitations! For example, the DoD used to have one solicitation in January, the first week or so. With the Christmas holiday, it would have been much better in February but once a year was nice. Then they added a summer topic list and last year there were four DoD SBIR topic solicitations. This is very disruptive and makes us feel like we are always writing SBIRs. My staff would love it if we could get back to once a year for each agency."

Need for Greater Expertise in Proposal Reviews

According to Dr. Scaringe, NASA reviewers do not appear to be well versed in the technology they are evaluating, probably because NASA subcontracts this work to independent firms to evaluate proposals. These subcontracted firms have no real expertise in the various topic areas and they have no passion for the success of the technology."

"Both NASA and the Department of Defense recently started using third parties to review proposals instead of using the scientific personnel that wrote the topic solicitation to address a technological need. This creates a problem, in that, no third party can have the resources and experts to handle all the different types of technologies addressed in the proposals; and therefore, the reviews are getting really bad. That is to say somewhat vague and poorer in quality, indicating that the review of the proposals should go to the person that wrote the topic solicitation. In addition, the most recent practice of deciding Phase II awards before the Phase I is even half over is terrible and should be discontinued."

To improve the review process, Dr. Scaringe recommends using as reviewers the people in the government that wrote the topic description because "they understand the problem." He urges that outside subcontractors, who care little and know even less about the subject area, not be used as reviewers.

Late Payments

"Payment is a major problem. We typically wait 60 to 90 days for payment. This new electronic payment system is a mess. We are having a tremendous problem getting paid. Either the system is not working properly or the government folks don't know how to use it. After more than 18 years in business, we have recently been forced to ask our local congressman to step in and help us get the government to pay its past due bills. The government does not consider these bills past due, because the invoices have not been "approved" by the government project engineer. In many cases the engineer is in the Middle East and not available for payment. It would be nice if payments could be more streamlined. However, I understand that in many cases these problems were impossible to anticipate."

Multiple Awards

According to Dr. Scaringe, SBIR mills (firms that are successful in getting SBIRs but not successful in commercialization of products resulting from the SBIR) should be restricted. "That money could be used to help needy firms that would have produced products, even if their proposal writing skills are not as strong."

PAPERS PUBLISHED OR PRESENTED

Mainstream provided a list of 115 scientific papers that have been published or presented, 51 patents, as well as numerous trademarks.

Space Photonics, Inc. (SPI)

Julie Ann Elston

May 2, 2005

OVERVIEW

SPI is a twelve-employee firm that specializes in optical communications systems and components for the aerospace industry. Located in the Genesis Incubator on the University of Arkansas Fayetteville campus, SPI seeks to provide innovative avionics and space optical communications components, networks, services and support. SPI was founded in 1999 by CEO Chuck Chalfant and CTO Fred Orlando, as a spin-off from Optical Networks Inc. (ONI) Systems in San Jose, California. To date they have received a total of $5.534 million in R&D funding for a number of specific photonic product development efforts. $4.86 million of this funding was received through the Small Business Innovation Research (SBIR) program. In 2004 Space Photonics became the first company to receive Arkansas' new tax incentive that provides up to 33 percent in matching tax credits for Federal R&D programs, and is a recipient of the SBA Tibbets Award for outstanding SBIR leadership.

HISTORY AND DEVELOPMENT OF THE FIRM, TECHNOLOGIES AND PRODUCTS

The founders, Chuck Chalfant and Fred Orlando, first met in 1985 when they worked at Lockheed Martin in Sunnyvale, California. The current location in Arkansas is due to Chalfant's love of the area he grew up in rather than strategic considerations, but they are now working on several SBIR-funded projects with various members of the University of Arkansas engineering faculty.

Chalfant became familiar with the SBIR program around 1988 just after he went to work for a new technology startup firm called Optivision. Both Orlando and Chalfant worked together on a series of fiber optical network projects in the Silicon Valley region. They estimate a total of six successful Phase I and four Phase II grants in the 1990-1995 period. At Optivision they worked on space applications of optical networks for DoD and NASA grants through primarily Goddard Space Center, and JPL. In 1995 they estimate gross revenues of $18-20 million, with 50 percent coming from government sources, mostly fiber optical switches, and 50 percent from commercial application in the form of video compression. By 1997 Optivision had 100 employees and a new president, but with diverging markets, Chalfant decided to join ten engineers to spin off their own firm—Optical Networks Incorporated (ONI). At this point roughly all intellectual property and optical work from the SBIR grants went to ONI. The 'novation" process of dividing up the grant contracts however was problematic and did not end until 1999. While VC firm Kleiner Perkins invested a total of $100 million over time in ONI to bring it public during the 2001 technology stock bubble, they specifically did not want to carry the government contracts with them, including the SBIRs, because of the high overhead and their wish to IPO clean of government ownership.

This fortuitous coincidence of events allowed the new spin-off firm, Space Photonics, incorporated in 1998, to obtain all of the government contracts and SBIR's of mostly NASA projects for Goddard and JPL, as well as $400,000 worth of government equipment. Without SBIR grants, both Chalfant and Orlando do not believe their firm would exist, let alone grow. Today, they have added several SBIR Phase Is and Phase IIs to their total from earlier firms bring the total including novated contracts to eight Phase Is and five Phase IIs, and have just received a $2.5 million contract from the Airforce (90 percent from SBIR), as well as two recently awarded Phase II SBIR contracts worth $1.5 million. Currently they are grossing about 80 percent from DoD and 20 percent from NASA contracts. Regarding growth, the SBIR program has been critical: in 2004 gross revenues were $650,000, and in 2005 revenues are expected to be $2.5 million.

After successfully completing several prototype development programs recently, they are now beginning a major aerospace product qualification program, with a current contract backlog of about $4 million, and anticipate adding five new employees by the end of the year.

Throughout their career, the SBIR program has been the common thread of funding and direction for innovation, although it is impossible to estimate via revenues or otherwise which SBIR grants are responsible for which outputs.

ROLE OF SBIR PROGRAM ON FIRM DEVELOPMENT AND TECHNOLOGY

One important point the founders made is that SBIR allowed them to grow without diluting their ownership of the firm (55 percent Chalfant, 40 percent Orlando, 5 percent other employees).

They also stated that they doubt they would exist without it, and that it is undoubtedly the "the best damn government program ever devised." Through specific program solicitations it has been directly responsible for the type of technologies developed as they allowed the solicitation process to lead them to develop the kind of technologies that were asked for "because we basically followed the money."

The SBIR program also assisted them in getting outside funding through the Air Force "Enhancement Program", in which the Air Force promised to fund a Phase II at $250,000 if SPI got an outside investor, which SPI did with $250,000 DoD matching funds.

SBIR AWARDS, PROGRAM FAIRNESS AND PROBLEMS

The founders also felt that the program was very fair, but did have one problem with a recent NSF proposal, which was rejected because "we could not demonstrate a nongovernmental commercial customer." They felt that this is (1) difficult to do with these types of technologies and that (2) DoD as a customer should be sufficient.

COMMERCIALIZATION ISSUES, FUNDING GAPS, AND PARTNERSHIPS

The biggest problem experienced in the SBIR program was moving from Phase II to Phase III. Specifically after the Phase II, funds are needed to carry though to the next step which is a protoflight. And since no one wants to buy an untested flight technology, this is a huge problem for SPI and similar firms. They also noted that the primes also would not fund the test flights.

SPI stressed that aeronautics is a tough field for any small firm to break into with the primes like McDonnell Douglass, Boeing, and Lockheed Martin—that are used to ruling the roost. Also these firms sometimes act like they are interested in the work or technology of smaller more innovative firms like SPI because the government wants them to do so. SPI has actually experienced a situation like this where these same firms then tell the government a technology is too risky, but later end up proposing the same type of project/technology to the government and charge the government 100 times as much money for a project than SPI would.

On the other hand, they also noted that Honeywell heard about one of their technologies through the SBIR Awards list and that it helped them to foster a joint project with them which has been very successful.

CURRENT AND PLANNED PRODUCTS AND PATENTS DERIVED FROM SBIR-FUNDED RESEARCH

- SPI's *LaserFire*® Free-Space Laser Communications Transceivers.
- *MEMSpot*® (two patents pending) beam steering devices are currently under development.
- Micro-Electro-Mechanical Systems (MEMS).
- SPI's *FireFiber*® 4-Channel transmitters and receivers operate at a data rate of 3.2 Gbps per channel, and can provide up to 12.8 Gbps of aggregate operational bandwidth.
- By 2007 they plan to provide upgrades for these transceivers providing up to 10 Gbps per channel operation and 40 Gbps of aggregate bandwidth.
- SPI's *FireRing*® High Speed Real-Time Fiber Optic Networks provide compatibility with network interface protocols including but not limited to ATM/SONET, Fibre Channel, Gigabit Ethernet, Firewire (IEEE 1394b), IEEE 1393, and HIC (IEEE 1355) network implementations.

SCIENTIFIC PAPERS RESULTING FROM SBIR-FUNDED RESEARCH

1. Chalfant, C.H., Orlando, F.J., and Parkerson, P.J., "Photonic Packaging for Space Applications," presented at the IMAPS OE Workshop, Oct. 12, 2001.

2. Andrucyk, D.J., Chalfant, C.H., Orlando, F.J., "IEEE 1393 Spaceborne Fiber Optic Data Bus: A Standard Approach to On-Board Payload Data Handling Networks," Published in the American Institute of Aeronautics and Astronautics Paper # 99-4507.

3. Chalfant, C.H., Orlando, F.J., and Parkerson, P.J., "Parallel Spaceborne Fiber Optic Data Bus Physical Layer" Invited Paper: SPIE Conference on Photonic Processing Technology and Applications II in Orlando, FL: April 1998.

4. Andrucyk, D.J., LaBel, K.A., Luers, P.J., Marshall, C.J., Marshall, P.W., Ott M.N., Reed, R.A., Seidleck, C.M., "On the Suitability of Fiber Optic Data Links in the Space Radiation Environment: A Historical and Scaling Technology Perspective".

5. Bretthauer, J.W., Chalfant, C.H., Orlando, F.J., Rezek, E., Sawyer, M., "Spaceborne Fiber Optic Data Bus (SFODB)".

6. Ott, M.N., "Twelve Channel Optical Fiber Connector Assembly: From Commercial Off the Shelf to Space Flight Use".

7. "Spaceborne Fiber Optic Data Bus (SFODB) Operational & Interface Description," SFODB Operational & Interface Description; Orlando & Associates, Inc., 1998.

TABLE App-E-4 Space Photonics SBIR Awards—As of May 1, 2005, Eight Phase I SBIRs and Five Phase II SBIRs Have Been Awarded

Project Description	Customer	Date	Status	Contract Award Amount ($)
Phase I SBIR—Enhanced IEEE 1393 Spaceborne Fiber Optic Transmitters and Receivers	Air Force—Kirtland AFB	1999	Completed in 2000	100,000
Phase I SBIR—IEEE 1394 Fiber Optic Transceiver	NASA/JPL	1999	Completed in 2000	70,000
Phase II SBIR—Enhanced IEEE 1393 Spaceborne Fiber Optic Transmitters and Receivers	Air Force—Kirtland AFB	2000	Completed in 2003	750,000
Phase II SBIR—Ultra-high Bandwidth Spaceborne Fiber Optic Data Networks	NASA/GSFC	2000	Completed in 2003	594,000
Phase I SBIR—Miniature Free Space Optical Transceiver for Space	Air Force—Kirtland AFB	2001	Completed in 2002	100,000
Phase I STTR—Dual Wavelength Optical Thyristor	Army	2001	Completed in 2002	100,000
Phase I SBIR	NSF	2003	Completed in 2004	100,000
Phase I SBIR—Intelligent Free Space Optical Communications Node	Air Force—Kirtland AFB	2003	Completed in 2004	100,000
Phase II SBIR plus the AF Enhancement & Extension—Miniature Free Space Optical Transceiver for Space	Air Force—Kirtland AFB	2003	Completion Target: May 1, 2006	1,250,000
Phase I SBIR—Free Space Laser Communications Turret for Aircraft	Air Force—Wright Patterson AFB	2004	Completed in 2004	100,000
Phase II SBIR—Intelligent Free Space Optical Communications Node	Air Force—Kirtland Node 2	2004	Start August 2004—End August 2006	750,000
Phase II SBIR—Free Space Laser Communications Turret for Aircraft	Air Force—Wright Patterson AFB	2005	Start February 2005—End February 2007	750,000
Phase I SBIR—Performance Enhanced Managed FPGA	Air Force—Eglin AFB	2005	Start May 2005—End February 2006	100,000
Total SBIR Awards				4,864,000

SOURCE: Space Photonics Inc.

Technology Management, Inc.

Michael S. Fogarty
Portland State University
and Case Western Reserve University

March 31, 2006

SUMMARY

Technology Management, Inc. (TMI), located in Cleveland, Ohio, was established in 1990 by Benson P. Lee to commercialize a patented SOFC (solid oxide fuel cell) technology developed by Standard Oil of Ohio (SOHIO) at their R&D Center in Warrensville Heights, Ohio, and later acquired by BP.[10]

TMI received its first SBIR award from DoE in 1991. Between 1991 and 2005, TMI received an additional nine Phase I and four Phase II awards totaling approximately $2.7 million. (See Table App-E-5.) Their SBIR funding has come from multiple agencies, including NASA, DoD (DARPA/TRP, Navy, MDA), DoE, and USDA. TMI has also received significant funding from other important non-SBIR sources: the National Institute of Standards & Technology (NIST) through the Advanced Technology Program ($2.8M); the NASA Glenn Garrett Morgan Commercialization Initiative ($60K); the U.S. Air Force Dual Use Science & Technology Program ($1.6M); EPRI (the Electric Power Research Institute ($400K); and the Ohio Department of Development's Technology Action and Third Frontier Fund ($2.8M), and the USDA/DoE Biomass R&D Initiative ($1.6M). TMI, which began with zero employees at the time of its first SBIR award, now employs over 20. Although they continue to apply for funding, the SBIR program is no longer a primary source of funding.

TMI illustrates several important SBIR issues. First is the significance of the SBIR as a source of early funding—to seed a larger funding strategy. In this case, TMI leveraged SBIR funds to obtain multiple awards from multiple agencies in developing complex technology capabilities. SBIR's early-stage funding was essential for TMI to pursue the basic and applied research necessary to prove the features of their SOFC technology. However, SBIR has been only one component of a portfolio of early-stage funding, including NIST's Advanced Technology Program and the State of Ohio.

Second, TMI's case also highlights the importance of patents as a vehicle for controlling the destiny of the technology, in this case for eventual commercialization and manufacture. (From the beginning TMI's goal has been to control the selection of manufacture, marketing and distribution partners to maximize

[10]The TMI case is mainly based on a telephone interview on May 16, 2005, and several email communications with Benson P. Lee, CEO of Technology Management, Inc.

TABLE App-E-5 TMI's SBIR Awards 1991-2004

Agency/ Type of Award	Year	Amount (thousands of dollars)	Primary Technical Achievement
DoD SBIR MDA	2004	100	Characterizes a regenerate fuel cell energy storage system
DoE SBIR Phase I	2000	60	Test an improved, lower cost, interconnect material
NASA SBIR Phase I	1998	70	Reversible Fuel Cell/Electrolyzer Developed
USDA SBIR Phase II	1997-99	200	Sulfur-Tolerant Reformer Stack Testing on Biogas
Navy SBIR Phase II	1996-99	743	Materials/Stack Development Systems Design for Shipboard SOFC
TRP SBIR Phase I	1994	100	Sulfur-bearing Logistic Fuel Operation, Stack Development
USDA SBIR Phase I	1996	50	Social and Economic Impact of Fuel Cells
USDA SBIR Phase I	1996	50	Alternative Fuels Testing
NASA SBIR Phase I and Phase II	1993 and 1996	670	Materials/Stack Development for Reversible Fuel Cells/Electrolyzer
DoE SBIR Phase I	1995	75	Seal Materials Development
DoE SBIR Phase I	1992	50	SOFC Component & Stack Development
DoE SBIR Phase I and Phase II	1991 and 1992-94	549	SOFC Components & Stack Development

SOURCE: Technology Management, Inc.

shareholder value.) TMI has seven patents granted and two current applications.[11] Their desire to control the technology is fundamental to the execution of their business model, which is based on multiple exclusive licenses with strategic partners. In order to accomplish commercialization through this business model, TMI has been constrained from using either spin-off or spin-in uses of the technology unless they are consistent with TMI's commercialization objectives. An example would be NASA's interest in using the reversible features demonstrated in their Phase II SBIR to advance the NASA mission. In this case, while the technology is clearly "dual-purpose," new incentives and new mechanisms may be necessary for achieving NASA's spin-in objectives. Just because the technology has

[11]Source: USPTO Web site search.

applications in both the private sector and in NASA doesn't guarantee that it will be used by NASA.

A third important issue represented by TMI's case is the significance of NASA's SBIR TRL (Technology Readiness Level) focus. TRL ranges from 1 through 9, where 1 is basic research and nine includes flight projects. In the past NASA has emphasized use of SBIR to fund TRL 3-6 projects. Current discussions suggest that NASA's increased emphasis on spin-in outcomes will lead to higher TRL uses of SBIR. If so, companies like TMI would be excluded from participation since they use SBIR funding to support early-stage R&D primarily oriented to private-sector commercialization of the technology. Some of the most significant technologies in U.S. history started with markets which did not exist or were not yet large enough to be measurable (e.g., electricity, the automobile, the airplane). These technologies, known as "disruptive," include the fuel cell. From the CEO's perspective, any distraction from a focus on commercialization is unwelcome. He views the current SBIR program as one of the few which weighs technical merit over market size.[12]

Finally, TMI's case illustrates the significance of location, which is Cleveland, one of the nation's older industrial regions. (Ohio receives a very small share of SBIR awards relative to the size of its economy.) Nevertheless, TMI views Ohio as providing several clear advantages for fuel-cell technology firms: (1) there is a balance of activity in fuel cells at all levels from materials to components to systems and applications. The Ohio Fuel Cell Coalition (OFCC) consists of business, academic and government leaders. The OFCC provides an important forum for knowledge sharing involving fuel cell technology; (2) Ohio provides an excellent supplier base for fuel cell companies. As a fuel cell systems integrator, TMI enjoys the proximity and interest of manufacturing companies making components for fuel cell systems; (3) The Ohio Department of Development contributed early-stage funding. For example, Ohio's Technology Action Fund, now known as the Third Frontier Fuel Cell Initiative, provided over $2 million to TMI, helping to provide cost share for several federal awards and fill cash gaps between the firm's awards. In addition, ODOD promotes fuel cells at national forums.

ORIGIN OF TMI

TMI was organized in 1990 to commercialize a single technology purchased from BP/SOHIO in 1990. The SOFC technology (solid oxide fuel cell) was originally developed by BP/SOHIO in Ohio. BP held multiple U.S. and foreign patents.

[12]Second, TMI's experience with its fuel-cell technology illustrates what is referred to as the "innovators dilemma." Because the fuel cell is a disruptive technology like the airplane, electricity, etc., commercialization presents a special challenge in that such technologies start with zero market demand.

Benson P. Lee, TMI's CEO, moved to Cleveland 35 years ago. He had been CEO of several startup companies prior to starting TMI. Beginning with zero employees at the time it received its first SBIR award (a 1991 DoE SBIR Phase I), TMI now employs over 20. TMI had no income until 1991.

The company used SBIR funding as a critical source of early-stage (seed) funding. SBIR was especially good because it required no matching funding. Now, following a decade's development of the technology, their record of achievements allow them to compete in open competition with much larger, multinational fuel-cell companies. An example is the $2.8 million ATP award to advance the technology. According to their CEO they "graduated" from being dependent on SBIRs as a primary source of funding, which is one measure of success. Their goal from day one has been to become competitive in the marketplace, not just as a developer of technology.

SBIR WAS KEY TO THE STARTUP AND DEVELOPMENT OF TMI'S CAPABILITIES

TMI's first income came from a $50,000 DoE SBIR Phase I award in 1991 (the company was founded one year earlier). This was followed by a second Phase I and then a Phase II. (See Table App-E-5 for a list of TMI's SBIR awards.)

When TMI was formed, they were not familiar with any large sources of seed funds other than SBIR. The company has received a total of $2.7 million SBIR funding since 1991. In the CEO's view (Benson Lee), they could not have developed the company without the early SBIR seed funds and a $400,000 award from EPRI (the Electric Power Research Institute). These were followed by a $4 million DARPA award. According to Mr. Lee, it is clear this funding would not have occurred without the work performed under their SBIR funding. Although they no longer look to SBIR as their primary funding source, TMI still writes two or three proposals a year, winning one about every 18 months. (They are now waiting on a Phase II from DoD.) They also plan to submit future proposals.

Mr. Lee cites two additional advantages of the SBIR program: First, merit competition levels the playing field for small businesses. This aspect of the SBIR program is very important because in open competition corporate scale is a factor as new technology ideas from small businesses must compete against the largest fuel-cell companies, where factors such as matching funds and Washington-based lobbyists as well as in-place manufacturing capability appear to have less risk. TMI considers the SBIR review process to be very good and typically fair and timely. Second, they view SBIR as conferring prestige on the company because the agencies provide a high quality review process. People know that the firm didn't lobby to get the award. Moreover, many of the program managers submitting SBIR abstracts are the same individuals who manage the largest programs in the agency.

PROPRIETARY TECHNOLOGY LIMITS SPIN-IN USES BY NASA

TMI describes its market entry product as follows: a compact, multifuel, modular, kilowatt class system, which can be delivered overnight by common carrier. The TMI system operates on common fuels and can be maintained by a single person without specialized tools, equipment or training. TMI's byline is: *"a fuel cell system which can be used anywhere, anytime, by anyone." According to TMI, no other known company has a fuel cell system with these features. TMI has used multiple laboratory systems to demonstrate these features and is currently raising funds to begin field testing and set up pre-commercial manufacturing for broader field trials.*

From the CEO's perspective, TMI is a classic example of planning the work and then working the plan. Whereas many small companies succumbed to being an R&D company surviving on R&D contracts, TMI never lost sight of the fact they were in the business of developing a commercially viable fuel cell system.

PATENTS ARE VERY IMPORTANT

According to Lee, all of their patents and their know-how, drawn from years of TMI's *generic* knowledge base are considered part of a core technology portfolio. Although none of the patents are specifically linked to any specific SBIR research because their patents are viewed as reflecting TMI's general knowledge, one key issue in evaluating SBIR is: How have SBIR awards shaped the company's knowledge base? And how has their knowledge base shaped the development of more specific technologies? In addition, for competitive reasons TMI does not publish papers, so there are no papers based on SBIR-supported research.

From day one TMI's goal has been to commercialize the technology and become a manufacturer—not simply a source of spin-in technology. Such firms present a challenge for spin-in uses of the SBIR Program. For example, highly innovative firms focused on commercialization of proprietary technology may choose to constrain spin-in uses of a technology, even when the technology has important mission purpose potential. According to Lee, "These are our crown jewels." The potential conflict is shown by the fact that TMI did not pursue an offer by NASA to undertake a Phase III project to advance the use of the technology for a space program because it did not present a pathway to a commercial market.

Their case raises an important issue, namely that TMI would probably be less likely to receive NASA funding with the agency's new emphasis on spin-in uses of SBIR/STTR.

The CEO stated that TMI would not be attracted by the shift to NASA's spin-in uses of SBIR if this change would require them to become an R&D consultant and divert them from their goal to pursue commercial products. Their view is that, unless the mission of the firm is to be an R&D consultant or to commercialize their technology for space applications, work for NASA could create an opportunity cost and be a distraction from the goal of commercialization into terrestrial markets.

According to TMI's CEO, increased spin-in uses of SBIR will require new mechanisms that foster synergy and collaborations. The challenge is to construct a relationship that benefits the agency while allowing the firm to pursue its main goal—whatever that may be. One question is: How can the topic be written to better align the project with what NASA would like to do? The idea is that NASA would utilize the knowledge developed by the firm using the SBIR award to think in new ways and cultivate innovation by NASA.

OHIO LOCATION OFFERS ADVANTAGES

TMI's view is that Ohio is a "superb" location for the *development* of fuel cell technology. According to the CEO, *market* success with the fuel cell technology will depend on the manufacturers, which is well suited to the Midwest. In fact, because Ohio is a location for three or four fuel cell, component and systems companies, TMI's location does not present a problem in recruiting bright young researchers. Ohio scores high in fuel-cell development. Silicon Valley may have a little better venture capital situation, but Ohio provides access to companies in the supply chain: pumps, pump makers, etc. One asset is the membership of the Ohio Fuel Cell Coalition (OFCC), which mostly consists of supplier firms.[13]

AWARD SIZE IS GOOD BUT PHASE I-PHASE II DELAYS PRESENT A BIG PROBLEM

TMI has no suggestions for altering the size of Phase I and Phase II awards. The $100,000 Phase I is ample to prove a concept. But the time gap between Phase I-Phase II often causes cash flow problems for a small business. The CEO didn't take a salary for the first 2-3 years. Recognizing the problem and with the belief that biotechnology and fuel cell technologies can be competitive in Northeast Ohio, the State of Ohio had a program that bridged Phase I to Phase II. Ohio's award was part of the state's fuel cell initiative.

[13]The coalition includes business, academic and government leaders. Also as of March 15, 2005, the following organizations are coalition members: NexTech Materials, BIOMEX, Cinergy Ventures, Molded Fiber Glass Companies, ThermalTech Engineering, Inc., Kent State, Sierra Lobo, HydroGen LLC, Graftech, AvMat LLC, Nordson, Primrose, Inc., CSA-International, Catacel, Lorain County Community College, University of Dayton Research Institute (UDRI), FirstEnergy, TMI, Meacham Company, Ohio Cat, PIA Group, Air Force Research Lab at WPAFB, Stark Development Board, Parker Hannifin, Sinclair Community College, City of Lorain, SGL Carbon, Hocking College, Technical Staffing Professionals, Metamateria, Behn Quartz, Refractory Specialties, Inc., Vanner, Inc., and LCP Holding, LLC.

TECHNOLOGY MANAGEMENT, INC.—ANNEX CEVEC (CUYAHOGA EAST VOCATIONAL EDUCATIONAL CONSORTIUM) DEMONSTRATION—OCTOBER, 2005

The first public demonstration (October 2005) was a 3kW system at CEVEC using three 1-kW modules connected in parallel and operating on propane. The photo to the right shows the 3kW system (on a transport cart) recharging a fork-lift and providing security lighting. TMI personnel are operating and monitoring the system with interaction with CEVEC staff during the demonstration. TMI believes this demonstration may be one of the very first known to use a multiple module SOFC configuration. The advantages of redundancy are higher reliability, power availability, and built-in back up. Particularly for mission critical applications such as telecommunications, which require continuous power and back up, this system design has the potential for also being extremely cost competitive over the full product life cycle.

TiNi Alloy[14]

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May 5, 2005

OVERVIEW

TiNi Alloy was started in 1987 in the Bay Area. SBIR funding has been essential to supporting the R&D that has created successful technology applications of the company's MEMS technology by other companies. One implication of this case is that an assessment of SBIR's contribution to TiNi Alloy requires examining both the innovative technologies created with SBIR support and the bulk of commercialization activity accomplished by other firms using the technologies. In other words, the economic assessment needs to allow for different firms playing separate roles: one being R&D and a second being the primary commercialization. TiNi has continued to employ 8-9 people throughout the 19 years since it was a startup. Their founder currently seeks a path that would involve the company's manufacture of a new product.

The TiNi Alloy case illustrates how SBIR was used to fund a startup whose main activity is R&D with most commercialization occurring through licensing of patents to companies successfully using the technology for new products. Specifically, the case illustrates several important features and issues with the SBIR program: (1) SBIR's current emphasis on shorter-term, less risky projects that meet a mission need would not support TiNi-type technology developments; (2) Evaluation of the economic effects of SBIR must allow for commercialization occurring in at least two steps: (a) the initial R&D and development of early-state technology, which has been TiNi's primary function; and (b) commercialization by different companies that license intellectual property produced by the SBIR-supported firm; (3) commercialization occurs with uncertainty and over long period of time, indicating the importance of evaluation taking a similarly long-time horizon; (4) location matters a lot, in some cases favoring an SBIR-supported firm (as in TiNi's case) and in others creating a disadvantage for the firm (a TiNi Alloy would be very unlikely to startup and become successful in a Cleveland, Buffalo, or Detroit). TiNi may also illustrate the importance of multiple SBIR awards from several agencies as essential for developing a technology that at least initially, because of there being no obvious large commercial product market, is not attractive to VC.

[14]This case was based on an interview with David Johnson, TiNi's founder and CEO, San Leandro, California; Web site information; patent data from USPTO; and the DoD's SBIR database.

TiNi represents *one* potential model for a successful SBIR outcome: use SBIR funds to support highly innovative R&D labs with a potentially important, commercializable technology that can be taken the next step by other firms with manufacturing and marketing capabilities.

COMPANY AND FOUNDER BACKGROUND

TiNi Alloy was founded in 1987 by A. David Johnson, who owns ninety percent of the company and is the CEO and CTO. TiNi is primarily an R&D lab specializing in MEMS and nanotechnology. They have employed eight or nine people almost from the beginning and produce revenues of $650,000 to $1,500,000 annually.

TiNi Has Received 31 SBIR Awards

TiNi had three employees at the time the first SBIR award was received. Over the lifetime of the company TiNi has received 21 Phase I awards, ten of which progressed to Phase II. Their Phase II awards have come from several sources, including NASA, DARPA, HHS/NIH, NSF, DoE, the Air Force, and BMDO/SDIO. Four Phase II awards are associated with NASA.

The company started by building heat engines that run on hot and cold water. A set of aerospace devices followed. Their recent focus has been microdevices and nanodevices made of TiNi thin film. The company believes that the next stage of their technology will involve nanodevices with implantable medical device applications.

The Silicon Valley Location Has Given Them a Key Advantage

The main advantages of their Bay Area location is, first, access to others doing MEMS work and, second, the ability to obtain and maintain important equipment that would be difficult elsewhere. In Johnson's view, "Silicon Valley offers a reservoir of talent, equipment, finances, expertise, and intellectual stimulation." He thinks that he's in Silicon Valley because of the factors that cause the region to feed on itself.

TiNi summarizes its history as follows: incorporated in 1987; launched TiNi Aerospace in 1995; obtained Lee Co. License in 1999 and a Smart Therapeutics license in 2000. Their current situation is also summarized: They have a technology, which is thin film TiNi microfabrication; they have patented the intellectual property; there exists an opportunity with a major medical device company; and they hope to develop a corneal implant manufacturing facility, with funding either through TiNi Alloy or as a spin-off company.

TiNi TECHNOLOGY

TiNi's Core Competency Includes Microfabrication and Materials Science

TiNi is derived from Titanium Nickel; AKA Nitinol. The company's strength is Microelectro-mechanical Systems (MEMS). Their core competency includes microfabrication (sputter deposition, photolithography, chemical milling, scanning electron microscopy) and materials science (Shape Memory Alloys, finite element analysis). Their MEMS technology combines silicon microfabrication with shape-memory metals. The result is micro-miniature valves and micro-switches with potential applications to consumer products and manufacturing.

Their technologies have applications in four areas: Biotech, Aerospace, Energy, and Medicine.

Biotech

Applications in biotech stem from increasingly small sample sizes coupled with more sophisticated instruments, which creates a need for miniature valves and pumps. Costly samples and chemicals require conservation of liquids and, therefore, the system's entire internal volume must be minimized. As a result, valves and pumps must be small and have the capability of controlling pressure up to several atmospheres.

Aerospace

The trend is toward smaller and more sophisticated space vehicles. TiNi Alloy develops micromachined liquid control and pneumatic valves. Through TiNi Aerospace they also provide separation devices for space vehicles.

Energy

Battery technology lags behind requirements for compact sources of electrical energy while portable computers and various other instruments require considerable power. One solution involves using fuel cells, which can potentially provide substantially more power density. However, they also require more sophisticated control systems and, consequently, miniature valves. TiNi's technology includes a liquid control valve to provide this application.

Medicine

One standard component used to treat cardiovascular disease is the stent. TiNi's thin film technology (in particular their 3-D devices) give access to the body's smaller blood vessels and other lumens. TiNi is also targeting their R&D

to clot retrievers and aneurysm closures for treating intracranial disease. They are also focusing R&D on implantable drug delivery systems.

COMMERCIALIZATION

Commercialization of Technology Has Occurred Through Licensing Its Patents to Commercially Successful Companies

To summarize David Johnson's view, TiNi has used SBIR awards to develop valuable technology but they have had limited success with commercialization through manufacturing and sales. Licensing of patents has brought them their largest financial returns.

TiNi has received more than 20 patents on its technology and has ten applications on file. TiNi's business model strategy is focused on technology development and licensing. Their inventions cover thin film technology, devices, and processes.

The company has three current licenses: (1) Lee: Pneumatic Valves (an agreement interpreted to include latching valves for NASA; (2) SMART/Boston Scientific (for intravascular stent devices; this acquisition provided TiNi with significant revenue); and (3) TiNi Aerospace (for separation devices used in satellites and spacecraft; the agreement involves inclusion of a "thermal fuse" valve for airliners). The company has two agreements that are being negotiated, one involving a consumer product and a second for a medical product. TiNi Aerospace is located about one mile away. Close cooperation between the two companies continues.

As of June 2003, commercialization associated with their Phase II awards produced total revenue of $5,918,000.

Their Frangibolt(TM) has become a standard component on satellites (a shape memory alloy powered separation device). The device has been used by TRW, the European Space Agency, and Lockheed-Martin. In addition, TiNi's pin-puller was used on the Mars Global Explorer, and is scheduled for use in NASA's STEREO program.

Evidence of Technology Benefits to Other Firms

Indirectly, TiNi's technology developments have influenced technology developments by other firms. They pioneered making shape memory alloy in the form of thin film and combining it with silicon to make MEMS devices. Several universities have established graduate research programs in this subject and two medical device companies are currently exploring its use in implantable devices.

Part of TiNi's funding has come from contracting R&D services to several commercial firms: GM's Delphi division (fuel injectors), JNJ (implantable medical systems), Ford Motor Company (electrical connectors), and SMART Therapeutics (intravascular devices).

IMPORTANCE OF SBIR

SBIR Was a "Godsend" to TiNi

Johnson considers "SBIR as a godsend to him." When the Superconductor-Super Collider program was eliminated in the early 1980s, his position with the Lawrence-Berkeley lab, where he had been for twenty years, was eliminated. He discovered the SBIR program when talking with a colleague about a Braille computer display. At the time he had no funding, so in 1987 he approached NIH for an SBIR. TiNi Alloy was founded before a proposal was submitted; however, the two first SBIR grants paid salaries for the first year of business.

But SBIR Is a Mixed Bag

Johnson views SBIR as a mixed bag (both positive and negative long-term consequences): It has been good for conducting experiments in interesting areas and encourages fiscal discipline, but it's insufficient to grow a company and, even if the concept is proven, a gap still exists. "What's needed is something that people will buy." SBIR has permitted TiNi to explore a wide range of technologies that would not have been possible otherwise. This had put them in a strong intellectual property position. However, jumping from one contract to another has prevented them from focusing on one application with sufficient effort to achieve manufacturing and sales of products.

Johnson has also co-founded a company that got angel and individual investment funding for a medical product. This company was acquired by a large medical firm, providing operating support for TiNi Alloy for several years. Johnson believes that the technology was the most important factor in getting funding. The SBIR awards did not have a major influence on the decision to fund the work. Although they have done contract work for several companies in the automotive and medical industries, this has not been their major revenue source.

ISSUES WITH THE CURRENT SBIR

Johnson believes that success comes in several forms: the SBIR firm can license, produce and sell, or be acquired and/or go public.

Phase I-Phase II Delays Handled Through Multiple Proposals

The delay in funding between Phase I and Phase II funding is a problem which they have handled by trying to have several proposals in the pipeline at the same time. As a result, however, they lose momentum, causing Phase II projects to be less successful.

SBIR Phase I Awards Should Be Smaller But with Reduced Goals

Johnson's view is that there should not be a fixed amount for Phase I. In fact, he thinks that it would sometimes be more effective if the grants were smaller and the goals were reduced accordingly. Other times the amount is too little, meaning that it is too small to expect significant results. He believes that the amount should be negotiated, taking into account the proposer's estimate of the project's challenge, with the implication that this approach encourages more innovation. He strongly believes that SBIR's current focus encourages significantly less innovation.

Parts of the Selection Process Are Fair But Other Aspects Are Unfair

He pointed out that his SBIR experience varies quite a bit by agency: Because each agency has its own objectives, the selection process varies by agency and, therefore, is at least fair from this perspective. He has experienced closer cooperation with NASA than with either NIH or DARPA. However, Johnson views the process as sometimes being unfair, "in particular when a solicitation is written to favor one proposer." For example, in his view, NIH seems to favor proposers with access to medical expertise—an MD or a university with a name and probably something that has already proven successful. He felt that even a Phase I requires these, and it will make money. This criterion needn't bear any relationship to the project's contribution to innovation. Nevertheless, he believes that this approach may not be unreasonable as long as everyone knows the rules.

Views SBIR's Increasing Focus on Less Risky, Less Innovative Projects as a Major Mistake

Johnson hasn't submitted an SBIR proposal for several years and will not submit further proposals unless the subject fits with the direction he wants TiNi to go. He is particularly concerned with the growing emphasis on short-term technology objectives. He views this trend as moving against SBIR's original purpose and causing less innovation.

In his view, Johnson sees the recent SBIR shift to shorter-term mission objectives as a major mistake. ("The focus on mission technology is a subversion of the program's intent.") He believes that SBIR should take risks that VC companies won't.

Two Interesting Examples

He gave an example of an innovation that stemmed from his idea. One day he got a telephone call asking about thin film. He then wrote a NASA SBIR, which got funded and allowed for demonstration of an application to computer memory. Although it didn't work, he made thin film. After this step, he created his first Web page. The Web page created contacts. This was followed by SBIRs from both NSF and DARPA. One contact from a person from New York University was about a medical application. After meeting, the NYU person licensed Johnson's technology and set up a new business, giving Johnson stock in the company. The company was formed as Smart Therapeutics. It developed a product that was sold to Boston Scientific, which provided TiNi Alloy with money. The point is that SBIR funded highly innovative thin film technology that required a second firm to complete the commercialization, indirectly further funding TiNi Alloy through the second company's sales. None of this was planned. "No one knows where the next good thing will come from." In fact, Johnson thinks that the best projects didn't have a business plan.

He gave a second interesting example. Shortly after he started TiNi, someone asked: Can the technology be used to make explosive bolts? After putting down the telephone, while walking down the stairs he got an idea: a device that breaks the bolt but not explosively. He made a prototype in a couple of weeks that proved the concept. Then he sought funding from SBIR but failed to get support. A Navy person saw the technology as a means to separate in space and funded it. The technology (the FRANGIBOLT) was used for the Clementine Space Mission. TiNi Aerospace was launched to commercialize the product and has paid royalties back to TiNi Alloy Company.

SBIR/States' Commercialization Support Has Not Been Important to TiNi Alloy

Johnson attended only one conference by MDA that was intended to provide commercialization advice and assistance. The effect on TiNi was minimal because there was no follow-up. He believes that people like himself need mentoring: help from people with experience taking things to market. One example involves working with larger companies. Sherwin-Williams, GM, and Gillette were all interested in Johnson's technology. He wrote proposals but nothing happened. How does a small firm make these connections?

He has also talked with VC. But the VC consider his technology too diverse. So he hasn't gotten VC funds. Does he need a partner to take the next step? TiNi Alloy Company and TiNi Aerospace are planning a spin-off to make a consumer product, and will invite VC investment.

Appendix F

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