SBIR at NASA

DETAILS

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

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* As of April 2016.

(continued)

Preface

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

The Small Business Innovation Research (SBIR) program is one of the largest examples of U.S. public-private partnerships. An underlying tenet of the program is that small businesses are a strong source of new ideas, and therefore economic growth, but that it is difficult to find financial support for these ideas in the early stages of their development and market implementation. The SBIR program was established in 1982 to encourage small businesses to develop new processes and products and to provide quality research and development in support of the U.S. government's many missions. By involving qualified small businesses in the nation's research and development (R&D) effort, SBIR grants stimulate innovative technologies to help federal agencies meet their specific functional needs in many areas, including health, the environment, and national defense.

[1]See L.M. Branscomb, K.P. Morse, M. J. Roberts, and D. Boville, *Managing Technical Risk: Understanding Private Sector Decision Making on Early Stage Technology Based Projects,* Gaithersburg, MD: National Institute of Standards and Technology, 2000.

The U.S. Congress tasked the National Research Council (NRC)[2] with undertaking a "comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet federal research and development needs" and with recommending further improvements to the program.[3] In the first-round study, an expert committee prepared a series of reports from 2004 to 2009 on the Small Business Innovation Research program at 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)—the five agencies responsible for 96 percent of the program's operations.[4]

Building on the outcomes from the first round, this second round, led by a new committee, examines topics of general policy interest that emerged during the first round as well as topics of specific interest to the individual agencies. The results will be published in reports of agency-specific and program-wide findings on the SBIR and Small Business Technology Transfer (STTR) programs to be submitted to the contracting agencies and Congress. In partial fulfillment of these objectives, this volume presents the committee's review of the SBIR program's operations at the National Aeronautics and Space Administration (NASA).[5]

PROJECT ANTECEDENTS

The current two-phase assessment of the SBIR program follows directly from an earlier analysis of public-private partnerships by the Board on Science, Technology, and Economic Policy (STEP). From 1990 to 2005, the 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]

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[2]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council are used in an historic context identifying programs prior to July 1.
[3]See the SBIR Reauthorization Act of 2000 (H.R. 5667, Section 108).
[4]For the overview report, see National Research Council, *An Assessment of the SBIR Program,* Washington, DC: The National Academies Press, 2008. See also National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration,* Washington, DC: The National Academies Press, 2009. The committee also prepared reports on the SBIR program at DoD, DoE, NIH, and NSF.
[5]The formal Statement of Task is presented in Chapter 1 of this report.
[6]For a summary of the topics covered and main lessons learned, see National Research Council, *Government-Industry Partnerships for the Development of New Technologies: Summary Report,* Washington, DC: National Academy Press, 2002.

This analysis of public-private partnerships includes two published studies of the SBIR program. Drawing from a 1998 workshop, the first report, *The Small Business Innovation Research Program: Challenges and Opportunities,* examined the origins of the program and identified operational challenges to its future effectiveness.[7] Research conducted for this 1999 report focused on the minimal academic research on the SBIR program.

After the release of this initial report, the DoD asked the committee to compare the operations of its Fast Track Initiative with those of its regular SBIR program. The resulting report, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* relying on case study and survey research, found that the DoD SBIR program was achieving its legislated goals. The report also found that the Fast Track Initiative was achieving its objective of greater commercialization and recommended that it be continued and expanded where appropriate.[8] The report recommended that the SBIR program overall would benefit from further research and analysis, a recommendation subsequently adopted by Congress.

ACKNOWLEDGMENTS

On behalf of The National Academies of Sciences, Engineering, and Medicine, we express our appreciation for and recognition of the valuable insights and close cooperation extended by NASA staff, the survey respondents, and case study interviewees, among others. The committee gives particular thanks to its lead researcher, Robin Gaster of Innovation Competitions LLC, to Rosalie Ruegg of TIA Consulting, and to Peter Grunwald of Grunwald Associates LLC, which conducted the surveys and described the results presented in this volume. David Dierksheide of the STEP staff is especially recognized for his important contributions to operation of this study and the preparation of this report.

Acknowledgment of Reviewers

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 of Sciences, Engineering, and Medicine's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study

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

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

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: Philip Auerswald, George Mason University; Fred Block, University of California, Davis; Thomas Crabb, Orbital Technologies Corporation; Earl Dowell, Duke University; David Finifter, College of William Mary; Thomas Irvine, American Institute of Aeronautics and Astronautics; Martin Kaszubowski, Old Dominion University; Bruce Marcus, TRW, Inc. (Retired); Anthony Mulligan, Hydronalix, Inc; Colm O'Muircheartaigh, University of Chicago; Marcia Rieke, University of Arizona; George Sutton, SPARTA (Retired); and John Watson, University of California, San Diego.

Although the reviewers listed above have provided many constructive comments 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 Ed Przybylowicz, Eastman Kodak (Retired) and Irwin Feller, Pennsylvania State University. Appointed by the 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 | Sujai J. Shivakumar

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Summary

Created in 1982 through the Small Business Innovation Development Act, the Small Business Innovation Research (SBIR) program remains the nation's single largest innovation program for small business. The SBIR program offers competitive awards to support the development and commercialization of innovative technologies by small private-sector businesses. At the same time, the program provides government agencies with technical and scientific solutions that address their different missions.

Adopting several recommendations from the 2008 National Research Council (NRC) study of the SBIR program, Congress reauthorized the program in December 2011 for an additional 6 years. In addition, Congress called for further studies by the Academies. In turn, the National Aeronautics and Space Administration (NASA) requested the Academies to provide a subsequent round of analysis, focused on operational questions with a view to identifying further improvements to the program.

FOCUS ON LEGISLATIVE OBJECTIVES

The SBIR programs are unique efforts designed by Congress to provide funding via government agencies in pursuit of four key objectives. These objectives are described in the Small Business Administration (SBA) Policy Directive that guides program implementation at all agencies. Section 1c of the Directive lists the program objectives as follows:

> *The statutory purpose of the SBIR Program is to strengthen the role of innovative small business concerns (SBCs) in Federally-funded research or research and development (R/R&D). Specific goals are to:*
>
> *(1) Stimulate technological innovation;*
> *(2) use small business to meet Federal R/R&D needs;*

(3) foster and encourage participation by socially and economically disadvantaged small businesses (SDBs; also called minority-owned small businesses [MOSBs] elsewhere in the report), and by woman-owned small businesses (WOSBs), in technological innovation; and

(4) increase private sector commercialization of innovations derived from Federal R/R&D, thereby increasing competition, productivity and economic growth.

SCOPE OF THE ASSESSMENT

This study recognizes that the NASA SBIR program is distinctive in terms of scale, integrity, and mission focus. It does not purport to benchmark the NASA SBIR against SBIR programs at other agencies or non-SBIR programs in the United States or abroad. Further, the study does not consider if the NASA SBIR should exist or not; rather, it assesses the extent to which the SBIR program at NASA has met the congressional objectives set for the program, examining the extent to which recent initiatives have improved program outcomes and providing recommendations for further improving the program to meet its objectives.

It is also important to note at the outset that this study does not seek to provide a comprehensive review of the value of the SBIR program, in particular measured against other possible alternative uses of federal funding. This is beyond the study scope. Our work is focused on assessing the extent to which the SBIR program at NASA has met the congressional objectives set for the program, to determine in particular whether recent administrative initiatives have improved program outcomes, and to provide recommendations for improving the program further.

STUDY METHODOLOGY AND LIMITATIONS

The committee's findings are based on a complement of quantitative and qualitative tools including a survey, case studies of award recipients, agency data, public workshops, and agency meetings. The methodology is described in Chapter 1 and Appendix A of this report. In reviewing the findings below, it is important to note that the Academies' 2011 Survey—hereafter referred to as the 2011 Survey—was sent to every principal investigator (PI) who won a Phase II award from NASA, FY1998-2007 (not the registered company points of contact [POC] for each company. Each PI was asked to complete a maximum of two questionnaires, which as a result excludes some awards from the survey. The preliminary population was developed by taking the original set of SBIR Phase II awards made by NASA during the study period and eliminating on a random basis awards to PIs who received more than two awards (to limit the burden on respondents). The resulting preliminary population was 1,131 awards. PIs for 641 of these awards were determined to be not contactable at the SBIR company listed in the NASA awards database. The remaining 490 awards constitute the effective population for this study. From the effective population, we received 179 responses. As a result, the response rate in relation to the preliminary population was 15.8 percent and in relation to the effective population response was 36.5 percent.

The committee acknowledges that because it was not possible to collect information from non-respondent PIs and because the agencies have minimal information about PIs which could be used to track potential non-respondent biases, we do not have data on which to develop an analysis of non-respondent bias. The committee has concluded that the data are likely to be biased toward PIs who are still working at companies that are still in business as corporate entities (i.e. have not failed or been acquired).

The absence of usable quantitative outcomes data from NASA further limits the conclusions that can be drawn from this assessment. Although the 2011 Survey provides quantitative data on NASA outcomes agency-wide, the number of responses is too limited to permit definitive conclusions. Similarly, although the limited data provided by NASA and that provided by Department of Defense (DoD) on NASA projects recorded in the DoD Company Commercialization Record database are helpful, neither is comprehensive.

Given the size of the survey population and response rates and overall potential sources of survey bias, the following findings and recommendations rely more heavily on company case studies, discussions with agency staff, and other documentation than we would have preferred. The committee's findings are accordingly qualified.

KEY FINDINGS

Although more and better data would improve the grounding for these findings, it is our judgment that the NASA SBIR program is encouraging the expansion of technical knowledge. And although the limited data available from the 2011 Survey indicates limited infusion of SBIR technologies into NASA Mission Directorates for awards made in FY1998-2007, the program has since then become increasingly aligned with NASA Mission Directorate needs. NASA SBIR projects commercialize at a level similar to that of comparable SBIR programs at DoD, although the small size of the NASA market limits the scale of commercialization. However, with regard to the third program objective, we conclude that the NASA SBIR program is not adequately fostering and encouraging participation by women and minorities and socially and economically disadvantaged small businesses.

The findings are organized in terms of the four legislative objectives of the SBIR program plus findings on the management of the program.

Commercialization

- In the main…it appears that many NASA SBIR companies are affected by the small size of the NASA marketplace and sometimes very long lags as technology matures and large scale programs evolve toward completion. In some ways, they also suffer from the NASA SBIR program's focus on NASA's specialized needs. (Finding I)
- NASA SBIR projects commercialize at a substantial rate. Forty-six percent of respondents to the 2011 Survey reported some sales. An additional 26 percent reported that they anticipate future sales. (Finding I-A)

Meeting the Mission Needs of the Agency

- The lack of comprehensive quantitative data concerning the agency uptake of SBIR-funded technologies prevented effective determination of the program's impact within NASA. NASA was unable to provide comprehensive data on follow-on contracts after Phase II. The new data collection mechanism may provide better data in the future. (Finding II-A)
- Responses to the 2011 Survey shows limited uptake of SBIR projects within NASA. An average of about 20 percent of reported project sales were to NASA or NASA primes. (Finding II-B)
- There is qualitative evidence on uptake of SBIR-funded technologies within NASA. Company case studies provide examples of technologies that were used on NASA missions or that made important contributions to NASA operations. (Finding II-C)

Fostering the Participation of Women and Other Under-represented Groups in the NASA SBIR Program

- The levels of participation by minority-owned and woman-owned firms in the NASA SBIR program are low and in some areas falling. Data from NASA indicate that approximately 8 percent of Phase I awards in FY2014 went to Woman-owned Small Businesses (WOSBs). Approximately an equal share went to Minority-owned Small Businesses (MOSBs). (Finding III-A)
- Phase I success rates (awards/applications) for MOSBs were lower than those for non-MOSBs every year since FY2005. In FY2014 the gap was more than 20 percentage points. (Finding III-A)
- Phase I success rates for WOSB were lower than those for non-WOSBs in all the years studied. The gap was largest in FY2014, about 20 percentage points. (Finding III-A)

- MOSB shares of Phase II awards fell substantially: MOSB firms received 19 Phase II awards in FY2009 and 5 in FY2014. Their share declined by over half after FY2006. The WOSB share of Phase II awards declined to below 8 percent in FY2011 and FY2012. (Finding III-A)
- MOSB Phase II success rates in every year FY2005-2012 were lower than those for non-MOSB firms. Overall, MOSB success rates were 13 percentage points lower than those for non-MOSBs. (Finding III-A)
- Phase II success rates for WOSBs were lower than those for non-WOSBs in every year of the study period (FY2005-2012) except for FY2005. (Finding III-A)
- NASA has not made sustained efforts to "foster and encourage" the participation of WOSBs and MOSBs. (Finding III-B)
- NASA does not report on or sufficiently track participation by WOSBs and MOSBs. NASA provided no separate data on Black-owned and Hispanic-owned small businesses or on minority or female principal investigators (PIs). NASA does not maintain data on woman and minority PIs. (Finding III-C)

Enhancing Science and Technology

- The SBIR program at NASA supports the development and adoption of technological innovations. However there is growing misalignment between the enhancement of science and technology and the demands of meeting specific agency mission needs. (Finding IV-A)
- The NASA SBIR program continues to connect companies and universities. Just over 30 percent of respondents reported a link to a university. About 21 percent of respondents reported that a research institution was a subcontractor; about 15 percent, reported that university faculty worked on the project (not as PI); and 14 percent reported employing graduate students. (Finding IV-B)
- NASA SBIR projects generate substantial knowledge-based outputs such as patents and peer reviewed publications. More than 80 percent of respondents reported at least one resulting peer-reviewed publication related to the surveyed project. (Finding IV-C)

Fostering Innovation Companies

- The NASA SBIR program fosters the formation of innovative small companies. Forty percent of respondents said that the company was founded entirely or in part because of the SBIR program. (Finding V-A)

Program Management

- NASA's SBIR program is not sufficiently driven by metrics. NASA lacks sufficient evidence on the operations of its SBIR program. (Finding VI-A)
- Many of NASA's commercialization initiatives are potentially promising but are too recent to provide an outcome assessment. (Finding VI-B)
- NASA's monitoring and evaluation of the SBIR program is insufficient. While NASA has initiated a tracking system focused on commercialization starting in 2012, participation is key. NASA has not provided metrics against which program improvement could be measured. (Finding VI-C)
- Some NASA program management practices do not reflect best practices. NASA's SBIR contracts management is unnecessarily rigid. Funding gaps between Phase I and Phase II have not been effectively addressed. (Finding VI-D)

KEY RECOMMENDATIONS

The following recommendations, which are organized in terms of four sets of leading actions needed to improve the SBIR program at NASA, can help improve outcomes.

Furthering a Culture of Monitoring, Evaluation, and Assessment Predicated on Enhanced Information Flows

- The NASA SBIR program should improve current data collection approaches and methodologies. NASA should make it a top priority to develop and implement appropriate metrics for assessing program outcomes. (Recommendation I-A)
- NASA should better use the data it collects on the SBIR program. These data should be utilized to systematically guide program management. (Recommendation I-C)
- NASA should improve its reporting on the SBIR program. The NASA SBIR program should provide a comprehensive annual report to Congress and the public on its operations. (Recommendation I-D)

Addressing Under-represented Populations

- NASA should immediately enhance efforts to address the Congressional mandate to foster the participation of under-represented populations in the SBIR program. (Recommendation II)

- Quotas are not necessary. While NASA should strive to increase participation of under-represented populations in the SBIR program, it should not develop quotas for that purpose. (Recommendation II-A)
- NASA should develop outreach and education programs focused on expanding participation of under-represented populations. NASA should develop a coherent and systematic outreach strategy that provides for cost-effective approaches to enhanced recruitment, developed in conjunction with other stakeholders and with experts in the field. This may in part build on existing efforts at some Field Centers, notably those at the Johnson Space Center as well as other efforts to enhance diversity at NASA. (Recommendation II-C)

Commercialization

- NASA should improve support for the commercialization of SBIR technologies by: (Recommendation III-A)

  - *Identifying and applying best practices*. Potentially, different approaches adopted by various NASA Field Centers could provide valuable data on more and less effective commercialization support strategies. Such analysis would of course require better data and a commitment to this kind of analysis and subsequent follow-up. (Recommendation III-A)
  - *Leveraging existing programs and opportunities*. For example NASA should explore more systematic ways to connect with DoD SBIR commercialization efforts, particularly given the significant overlap between NASA and DoD revealed by the 2011 Survey and the DoD CCR database. (Recommendation III-A)

Improving Program Management

- NASA should improve the application process. *NASA should improve connections with applicants prior to application*. (Recommendation IV-A)
- NASA should adopt more flexible contracting practices to encourage firm participation in the program. (Recommendation IV-B)

1

Introduction

Small businesses continue to be an important driver of innovation and economic growth,[1] given the challenges of changing global environments and the impacts of the 2008 financial crisis and subsequent recession.[2] In the face of these challenges, supporting innovative small businesses in their development and commercialization of new products is essential for U.S. competitiveness and national security.

Created in 1982 through the Small Business Innovation Development Act, the Small Business Innovation Research (SBIR) program remains the nation's largest innovation program for small business. The SBIR program offers competitive awards[3] to support the development and commercialization of innovative technologies by small private-sector businesses. At the same time,

[1]See Z. Acs and D. Audretsch, "Innovation in large and small firms: An empirical analysis," *The American Economic Review*, 78(4):678-690, 1988. See also Z. Acs and D. Audretsch, *Innovation and Small Firms*, Cambridge, MA: The MIT Press, 1991; E. Stam and K. Wennberg, "The roles of R&D in new firm growth," *Small Business Economics,* 33:77-89, 2009; E. Fischer and A.R. Reuber, "Support for rapid-growth firms: A comparison of the views of founders, government policymakers, and private sector resource providers," *Journal of Small Business Management*, 41(4):346-365, 2003; M. Henrekson and D. Johansson, "Competencies and institutions fostering high-growth firms," *Foundations and Trends in Entrepreneurship*, 5(1):1-80, 2009.

[2]See D. Archibugi, A. Filippetti, and M. Frenz, "Economic crisis and innovation: Is destruction prevailing over accumulation?" *Research Policy*, 42(2):303-314, 2013. The authors show that "the 2008 economic crisis has severely reduced the short-term willingness of firms to invest in innovation" and also that it "led to a concentration of innovative activities within a small group of fast growing new firms and those firms already highly innovative before the crisis." They conclude that "the companies in pursuit of more explorative strategies towards new product and market developments are those able to cope better with the crisis."

[3]SBIR awards can be made as grants or as contracts. Grants do not require the awardee to provide an agreed deliverable; for contracts there is often a prototype at the end of Phase II. Contracts are also governed by federal contracting regulations, which are considerably more demanding from the small business perspective. Historically, all Department of Defense (DoD) and National Aeronautics and Space Administration (NASA) awards have been contracts, all National Science Foundation (NSF) and most National Institutes of Health (NIH) awards have been grants, and the Department of Energy (DoE) has used both vehicles.

the program provides government agencies with technical and scientific solutions that address their different missions.

Currently, the program consists of three phases:

- Phase I provides limited funding (up to $100,000 prior to the 2011 reauthorization and up to $150,000 thereafter) for feasibility studies.
- Phase II provides more substantial funding for further research and development (typically up to $750,000 prior to 2012 and $1 million after the 2011 reauthorization).[4]
- Phase III reflects commercialization without providing access to any additional SBIR funding, although funding from other federal government accounts is permitted.

The program has four Congressionally mandated goals: (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.

Research agencies have pursued these goals through the development of SBIR programs that in many respects differ from each other, utilizing the administrative flexibility built into the general program to address their unique mission needs.

In recent years, about 18 percent of Phase I applications to NASA resulted in an award, making it a highly competitive program.[5] Before 2011, Phase II funding could be awarded only to projects that had successfully completed Phase I. Just over half of Phase II applications to NASA were successfully completed (51 percent). Thus, fewer than 10 percent of Phase I applications resulted in a Phase II award.

Over time, through a series of reauthorizations, SBIR legislation has required federal agencies with extramural research and development (R&D) budgets in excess of $100 million to set aside a growing share of their budgets for the SBIR program. Reaching a set-aside of 2.5 percent, the 11 federal agencies administering the SBIR program obligated $1.9 billion to fund 4,792 SBIR awards in fiscal year (FY) 2014.[6] These agencies include the Department of Agriculture, Department of Commerce, Department of Defense (DoD), Department of Education, Department of Energy (DoE), Department of Health and Human Services (DHHS), Department of Homeland Security, Department

[4]All resource and time constraints imposed by the program are somewhat flexible and are addressed by different agencies in different ways. For example, NIH and to a much lesser degree DoD have provided awards that are much larger than the standard amounts, and NIH has a tradition of offering no-cost extensions to see work completed on an extended timeline.

[5]NASA data provided to the Academies.

[6]Small Business Association (SBA) SBIR/STTR awards database, https://www.sbir.gov/analytics-dashboard/, accessed March 15, 2016.

of Transportation, Environmental Protection Agency, NASA, and the National Science Foundation (NSF).

Five agencies administer greater than 98 percent of SBIR funds: DoD, DHHS (particularly the National Institutes of Health [NIH]), DoE, NASA, and NSF (see Figure 1-1 for their respective shares). In FY2014, for example, NASA made 467 SBIR awards, requiring $141.8 million in funds obligated, comprising 7 percent of the overall SBIR total obligations.

In December 2011, Congress reauthorized the program for an additional 6 years,[7] with a number of important modifications. Many of these modifications—for example, changes in standard award size—were consistent with or followed recommendations made in a 2008 National Research Council (NRC)[8] report on the SBIR program, a study mandated as part of the program's

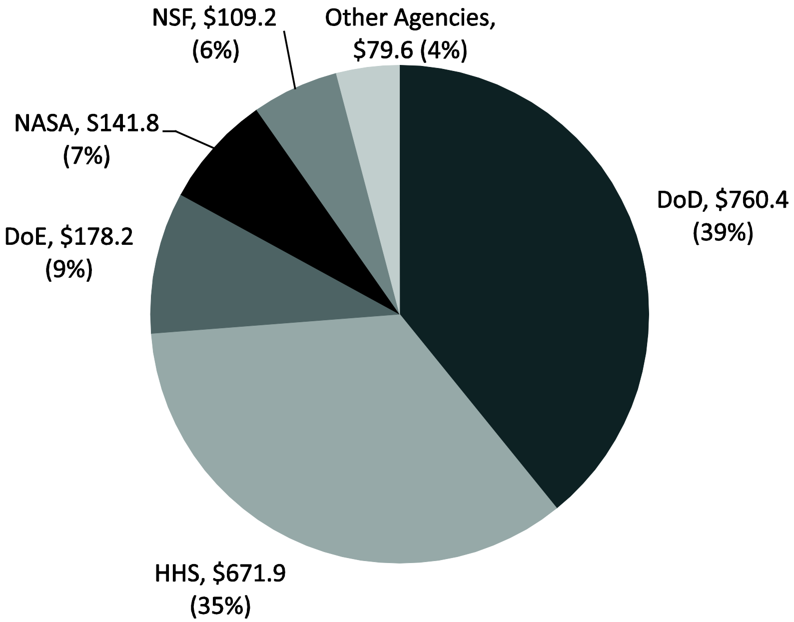

FIGURE 1-1 SBIR dollar obligations in millions, and percentage share of total, by federal agency, FY2014.
SOURCE: Small Business Association (SBA) SBIR/STTR awards database, https://www.sbir.gov/analytics-dashboard/, accessed March 15, 2016.

[7]Section 5137 of P.L. 112-81.
[8]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council, or NRC, are used in an historic context identifying programs prior to July 1.

2000 reauthorization.[9] The 2011 reauthorization also called for further studies by the Academies.[10]

The first-round assessment resulted in 11 reports, including the 2008 report cited above. (See Box 1-1 for the list of reports.) In a follow-up to the first round, NASA requested from the Academies an assessment focused on operational questions in order to identify further improvements to the program.

This introduction provides context for analysis of the program developments and transitions described in the remainder of the report. The first section of the introduction provides an overview of the program's history and structure across the federal government. This is followed by a summary of the major changes mandated through the 2011 reauthorization and the subsequent Small Business Administration (SBA) Policy Directive; a review of the program's advantages and limitations, in particular the challenges faced by entrepreneurs using (and seeking to use) the program and by agency officials running the program; an overview of the study methodology; and a summary of the technical challenges to assessment and our solutions to those challenges.

PROGRAM HISTORY AND STRUCTURE[11]

A review of the program's origins and legislative history provides context to its place in the U.S. innovation landscape. During the 1980s, the perceived decline in U.S. competitiveness due to Japanese industrial growth in sectors traditionally dominated by U.S. firms—autos, steel, and semiconductors—led to concerns about future U.S. economic growth.[12] A key concern was the perceived failure of American industry "to translate its research prowess into commercial advantage."[13] Although the United States enjoyed dominance in basic research—much of which was federally funded—applying

[9]National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, 2008. The National Research Council's first-round assessment of the SBIR program was mandated in the SBIR Reauthorization Act of 2000, P.L. 106-554, Appendix I-H.R. 5667, Section 108.

[10]The National Defense Reauthorization Act for Fiscal Year 2012, P.L. 112-81, Section 5137. It is referenced in the text by its calendar date of passage, December 2011; hence, the 2011 Reauthorization Act.

[11]Parts of this section are based on the previous report on the NASA SBIR program, National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Washington, DC: The National Academies Press, 2009.

[12]See J. Alic, "Evaluating competitiveness at the office of technology assessment," *Technology in Society*, 9(1):1-17, 1987, for a review of how these issues emerged and evolved within the context of a series of analyses at a Congressional agency.

[13]D.C. Mowery, "America's industrial resurgence (?): An overview," in D.C. Mowery, ed., *U.S. Industry in 2000: Studies in Competitive Performance*, Washington, DC: National Academy Press, 1999, p. 1. Other studies highlighting poor economic performance in the 1980s include M.L. Dertouzos et al., *Made in America: The MIT Commission on Industrial Productivity*, Cambridge, MA: The MIT Press, 1989; and O. Eckstein, *DRI Report on U.S. Manufacturing Industries*, New York: McGraw Hill, 1984.

BOX 1-1
First-Round Assessment
of the Small Business Innovation Research (SBIR) Program

Mandated by Congress in the 2000 reauthorization of the SBIR program, the National Research Council's (NRC) first-round assessment reviewed the SBIR programs at the Department of Defense, National Institutes of Health, National Aeronautics and Space Administration (NASA), Department of Energy, and National Science Foundation. In addition to the reports focused on the SBIR program at each agency and a report of the program methodology, the study resulted in a summary of a symposium focused on the program's diversity and assessment challenges, a summary report of a symposium focused on challenges to commercializing SBIR-funded technologies, two reports on special topics, and the overall summary report, *An Assessment of the SBIR Program*. In all, 11 study reports were published[a]:

An Assessment of the Small Business Innovation Research Program: Project Methodology (2004)
SBIR—Program Diversity and Assessment Challenges: Report of a Symposium (2004)
SBIR and the Phase III Challenge of Commercialization: Report of a Symposium (2007)
An Assessment of the SBIR Program at the National Science Foundation (2007)
An Assessment of the SBIR Program at the Department of Energy (2008)
An Assessment of the SBIR Program (2008)
An Assessment of the SBIR Program at the Department of Defense (2009)
An Assessment of the SBIR Program at the National Aeronautics and Space Administration (2009)
An Assessment of the SBIR Program at the National Institutes of Health (2009)
Venture Funding and the NIH SBIR Program (2009)
Revisiting the Department of Defense SBIR Fast Track Initiative (2009)

[a] National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004; National Research Council, *SBIR—Program Diversity and Assessment Challenges: Report of a Symposium*, Washington, DC: The National Academies Press, 2004; National Research Council, *SBIR and the Phase III Challenge of Commercialization: Report of a Symposium*, Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Washington, DC: The National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Washington, DC: The National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Washington, DC: The National Academies Press, 2009; National Research Council, *Venture Funding and the NIH SBIR Program*, Washington, DC: The National Academies Press, 2009; and National Research Council, *Revisiting the Department of Defense SBIR Fast Track Initiative*, Washington, DC: The National Academies Press, 2009.

this research to the development of innovative products and technologies that were taken to market remained challenging. As the great corporate laboratories of the post-war period were buffeted by change, new models such as the cooperative model utilized by some Japanese kieretsu seemed to offer greater sources of dynamism and more competitive firms.

At the same time, new evidence emerged to indicate that small businesses were an increasingly important source of both innovation and job creation.[14] This evidence reinforced recommendations from federal commissions dating back to the 1960s, that federal R&D funding should provide more support for innovative small businesses (recommendations that were opposed by traditional recipients of government R&D funding).[15]

Early-stage financial support for high-risk technologies with commercial promise was first advanced by Roland Tibbetts at NSF. In 1976, Mr. Tibbetts advocated for shifting some NSF funding to innovative, technology-based, small businesses. NSF adopted this initiative before other agencies, and, after a period of analysis and discussion, the Reagan administration supported an expansion of this initiative across the federal government. Congress then passed the Small Business Innovation Research Development Act of 1982, which established the SBIR program.

The program was ramped up gradually. Initially, the SBIR program required agencies with extramural R&D budgets in excess of $100 million[16] to set aside 0.2 percent of their funds for SBIR. In the program's first year of operation (1983), funding totaled $45 million. Over the next 6 years, the set-aside grew to 1.25 percent of agency extramural R&D budgets.[17]

The SBIR Reauthorizations of 1992 and 2000

The SBIR program approached reauthorization in 1992 amidst continued worries about the ability of U.S. firms to commercialize inventions. (See Box 1-2.) Finding that "U.S. technological performance is challenged less in the creation of new technologies than in their commercialization and

[14]See S.J. Davis, J. Haltiwanger, and S. Schuh, *Small Business and Job Creation: Dissecting the Myth and Reassessing the Facts*, Working Paper No. 4492, Cambridge, MA: National Bureau of Economic Research, 1993. According to Per Davidsson, these methodological fallacies, however, "ha[ve] not had a major influence on the empirically based conclusion that small firms are over-represented in job creation." See P. Davidsson, "Methodological concerns in the estimation of job creation in different firm size classes," Working Paper, Jönköping International Business School, 1996.

[15]For an overview of the origins and history of the SBIR program, see G. Brown and J. Turner, "The federal role in small business research," *Issues in Science and Technology*, Summer 1999, pp. 51-58.

[16]That is, those agencies spending more than $100 million on research conducted outside agency labs.

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

adoption," the NRC recommended an increase in SBIR funding as a means to improve the economy's ability to adopt and commercialize new technologies.[18]

The Small Business Research and Development Enhancement Act (P.L. 102-564) reauthorized the SBIR program until September 30, 2000, and doubled the set-aside rate to 2.5 percent. The legislation also more strongly emphasized the need for commercialization of SBIR-funded technologies.[19] Legislative language explicitly highlighted commercial potential as a criterion for awarding SBIR contracts and grants.

At the same time, Congress expanded the SBIR program's 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 the small business innovation, particularly with regard to woman-owned business concerns and by socially and economically disadvantaged small business concerns."[20]

The Small Business Reauthorization Act of 2000 (P.L. 106-554) extended the SBIR program until September 30, 2008. It also called for an NRC

BOX 1-2
Commercialization Language from 1992 SBIR Reauthorization

Phase II "awards shall be made based on the scientific and technical merit and feasibility of the proposals, as evidenced by the first phase, considering, among other things, the proposal's commercial potential, as evidenced by
(i) the small business concern's record of successfully commercializing SBIR or other research;
(ii) the existence of second phase funding commitments from private sector or non-SBIR funding sources;
(iii) the existence of third phase, follow-on commitments for the subject of the research; and
(iv) the presence of other indicators of the commercial potential of the idea."

SOURCE: P.L. 102-564-OCT. 28, 1992.

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[18]See National Research Council, *The Government Role in Civilian Technology: Building a New Alliance*, Washington, DC: National Academy Press, 1992, p. 29.
[19]See R. Archibald and D. 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*, Washington, DC: National Academy Press, 2000, pp. 211-250.
[20]The Small Business Research and Development Enhancement Act (P.L. 102-564), Sec. 102(b)(4).

assessment of the program's broader impacts, including those on employment, health, national security, and national competitiveness.[21]

The 2011 Reauthorization

The anticipated 2008 reauthorization was delayed in large part by a disagreement between long-time program participants and their advocates in the small business community and proponents of expanded access for venture-backed firms. The issue of venture backing was particularly relevant in biotechnology where proponents argued that the standard path to commercial success invariably includes venture funding at some point.[22] Other issues were also difficult to resolve, but the conflict over participation of venture-backed companies dominated the process[23] following an administrative decision to exclude these firms more systematically.[24]

After a much extended discussion, passage of the National Defense Act of December 2011 reauthorized the SBIR and Small Business Technology Transfer (STTR) programs through FY2017.[25] The new law maintained much of the core structure of both programs but made some important changes, which were to be implemented via the SBA's subsequent Policy Guidance.[26]

The eventual compromise on the venture funding issue allowed (but did not require) agencies to award up to 25 percent of their SBIR grants or contracts (at NIH, DoE, and NSF) or 15 percent (at the other awarding agencies) to firms that benefit from private, venture capital investment. It is too early in the implementation process to gauge the impact of this change.

The reauthorization made changes in the SBIR program that were recommended in prior Academies reports.[27] These included the following:

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[21]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 Government Accountability Office (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.

[22]D.C. Specht, "Recent SBIR extension debate reveals venture capital influence," *Procurement Law,* 45:1, 2009.

[23]W.H. Schacht, "The Small Business Innovation Research (SBIR) program: Reauthorization efforts," Congressional Research Service, Library of Congress, 2008.

[24]A. Bouchie, "Increasing number of companies found ineligible for SBIR funding," *Nature Biotechnology,* 21(10):1121-1122, 2003.

[25]National Defense Authorization Act for Fiscal Year 2012, P.L., December 31, 2011. The STTR program refers to the Small Business Technology Transfer Program. Although similar to the SBIR program, the STTR program requires the small business to "formally collaborate with a research institution in Phase I and Phase II." Small Business Administration website, "About STTR," https://www.sbir.gov/about/about-sttr , accessed June 15, 2015.

[26]See SBA post, S. Greene, "Implementing the SBIR and STTR Reauthorizations: Our Plan of Attack," http://www.sbir.gov/news/implementing-sbir-and-sttr-reauthorization-our-plan-attack, accessed February 21, 2012.

[27]See Appendix B for a list of the major changes to the SBIR program resulting from the 2011 Reauthorization Act.

- Increased award size limits.
- Expanded program size through modification to the percentage set-aside. The set-aside was increased from 2.5 to 2.6 percent for FY2012, and it will increase by 0.1 percentage point in each subsequent fiscal year until it reaches 3.2 percent. Thereafter, the set-aside percentage will remain at 3.2 percent.[28]
- Enhanced agency flexibility—for example, for Phase I awardees from other agencies to be eligible for Phase II awards or to add a second Phase II.
- Improved incentives for the utilization of SBIR technologies in agency acquisition programs.
- Explicit requirements for better connecting prime contractors with SBIR awardees.
- Substantial emphasis on developing a more data-driven culture, which has led to several major reforms, including the following:

    - adding numerous areas of expanded reporting
    - extending the Academies' evaluation
    - adding further evaluation, such as by the Government Accountability Office and Comptroller General
    - tasking the SBA with creating a unified platform for data collection.

- Expanded management resources (through provisions permitting use of up to 3 percent of program funds for [defined] management purposes).
- Expanded commercialization support (through provisions providing companies with direct access to commercialization support funding and through approval of the approaches piloted in Commercialization Pilot Programs).
- Options for agencies to add flexibility by developing other pilot programs—for example, to allow awardees to skip Phase I and apply for a Phase II award directly or for NIH to support a new Phase 0 pilot program.

The reauthorization also made changes that were not mentioned in previous reports of the Academies. These included the following:

- Expansion of the STTR program.[29]
- Limitations on agency flexibility—particularly in the provision of larger awards.

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[28]See "Key Changes in SBIR and STTR Policy Directives-Funding," http://www.sba.gov/content/key-changes-sbir-and-sttr-policy -directives.
[29]The first round study assessed only the SBIR program.

- Introduction of commercialization benchmarks for companies, which must be met if companies are to remain in the program. These benchmarks would be established by each agency.

Other clauses of the legislation affect operational issues, such as the definition of specific terms (such as "Phase III"), continued and expanded evaluation by the Academies, mandated reports from the Comptroller General on combating fraud and abuse within the program, and protection of small firms' intellectual property within the program.

PREVIOUS RESEARCH ON SBIR

Although there have been previous studies, most notably by the General Accounting Office and the SBA, they have focused on specific aspects or components of the program.[30] Prior to the first-round assessment by the Academies, there had been few internal assessments of agency programs. The academic literature on SBIR was also limited,[31] except for an assessment in the 1990s by Joshua Lerner of the Harvard Business School, who found "that SBIR awardees grew significantly faster than a matched set of firms over a ten-year period."[32]

To help fill this assessment gap and to learn about a large, relatively under-evaluated program, the NRC's Committee for Government-Industry Partnerships for the Development of New Technologies (GIP—which preceded the NRC's first-round congressionally mandated study of the SBIR) convened a workshop to discuss the SBIR program's history and rationale, review existing research, and identify areas for further research and program improvements.[33] In addition, in its report on the SBIR Fast Track Initiative at the Department of Defense, the GIP committee found that the SBIR program contributed to mission goals by funding "valuable innovative projects."[34] It concluded that a

[30]An important step in the evaluation of the program has been to identify existing evaluations of the program. These include U.S. Government Accounting Office, *Federal Research: Small Business Innovation Research Shows Success But Can Be Strengthened*, Washington, DC: U.S. General Accounting Office, 1992; and U.S. Government Accounting Office, *Evaluation of Small Business Innovation Can Be Strengthened*, Washington, DC: U.S. General Accounting Office, 1999. There is also a 1999 unpublished SBA study on the commercialization of SBIR Phase II awards from 1983 to 1993 among non-DoD agencies.

[31]Early examples of evaluations of the SBIR program include S. Myers, R. L. Stern, and M. L. Rorke, *A Study of the Small Business Innovation Research Program*, Lake Forest, IL: Mohawk Research Corporation, 1983; and Price Waterhouse, *Survey of Small High-tech Businesses Shows Federal SBIR Awards Spurring Job Growth, Commercial Sales*, Washington, DC: Small Business High Technology Institute, 1985.

[32]See J. Lerner, "The government as venture capitalist: The long-run effects of the SBIR Program," *Journal of Business*, 72(3), 1999.

[33]See National Research Council, *The Small Business Innovation Research Program: Challenges and Opportunities*, Washington, DC: National Academy Press, 1999.

[34]National Research Council, *An Assessment of the Department of Defense Fast Track Initiative*, see Chapter III: Recommendations and Findings, p. 32.

significant number of these projects would not have been undertaken absent SBIR funding[35] and that DoD's Fast Track Initiative encouraged the commercialization of new technologies[36] and the entry of new firms into the program.[37]

The GIP committee also found that the SBIR program improved both the development and utilization of human capital and the diffusion of technological knowledge.[38] Case studies provided some evidence that the knowledge and human capital generated by the SBIR program have positive economic value, which spills over into other firms through the movement of people and ideas.[39] Furthermore, by acting as a "certifier" of promising new technologies, SBIR awards encourage further private-sector investment in an award-winning firm's technology.[40]

THE ROUND-ONE STUDY OF SBIR

The 2000 SBIR reauthorization mandated that the NRC complete a comprehensive assessment of the SBIR program.[41] The assessment of the programs at DoD, NIH, NASA, NSF, and DoE began in 2002 and was conducted in three steps. During the first step, the committee developed a research methodology[42] and gathered information about the program by engaging in discussion with officials at the relevant federal agencies and by inviting those officials to describe program operations, challenges, and accomplishments at two major conferences. These conferences highlighted the important differences in agency goals, practices, and evaluations. They also served to describe the evaluation challenges that arise from the diversity in program objectives and practices.[43]

The committee implemented the research methodology during the second step. The committee deployed multiple data collection modalities including the first large-scale survey of SBIR recipients, and its researchers conducted case studies of a wide variety of SBIR firms. The Committee then evaluated the results and developed the findings and recommendations presented in their reports for improving the effectiveness of the SBIR program.

During the third step, the committee reported on the program through a series of publications in 2008-2010: five individual volumes on the five major funding agencies and an additional overview volume titled *An Assessment of the*

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[35]Ibid, p. 32.
[36]Ibid, p. 33.
[37]Ibid, p. 34.
[38]Ibid, p. 33.
[39]Ibid, p. 33.
[40]Ibid, p. 33.
[41]SBIR Reauthorization Act of 2000, P.L. 106-554, Appendix I-H.R. 5667, Section 108.
[42]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.
[43]Adapted from National Research Council, *SBIR: Program Diversity and Assessment Challenges*.

SBIR Program.[44] Together, these reports provided the first detailed and comprehensive review of the SBIR program and, as noted above, became an important input into SBIR reauthorization prior to December 2011. (See Box 1-1.)

THE CURRENT, SECOND-ROUND STUDY: CHALLENGES AND OPPORTUNITIES

The set of reports from the Academies' first-round study of the SBIR program found that the program was, overall, "sound in concept and effective in practice."[45] Furthermore, in its 2009 review of the NASA SBIR program, the committee concluded, "**The NASA SBIR program is making significant progress in achieving the congressional goals for the program.** [emphasis in original] 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."[46] The current study, described in the Statement of Task in Box 1-3, provides a second snapshot to measure the program's progress against its legislative goals.

Along with the current volume, several workshops and other publications will fully address this Statement of Task. The workshops convened included one on the participation of women and minorities in the SBIR/STTR programs (February 2013), one on the evolving role of university participation in the program (February 2014), and one on the relationship between state innovation programs and the SBIR program (October 2014—See Box 1-4).

The current volume is focused on updating the 2009 assessment of the NASA SBIR program, by updating data, providing new descriptions of recent programs and developments, and providing fresh company case studies. Guided by the Statement of Task, we have sought answers to questions such as the following:

- Are there initiatives and programs within NASA that have made a significant difference to outcomes and in particular to agency take-up of SBIR-funded technologies?
    - Can they be replicated and expanded?
- What are the main barriers to meeting Congressional objectives more fully?
- What program adjustments would better support commercialization?
- Are there tools that would expand utilization by woman- and minority-owned firms and participation by female and minority principal investigators?

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[44]National Research Council, *An Assessment of the SBIR Program*.
[45]Ibid, p. 54.
[46]National Research Council, *An Assessment of the Small Business Innovation Research Program at the National Aeronautics and Space Administration,* 26.

BOX 1-3
Statement of Task

In accordance with H.R. 5667, Sec. 108, enacted in Public Law 106-554, as amended by H.R. 1540, Sec. 5137, enacted in Public Law 112-81, the National Research Council is to review the Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs at the Department of Defense, the National Institutes of Health, the National Aeronautics and Space Administration, the Department of Energy, and the National Science Foundation. Building on the outcomes from the Phase I study, this second study is to examine both topics of general policy interest that emerged during the first-phase study and topics of specific interest to individual agencies.[a]

Drawing on the methodology developed in the previous study, an ad hoc committee will issue a revised survey, revisit case studies, and develop additional cases, thereby providing a second snapshot to measure the program's progress against its legislative goals. The committee will prepare one consensus report on the SBIR program at each of the five agencies, providing a second review of the operation of the program, analyzing new topics, and identifying accomplishments, emerging challenges, and possible policy solutions. The committee will prepare an additional consensus report focused on the STTR Program at all five agencies. The agency reports will include agency-specific and program-wide findings on the SBIR and STTR programs to submit to the contracting agencies and Congress.

Although each agency report will be tailored to the needs of that agency, all reports will, where appropriate:

1. Review institutional initiatives and structural elements contributing to programmatic success, including gap funding mechanisms such as applying Phase II-plus awards more broadly to address agency needs and operations and streamlining the application process.
2. Explore methods to encourage the participation of minorities and women in SBIR and STTR.
3. Identify best practice in university-industry partnering and synergies with the two programs.
4. Document the role of complementary state and federal programs.
5. Assess the efficacy of post-award commercialization programs.

In addition, the committee will convene symposia to gather information on specific topics related to the SBIR/STTR programs overall or specific agency requests with some workshops resulting in individually-authored workshop summaries.

In partial fulfillment of this Statement of Task, this volume presents the committee's review of the operation of the SBIR program at NASA.

[a]The Phase I study refers to the first-round assessments discussed above.

BOX 1-4
Workshop on SBIR/STTR & and the Role of State Programs

As part of the review of the Small Business Innovation Research and Small Business Technology Transfer (STTR) Programs, a workshop on *SBIR/STTR & the Role of State Programs* [a] was convened on October 7, 2014 with the goal of reviewing the growth of state programs that complement and leverage the SBIR and STTR programs for regional growth. State-based initiatives described at the event included a range of activities from proposal assistance, matching funds, business development assistance, and a variety of outreach mechanisms to match companies with resources at universities and federal laboratories. In view of the topic and resulting interest in the states, the event was available via webcast. Among the highlights of the event:

- In a keynote address Javier Saade of the Small Business Administration noted the importance of state support for companies in applying for awards, indicating that 16 of the 50 states give direct financial support to SBIR and STTR recipients.
- Mahendra Jain of the Kentucky Science and Technology Corporation described his organization's efforts to complement the SBIR/STTR investments. Among the levers employed are pre-proposal technical consultations, "Phase Zero" grants for assistance in proposal preparation, general business training and education, and Phase I and Phase II matching grants for SBIR and STTR awardees, matching up to $150,000 for Phase I and $500,000 per year for two years for Phase II. These matching grants allow for patent and equipment costs.
- Roy Keller of the Louisiana Business and Technology Center outlined efforts in Louisiana to partner with federal labs and described the Louisiana Business and Technology Center's (LBTC) assistance and training for Louisiana companies – including the operation of an incubator, a student incubator, and a mobile assistance center that provides outreach around the state—and he described LBTC's focus on leveraging federal investments to promote economic development. Not having a federal lab within the state's borders, the LBTC operates an office at Stennis Space Center in Mississippi.

Key programs described at this workshop include:

- Connecticut Innovation, which among other activities provides SBIR/STTR grant support, and helps link the state's leading universities to SBIR/STTR though conferences and other outreach activities.

- Kentucky's SBIR/STTR Program, which provides pre-application assistance (including Phase 0 grants of up to $4,000) and post-award assistance matching grants.
- Louisiana's Technology Transfer Office, which promotes the SBIR/STTR to Louisiana companies and assists businesses in the state to apply for and win these grants and contracts.
- Maryland's BioHealth Initiative, which offers biohealth companies support in preparing applications for SBIRs, STTRs, and other federal government awards.
- Michigan's Economic Development Corporation, which provides SBIR/STTR proposal writing assistance, the Technology Assistance Fund, which provides commercialization matching funds, and ETF Awards, which provides supplements to SBIR/STTR awards.
- Pennsylvania's IPart, which provides free pre-proposal SBIR/STTR technical reviews to small businesses.

In addition, the committee convened on April 12, 2016, a workshop on SBIR/STTR and the Commercialization Challenge, where Dr. Maryann Feldman presented a review of U.S. state SBIR match programs (See Table 1-1).[b]

[a]National Academies of Sciences, Engineering, and Medicine, Workshop on *SBIR/STTR & the Role of State Programs*, Washington, DC, October 7, 2014. An archived copy of the webcast and a copy of the workshop agenda are available on the website of the National Academies of Sciences, Engineering, and Medicine website at http://sites.nationalacademies.org/PGA/step/PGA_152137.
[b] National Academies of Sciences, Engineering, and Medicine, Workshop on SBIR/STTR and the Commercialization Challenge, Washington, DC, April 12, 2016. An archived copy of the webcast and a copy of the workshop agenda are available on the website of the Academies at http://sites.nationalacademies.org/PGA/step/sbir/PGA_171335. See also Lauren Lanahan, and Maryann P. Feldman, "Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program," *Research Policy*, 44(7), 2015; and Lauren Lanahan and Maryann Feldman, "Multilevel public funding for small business innovation: A review of US state SBIR match programs," *Journal of Technology Transfer*, 2015.

- Can links with universities be improved? In what ways and to what effect?
- Are there aspects of the program that make it less attractive? Could they be addressed?
- What can be done to expand access in underserved states while maintaining the competitive character of the program?
- Can the program generate better data on both process and outcomes and use those data to fine-tune program management?

TABLE 1-1 SBIR State Match Funds

State	Program	Program Features	Years
New York	NY State Office Science, Technology, and Academic Research (NYSTAR)	Up to 100% match	1994-1991
Hawaii	High Technology Development Corporation	Funding amounts vary, up to $25,000 match	1989
Oklahoma	OK Center for the Advancement of Science and Technology (OCAST) SBIR	Up to 50% match	1989
Indiana	Indiana 21st Century Research and Technology Fund	Approximately 400 Phase I matches were made from 2003 to 2011	2003
Kansas	Kansas Bioscience Authority	Up to 50% match	2004
New Jersey	NJ SBIR Bridge Grant Program	Up to $50,000 match	2005-2009
North Carolina	One NC Small Business Program	Range from $30,000 to $100,000 (subject to availability of funds)	2006-2001; 2014
Kentucky	KY SBIR/STTR Matching Funds Program	Up to 100% match	2007
Illinois	IL Department of Commerce and Economic Opportunity	Up to 50 percent match	2007-2008
Michigan	MI Emerging Technologies Fund	Up to 25 percent match (until funds are exhausted)	2008-2011
Nebraska	NE SBIR Initiative	Total funds are capped at $1,000,000 per year	2011
Connecticut	CT Innovations	Matches require 50 percent match from third party	2012
Montana	MT SBIR/STTR Matching Funds Program	Up to $30,000	2012
Virginia	Center for Innovative Technology	Matching funds for DHHS SBIR recipients	2012

SOURCE: Presentation by M. P. Feldman, “SBIR State Matching Programs: Science Experiments in the Laboratories of Democracy” at the National Academy of Sciences, Engineering, and Medicine workshop on “SBIR/STTR and the Commercialization Challenge,” Washington, DC, April 12, 2016.

STUDY METHODOLOGY

The SBIR/STTR programs are unique in terms of scale and mission focus. In addition, the evidence suggests that no truly comparable programs exist in the United States, and those in other countries operate in such different ways that their relevance is limited.[47] Thus, it is difficult to identify comparable programs against which to benchmark the SBIR/STTR program results.

Assessing the SBIR program at NASA is challenging for other reasons as well. Unlike some agencies where the mission and related objectives have remained stable, NASA's core missions have been in a state of flux for much of the past 10 years. For example, the role of human exploration in space remains uncertain, areas of focus may change, and the role of the private sector in space exploration is evolving rapidly. In addition, NASA has undergone numerous major reorganizations, which has resulted in significant changes to the pathway into NASA for emerging technologies.

Focus on Legislative Objectives

It is important to emphasize at the outset that this volume—and this study—do not seek to provide a comprehensive review of the value of the SBIR program, particularly as measured against other possible alternative uses of federal funding. Such a review is beyond our scope. Rather, our work focuses on assessing the extent to which the SBIR program at NASA has met the congressional objectives set for the program, determining in particular whether recent initiatives have improved program outcomes, and providing recommendations for further improvements to the program.[48]

Thus, as in the first round, the objective of this study is *not* to consider whether or not SBIR should exist. Congress has already decided affirmatively on this issue, most recently in the 2011 reauthorization of the program.[49] Rather, this study is charged with "providing assessment-based findings of the benefits and costs of SBIR . . . to improve public understanding of the program, as well as recommendations to improve the program's effectiveness." Also following the first round, this study "will *not* seek to compare the value of one area with other areas; this task is the prerogative of the Congress and the Administration acting through the agencies. Instead, the study is concerned with the effective review of each area."[50]

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[47]See National Academies of Sciences, Engineering, and Medicine, Workshop on "Learning from Each Other: U.S. and European Perspectives on Small Business Innovation Programs," Washington, DC, March 19, 2015.

[48]These limited objectives are consistent with the methodology developed by the committee. See National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*.

[49]National Defense Authorization Act of 2012 (NDAA), HR.1540, Title LI.

[50]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*.

Defining Commercialization

Commercialization offers practical and definitional challenges. As described in Chapter 5, several different definitions of commercialization can be used when describing the SBIR program. For this reason, the study uses more than one simple definition. For example, the simple percentage of funded projects that reach the marketplace is not the only measure of commercial success.

In the private sector, commercial success over the long term requires profitability. However, in the short term, commercialization can involve many different aspects of commercial activity, from product rollout to patenting to licensing to acquisition. Even during new product rollout, companies often do not generate immediate profits, and they do not necessarily earn a profit on all product offerings. This report uses multiple metrics to address the question of commercialization (see Chapter 5).

In the case of NASA, there are special challenges to defining commercialization. NASA is an "acquisition agency"—it utilizes the results of at least a portion of SBIR-funded research—unlike NSF and NIH. It also differs from DoD—the other major acquisition agency—in that it rarely purchases a sufficient quantity of any product to create a viable commercial market. Therefore, we stress that commercialization at NASA includes as a primary characteristic the take-up of SBIR-funded technologies for use within NASA, regardless of whether a viable commercial market results. In addition, the study recognizes that some NASA's SBIR awards support the development of aeronautics-related technologies for which NASA has no direct acquisition activity and that have commercialization potential outside of NASA programs.

Quantitative Assessment Methods

From a more practical perspective, several issues relate to the application of quantitative assessment methods, including decisions about which kinds of program participants should be targeted for survey deployment, the number of responses that are appropriate, selection bias, nonresponse bias, the design and implementation of survey questionnaires, and the level of statistical evidence required for drawing conclusions in this case. These and other issues were discussed at a workshop and summarized in a 2004 report.[51] The peer-reviewed study methodology developed by the first-round committee provided the baseline for that study and for follow-on studies—such as this one.[52]

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[51]National Research Council, *The Small Business Innovation Research Program: Program Diversity and Assessment Challenges*.
[52]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*.

Survey Development

For the current study, the committee developed and deployed a new survey of SBIR recipients. Although the committee based the survey[53] closely on previous surveys, particularly one deployed in 2005, it made several improvements. Most notably, it made an ambitious but ultimately unsuccessful effort to develop a comparison group to provide context and a benchmark for analyzing results (this effort is discussed in Appendix A).[54] Randomly assigned control groups were found to be not a possible alternative because of the nature of the SBIR program. Efforts to develop comparison groups from Phase I awardees that had not received a Phase II award, or from Phase II SBIR awardees, were also not successful. Likewise, efforts to identify SBIR-like companies from industry data sources to serve as a comparison group were not successful because sufficiently detailed and structured information about companies was not available.

The survey more deeply explored the program's demographics. It also included questions about the role of agency liaisons, who deal with award operations and thereby provide a link between individual projects and NASA. Furthermore, it offered unique opportunities to collect qualitative opinions and recommendations for improvement from award recipients. The survey generated 179 responses from NASA Phase II awardees and is an important component of the research conducted for this volume. Appendix A provides a detailed discussion of the issues related to quantitative methodologies, as well as a review of potential biases.

It is recognized that there are significant limitations on the conclusions that can be drawn from this quantitative assessment, and this recognition is reflected in the language of the findings and recommendations (Chapter 8). At the same time, drawing on quantitative analysis is a crucial component of the overall study, particularly given the need to identify and assess outcomes that are to be found only at the level of individual projects and participating companies.

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[53]The survey carried out as part of this study was administered in 2011, and the survey completed as part of the first-round assessment of SBIR was administered in 2005. In this volume all survey references are to the 2011 Survey unless noted otherwise.

[54]Experimental and quasi-experimental study designs use control or comparison groups—one that has received the subject intervention (such as an SBIR award) and one group that has not—to assess the impact of the intervention. The absence of a comparison group means that the study design is non-experimental and that other approaches will be needed to determine the effect of the intervention and to eliminate potential rival explanations. See D. Campbell and J. Stanley, *Experimental and Quasi-experimental Designs for Research*, Chicago: Rand McNally, 1963; P. Rossi et al., *Evaluation: A Systematic Approach*, Thousand Oaks, CA: Sage, 2003; and E.M. Berman and X. Wang, *Essential Statistics for Public Managers and Policy Analysts,* Thousand Oaks, CA: Sage, 2012.

A Complement of Approaches

Partly because of these limitations, the 2004 review of methodology stressed the importance of utilizing a complement of research modalities,[55] an approach that has been adopted here. Although quantitative assessment represents the bedrock of the research and provides insights and evidence that could not be generated through any other modality, it is, in and of itself, insufficient to address the multiple questions posed in this analysis. Consequently, we undertook a series of additional activities:

- **Case studies**. We conducted in-depth case studies of 10 NASA SBIR awardees. These selected companies were geographically and demographically diverse, sponsored by several different NASA Centers, and at different stages of the company life cycle. Lessons learned from the case studies are described in Chapter 7, and the case studies themselves are included as Appendix E.
- **Workshops.** We conducted workshops, including workshops to discuss the participation of women and minorities, as well as the role of universities, in the SBIR program[56] to allow stakeholders, agency staff, and academic experts to provide insights into program operations and to identify issues that need to be addressed.
- **Analysis of agency data**. As appropriate, we analyzed and included data from NASA that cover various aspects of SBIR activities.
- **Open-ended responses from SBIR awardees.** For the first time, we collected textual responses in the survey. More than 150 awardees provided narrative comments, which are discussed in Chapter 7.
- **Agency consultations**. We engaged in discussions with agency staff at several NASA centers and facilities about the operation of their program and the challenges they face.
- **Literature review.** Since the start of our research in this area, a number of papers have been published that address various aspects of the SBIR program. In addition, other organizations—such as the Government Accountability Office—have reviewed specific parts of the SBIR program. We incorporated references to this work, when useful, into our analysis.

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[55]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*.

[56]Workshops convened by the committee as part of the overall analysis include *NASA Small Business Innovation Research Program Assessment: Second Phase Analysis*, January 28, 2010; *Early-stage Capital in the United States: Moving Research Across the Valley of Death and the Role of SBIR*, April 16, 2010; *Early-Stage Capital for Innovation—SBIR: Beyond Phase II*, January 27, 2011; *NASA's SBIR Community: Opportunities and Challenges*, June 21, 2011; *Innovation, Diversity, and Success in the SBIR/STTR Programs*, February 7, 2013; and *Commercializing University Research: The Role of SBIR and STTR*, February 5, 2014. Each of these workshops was held in Washington, DC.

Data Sources and Limitations

Multiple research modalities are especially important because limitations still exist in the data collected for the SBIR program. As described in Chapter 3, NASA has not developed or maintained a comprehensive dataset on outcomes from awards and did not provide data about the take-up of SBIR-funded technologies within NASA. In addition, NASA has not made a systematic effort to utilize the Federal Procurement Data System (FPDS), which tracks federal contracts; and based on the committee's research, it appears that NASA contract officers are not trained to recognize and record contracts based on SBIR technologies as Phase III contracts. However, as noted in Chapter 3, utilization of NASA's Electronic Handbook has the potential to greatly enhance NASA's access to data on its SBIR program.

The lack of data from NASA makes the 2011 Survey data all the more important in assessing SBIR outcomes and processes at NASA. That said, the Survey data also has limitations due to a small response rate, but the data have been analyzed to extract as much information on outcomes as possible.[57] Future evaluation studies may be able to draw on NASA's Electronic Handbook (EHB) for in-house data.

Cooperation with NASA

In general, we received sufficient cooperation from NASA and the NASA Centers. Numerous discussions took place between agency staff and the Academies to identify and request information, and NASA followed through in providing the requested data, papers, and presentations.

Late in the committee's deliberative process, it received from a reviewer of this report a draft copy of a 2015 report, commissioned by NASA, which analyzed the SBIR/STTR programs in the mission directorates. Since the analysis was based on data from the Electronic Handbooks (EHBs), it was of particular interest to this committee's work. Because the report had not been publicly released, the committee requested official copies of this and two other consultant reports commissioned by NASA. However, SBIR program executives at the agency were either unwilling or unable to provide these reports.

With regard to data from the Electronic Handbooks, the NASA Program Office had initially indicated that EHB data would not be provided for the study. Some data were eventually delivered in March 2015, but they were very incomplete and deemed unusable for the study. The committee urges that in any future evaluations of the SBIR/STTR programs, NASA provide access to EHB data as well as to any relevant studies, so that the resulting reports can be based on the full range of information that exists on the programs.

In short, within the limitations described, the study has used a complement of tools to ensure that a full spectrum of perspectives and expertise

[57]Averaged survey response data is reported to the nearest whole number.

is reflected in the findings and recommendations. Appendix A provides an overview of the methodological approaches, data sources, and survey tools used in this study.

ORGANIZATION OF THE REPORT

Analyses and findings are organized as follows: Chapter 2 reviews program operations, including the role of agency liaison offices, auditing, and contracts. Chapter 3 describes and analyzes agency initiatives that have been developed and implemented over the past 8 to 10 years, largely aimed at improving program outcomes. Chapter 4 reviews NASA data concerning applications and awards, drawing out demographic and geographic differences as well as previous experience with the program. Chapter 5 provides a quantitative assessment of the program. This is based primarily on the 2011 Survey given the paucity of data from NASA or other sources. Chapter 6 addresses data and NASA efforts concerning the participation of women and minorities in the program. Chapter 7 draws on company case studies and the textual responses from survey respondents to provide a qualitative picture of program operations, issues, and possible solutions. Chapter 8 provides the findings and recommendations from the study.

The report's appendixes provide additional information. Appendix A provides an overview of the methodological approaches, data sources, and survey tools used in this assessment. Appendix B describes key changes to the SBIR program from the 2011 reauthorization. Appendix C reproduces the 2011 Survey instrument. Appendix D lists the universities involved in NASA SBIR awards. Appendix E presents the case studies of selected NASA SBIR firms. Appendix F and Appendix G serve as annexes to Chapter 5, the first with additional data from the 2011 Survey and the second with supplementary data from DoD about NASA SBIR awards. Finally, Appendix H provides a glossary of acronyms used, and Appendix I provides a list of references.

2

Program Management

With the fourth largest federal Small Business Innovation Research (SBIR) program in terms of SBIR dollar obligations, the National Aeronautics and Space Administration (NASA) obligated $141.8 million in SBIR awards in FY2014. During the (FY) 2005-2014 period, NASA SBIR funds supported an annual average of 318 Phase I and 135 Phase II awards, all of which were contracts rather than grants.

This chapter reviews key features of the NASA SBIR program and highlights issues and concerns about its management. More recent initiatives within the program are discussed separately in Chapter 3. Sources for this chapter include discussions with NASA staff, information from the 2011 Survey[1] and company case studies, and documentation from NASA.

NASA PROGRAM ORGANIZATION

As a part of the agency's reorganization, NASA's SBIR program is now located within the Space Technology Mission Directorate. The Program Executive at NASA Headquarters provides strategy and guidance, but operations, including decisions about awards (see below), are handled within the Field Centers and Mission Directorates. The NASA organization chart showing the SBIR program is provided in Figure 2-1.

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[1]As noted in greater detail at the beginning of Chapter 5, the overall target population for the survey reported in this chapter is NASA Phase II awards made FY1998-2007,[1] and most response data is reported at the project level. See Box 5-1 and Appendix A for a description of filters applied to the starting population.

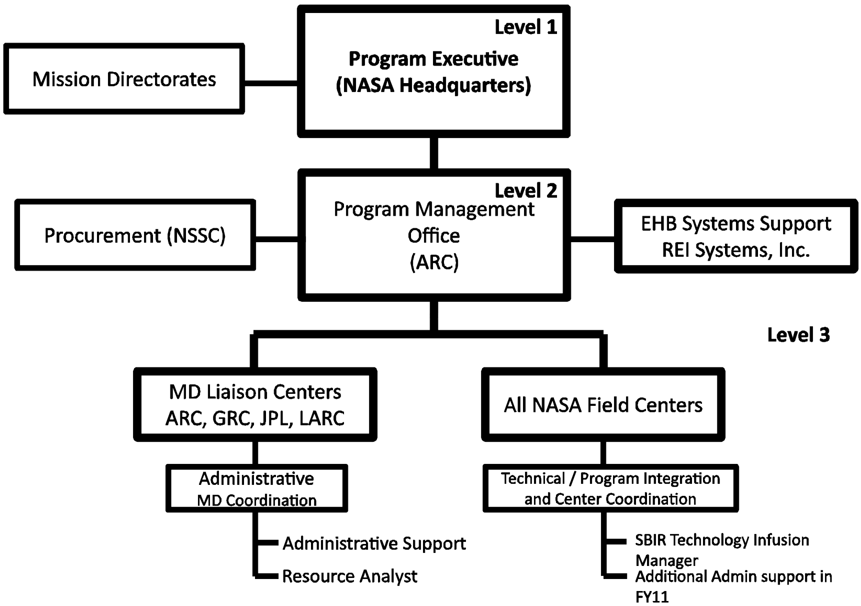

FIGURE 2-1 Organization chart for NASA SBIR program.
SOURCE: Ryszard Pisarski and Heather Morgan, "The NASA Small Business Innovation Research and STTR Program," Presentation to the National SBIR/STTR Conference, Madison, Wisconsin, April 11, 2011.

COMPANY ELIGIBILITY

As described in the Small Business Administration (SBA) Policy Directive that governs program administration, an applicant to the SBIR program must be a for-profit business located in the United States and must be more than 50 percent directly owned and controlled by one or more individuals who are citizens or permanent resident aliens of the United States, by other business concerns each of which is more than 50 percent directly owned and controlled by individuals who are citizens or permanent resident aliens of the United States, or any combination of these.[2] Up to 15 percent of NASA SBIR funds may be awarded to small businesses that are majority owned by multiple venture capital, hedge fund, or private equity firms.[3] The principal investigator must be employed by the small business at least two-thirds time for Phase I and half time for Phase II.

[2]See SBA Policy Directive, https://www.sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf.
[3]See SBA Policy Directive, https://www.sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf, page 16.

In addition, the 2011 SBIR reauthorization act required that firms winning several Phase I awards should provide evidence of successful transition to Phase II. Writing in the NASA SBIR newsletter, Rich Leshner, a former program director, stated, "To be eligible for a Phase I award, proposers that have previously won over 20 Phase I SBIR/STTR awards over the past 5 years (excluding the most recently completed fiscal year) must satisfy the Phase I-Phase II transition rate benchmark, which requires SBIR/STTR firms to have at least a 25 percent Phase I to Phase II success rate."[4] However, NASA has not yet excluded firms on this basis, perhaps reflecting the fact that this 25 percent benchmark is well below the average transition rate of 42 percent.

TOPICS AND APPLICATIONS

Consistent with the 2011 reauthorization act, NASA has increased the size of both Phase I and Phase II awards. Phase I now provides maximum funding of $125,000, with a maximum duration of 6 months for SBIR and 12 months for Small Business Technology Transfer (STTR) awards. Phase II awards are for 24 months, with a maximum award of $750,000. NASA guidelines expect that Phase II will result in "the delivery of a prototype unit or software package, or a more complete product or service, for NASA testing and utilization."[5] In addition to the standard Phase I and Phase II programs, NASA offers two additional funding mechanisms, Phase II-Enhancement (Phase II-E) and Phase II-EXpanded (Phase II-X).[6] These program enhancements, summarized in Table 2-1, are discussed in detail in Chapter 3.

Single Solicitation

NASA continues to offer one application period per year. Other agencies have moved toward multiple annual solicitations in recognition of the accelerating pace of technical change. Because the NASA SBIR program offers tightly defined topics that may not be well suited to some potential applicants, this limited window has a significant impact. Small, often fragile companies may not be able to wait 12 months for the next opportunity to apply.

Topic Selection

As a part of a 2007 reorganization of NASA, the SBIR program became the responsibility of the four NASA Mission Directorates. The program office is now located within the Space Technology Mission Directorate,[7] and

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[4]Rich Leshner, Discussion, January 17, 2014.
[5]NASA SBIR/STTR Participation Guide, 2015, p.3.
[6]NASA, *The Concept*, 4(1):1, Spring 2009.
[7]Prior to 2007, the Science Mission Directorate was responsible for the SBIR program.

TABLE 2-1 Funding and Duration for NASA SBIR, STTR, and SBIR Select, by Phase

	Program		
	SBIR	STTR	SBIR Select
Phase I	Maximum Funding: $125,000 Period of Performance: 6 months	Maximum Funding: $125,000 Period of Performance: 6 months	Maximum Funding: $125,000 Period of Performance: 6 months
Phase II	Maximum Funding: $750,000 Period of Performance: 24 months	Maximum Funding: $750,000 Period of Performance: 24 months	Maximum Funding: $1,500,000 Period of Performance: 24 months
Phase II-E	Maximum Funding: $150,000 Phase II contract extension: up to 6-12 months	Maximum Funding: $150,000 Phase II contract extension: up to 6-12 months	Maximum Funding: $150,000 Phase II contract extension: up to 6-12 months
Phase II-X	Maximum Funding: $500,000 Phase II contract extension: up to 12-24 months	Maximum Funding: $500,000 Phase II contract extension: up to 12-24 months	Maximum Funding: $500,000 Phase II contract extension: up to 12-24 months

NOTE: SBIR Select is a new initiative from NASA, starting in 2013, which provides up to $1.5 million in Phase II awards for companies whose technologies are of more immediate interest to NASA.
SOURCE: NASA, *The Concept*, 4(1), Winter 2013.

each Mission Directorate provides a representative to the SBIR program, each of whom is responsible for ensuring that SBIR topics meet the mission needs of the particular Mission Directorate. Subtopics can be nominated by anyone at NASA, provided they align with broader topics defined by the Mission Directorate representatives. Individual NASA centers do not set quotas for SBIR subtopics.[8] (See Figure 2-2.)

Once the subtopic nomination period closes, each Mission Directorate reviews its subtopics. Decisions on which subtopics to approve are usually made by committees of senior technical staff within the Mission Directorates, although each Mission Directorate can make these decisions its own way. At this point in the process, the staff of each Mission Directorate can

[8]Unique among SBIR agencies, topics within NASA are developed through quite separate processes for the SBIR and STTR programs. The STTR process is managed within the office of the chief technologist. Subtopic areas are distributed more or less pro rata (2-3 each) to the individual Centers, which individually take the lead on specific topic areas. Centers propose subtopics based on agreed technology roadmaps. Proposed topics are reviewed by a committee of senior technology officers. Overall, about three-quarters of subtopic areas remain essentially the same year to year, although details may change.

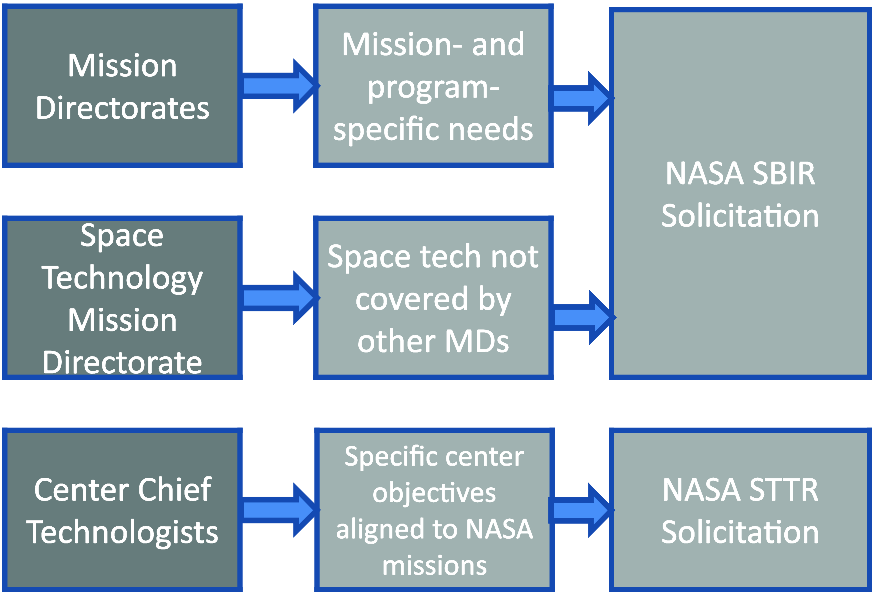

FIGURE 2-2 Subtopic development for SBIR and STTR.
SOURCE: NASA Program Presentation, SBIR National Conference, November 2014.

identify subtopics of particular importance to its Mission Directorate, where successful technologies would be prime candidates for take-up ("infusion") by the Mission Directorates. These subtopics can be nominated as "select subtopics." This is a new initiative, starting in 2013, which provides up to $1.5 million in Phase II awards for companies whose technologies are of more immediate interest to NASA.[9] According to Rich Leshner, former program director, these topics are focused on the following:

1. Projects with more immediate infusion opportunities (e.g., a Mission Directorate program has an immediate interest in using a successful prototype from Phase II);
2. Projects for which additional funding is justified to cross a boundary, which will, if successful, provide more than a 2:1 return; and
3. Projects that permit a science mission to be undertaken in a completely new way (e.g., a topic on balloon-based astronomy that was approved for "select" status at Marshall Space Center).[10]

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[9]For additional discussion of Select Topics, see Chapter 3 (Initiatives).
[10]Rich Leshner, Discussion, January 17, 2014.

Some NASA staff observed that this change in the topic development process has resulted in a tight focus on the short-term needs of Mission Directorates, often at the expense of more innovative or disruptive technologies. For example, NASA has, according to some staff, lagged in its efforts to introduce topics on information technology tools to help run its operations, which would in turn require a commitment to longer-term strategy.[11] Indeed, one staff member recommended that some funding should be set aside within the NASA program explicitly for more innovative projects. However, as Rich Leshner has observed, SBIR projects must be aligned with NASA Mission Directorate programs or they will not be adopted by NASA and the program will have limited value.[12]

Access to Program Staff During Solicitation Period

Once the NASA SBIR/STTR General Solicitation opens, NASA will only accept questions seeking clarification of proposal instructions and administrative matters. During this period, NASA staff is not permitted to answer questions about technical topics and/or subtopics. It should be noted, however, that it is not unusual for government solicitations to limit or control contact during a competition in order to preserve the fairness and appearance of fairness of the awards process.

Before the solicitation is published, NASA allows contacts from companies. NASA states that "Firms are encouraged to communicate with NASA mission program personnel and researchers to learn about the needs and objectives of mission programs." The NASA SBIR/STTR website provides contact information for program contacts in the Program Management Office and in each of the NASA Centers for SBIR/STTR programs, by clicking on "Contact Us". However, other than frequently asked questions (FAQ), there was no evidence that all questions and answers concerning solicitations are published online.

Somewhat different rules govern the new Select Solicitation: proposers can submit questions online via the NASA SBIR/STTR website for a period of 10 business days after the solicitation opens. This new approach suggests that NASA could also adopt a more open approach during the standard SBIR solicitation. Again, the questions and answers are not published online for all to see.

The arms-length approach adopted by NASA is likely to generate significant information gaps and difficulties for small companies. Given that questions are in fact permitted for select solicitations, the general prohibition outlined above is merely a matter of convenience for NASA; it saves technical

[11]As part of the research for this assessment, Academies' staff held discussions with NASA SBIR program and Mission Directorate staff at several NASA Centers, including Ames, Glenn, Jet Propulsion Laboratory (JPL), and Johnson.
[12]Rich Leshner, Discussion, January 17, 2014.

staff from the time and effort of having to answer questions, some of which will undoubtedly be irrelevant.

Application

The solicitation is open for 60 days. All applications must be made through NASA's in-house Electronic Handbook (EHB), which provides guidance and eventually the electronic support for project management, tracking, and evaluation.[13]

Subtopic managers are responsible for identifying and selecting proposal reviewers, all of whom are from within NASA, because the agency does not use third-party reviewers. In general, experts are identified before the topic is formally published in the solicitation. A minimum of two expert reviewers are required; in some cases, three are used.

SELECTION

NASA uses a standard template for evaluating proposals. Scoring is broken out as follows:

- Technology: 50 percent
- Work plan: 25 percent
- Qualifications: 25 percent
- Community impact: textual response only

Proposals that score 85 percent or higher are judged to be "recommended." According to agency staff, as much as 85 percent of Phase I applications meet this standard. The subtopic manager then ranks the recommended proposals (perhaps on the order of 50 proposals).

For Phase II only, proposers are required to include a commercialization plan, which is separately reviewed by contractors hired by NASA's Jet Propulsion Laboratory. The contractors score each proposal on a five-point scale (excellent, very good, good, fair, and poor). However, these scores do not impact the numerical score of the proposal and do not affect the initial ranking.

The topic manager, assigned by the Mission Directorate, then collates and ranks all Phase II proposals for a given topic (which would include proposals from several subtopics). Phase II commercialization scores are primarily addressed at this point in the process. According to agency staff, this ranking is based more on agency mission needs, expressed as alignment with Mission Directorate objectives, than on the technical scores generated during initial review or the broader commercial potential of the project. As one staff

[13]The role and potential of the EHB is further discussed in Chapter 3 (Initiatives).

member noted, "In the end, we use a very simple metric—impact on NASA. That really drives selection, but we don't really stress this even to companies." An unpublished staff analysis indicated a very strong positive correlation between proposed impact on agency programs and selection.

Once the topic manager review is complete, the Mission Directorate convenes a board of all of its SBIR/STTR topic managers, which develops a final prioritized list of proposals. SBIR/STTR funds are distributed to the proposals that are identified as top priorities by the Mission Directorate boards of topic managers. Funding is proportionate to the overall NASA R&D budget. For example, aeronautics, which accounts for about 3 percent of NASA's R&D budget, will receive about 3 percent of NASA SBIR/STTR funding.

Review procedures are apparently identical for Phase I and Phase II, with the exception of the commercialization review of Phase II awards discussed above. The selection process is entirely siloed within each Mission Directorate. No evidence was found of collaboration or communication across Mission Directorates in the selection of proposals.

Limits on Submissions and the Encouragement of New Participants

NASA currently imposes a limit of 10 proposals per company per solicitation.[14] The limit at NASA, which was imposed in FY2007-2008, has made a difference: Several of the companies that have been the most successful in winning awards—such as Advanced Cooling Technologies, Creare, and Honeybee—have significantly reduced their number of applications. This limit may explain partly the about 20 percent decline in the number of proposals submitted between FY2007 and FY2008.

At least two rationales prevail for limiting the number of submissions at the individual company level. One is that a limit effectively pushes part of the review and decision-making process back onto the company, which best knows its own capabilities and interests. Another is that a limit enables increased attention to a greater variety of small companies.

CONTRACTING AND FUNDING

Winning proposals are announced on the NASA website. This announcement starts a process of contract negotiation between NASA contracting officers and the firm. This typically lasts about 2 months. At this point the contracts still require detailed cost justification. Contracting is handled by the NASA Shared Services Center (NSSC). One experienced NASA SBIR official noted that she had never seen a contract rejected at that stage.

[14]NASA SBIR/STTR Program Description, http://sbir.gsfc.nasa.gov/solicit/52896/detail?l1=52931.

Each contract requires that NASA be represented by a contracting officer representative (COR),[15] who must undergo an initial 40-hour training and additional continuing education thereafter. Perhaps unsurprisingly, some NASA staff indicated that finding CORs for SBIR/STTR awards was sometimes a significant challenge. The training is primarily designed so that CORs can manage major contracts, and some NASA SBIR staff suggested that a less onerous training program ("COR Lite") could be more appropriate for SBIR and also allow for rapid deployment of sufficiently qualified staff.

In FY2012, NASA shifted its base SBIR/STTR contract to become non-severable, that is, to provide for a commitment across the entire span of a 2-year Phase II award. As a result, there was no solicitation during 2013, because those funds were reallocated to fully fund the 2012 awards.

Phase I awards are reviewed in January/February and start in April/May. Phase II review starts in October/November, and Phase II awards are usually made in January of the following year, with contracts in place by February/March.

NASA does not permit no-cost extensions for the 6-month Phase I awards. Phase II applications are accepted during a short (2-week) time period at the end of the Phase I award. This timing suggests that the Phase II application process starts weeks before the end of the Phase I award. Given the very short timeframe of the NASA Phase I award, this suggests that projects would have an advantage if some Phase I technical results were known very early in the Phase I period, which in turn suggests that perhaps the program is not designed to support more ambitious efforts that might require longer time frames especially at the feasibility stage.

Funding Gaps

Funding gaps can develop between Phase I and Phase II of an SBIR award, creating challenges for small firms that are less likely to have other funding sources to sustain projects until Phase II funding arrives. Unlike other agencies, NASA does not offer bridge funding between Phase I and Phase II. It also does not offer a "work at your own risk" contracting approach. Under such a scheme, companies can proceed without a contract into Phase II, with costs reimbursed only if a Phase II contract is finalized.

More than 80 percent of NASA Phase II respondents to the 2011 Survey indicated they had experienced a gap between the end of Phase I and the start of Phase II for the surveyed award (see Table 2-2). A funding gap can have a range of consequences for a company, as presented in Table 2-3. Two-thirds of all respondents reported that they stopped work during this period, while a large

[15] NASA contracts require that there be a contracting officer representative (COR), who handles contracting matters, and a contracting officer technical representative (COTR), who handles technical aspects of the contract. See discussion of COTR later in this chapter.

TABLE 2-2 Funding Gap Between NASA SBIR Phase I and Phase II Awards, Reported by 2011 Survey Respondents

Experienced Phase I-Phase II Funding Gap for the Surveyed Award	Percentage of Respondents
Yes	83
No	18

NOTE: N=177 Respondents. According to NASA's annual report to the SBA, in 2012, the lag between the end of Phase I and the beginning of Phase II averaged 233 days. The lag was 160 days between the date of notification of a Phase II award and the first day of performance under the contract. NASA Small Business Innovation Research (SBIR) Program Annual Report to the U.S. Small Business Administration for FY 2012, p. 8.
SOURCE: 2011 Survey, Question 22.

TABLE 2-3 NASA SBIR: Effects of Funding Gap on Surveyed Project, Reported by 2011 Survey Respondents

Effect of Phase I-Phase II Funding Gap	Percentage of Respondents
Stopped work on this project during funding gap	66
Continued work at reduced pace during funding gap	26
Continued work at pace equal to or greater than Phase I pace during funding gap	3
Company ceased all operations during funding gap	1
Other (please specify)	3
Total	100

NOTE: N=146 Respondents.
SOURCE: 2011 Survey, Question 23.

majority of the remaining one-third worked at a reduced level of effort. One percent ceased operations. Aside from delaying projects, funding gaps can result in significant negative long-term consequences, especially for smaller companies, where in some cases there is insufficient work to retain key project staff during the gap period.

In some cases, the flow of funding from the agency to the awardee can be interrupted between phases of an SBIR award. According to NASA's annual report to the SBA, in 2012, the lag between the end of Phase I and the beginning of Phase II averaged 233 days. The lag was 160 days between the date of notification of a Phase II award and the first day of performance under the contract.[16] These lags present a major challenge to small firms that do not have other projects on which to place staff during the gap period.

[16]NASA Small Business Innovation Research (SBIR) Program Annual Report to the U.S. Small Business Administration for FY 2012, p. 8.

Adequacy of Funding and Size of Awards

Although award recipients could be expected to say that the amount of money provided was not sufficient for a given project, there can be some value in determining the extent of alternative responses, particularly when the issue is posed as a trade-off between the number and the size of awards.

As reported in Table 2-4, 55 percent of 2011 Survey respondents indicated that the funding was sufficient, and 45 percent indicated that more funding was required. None reported that the funding was more than necessary. In other contexts (e.g., case studies), awardees often suggest that the size of the SBIR awards should be increased (a view especially prevalent before the recent changes in the 2011 SBIR reauthorization act). The 2011 Survey asked directly about the possible trade-off between the size of awards and the number of awards: unless agency funding for SBIR programs increases, larger awards inevitably imply fewer awards. In the context of that trade-off, there was no clear majority for (or against) an increase in the size of individual SBIR awards, although a plurality was opposed, as summarized in Table 2-5.

WORKING WITH THE CONTRACTING OFFICER TECHNICAL REPRESENTATIVE

Case studies of SBIR companies suggest that a critical factor affecting the success of SBIR projects is the relationship between the awardee and the

TABLE 2-4 NASA SBIR: Adequacy of Phase II Funding Reported by 2011 Survey Respondents

SBIR project funding was…	Percentage of Respondents
More than enough	0
About the right amount	55
Not enough	45
Total	100

NOTE: N=179 Respondents.
SOURCE: 2011 Survey, Question 42.

TABLE 2-5 NASA SBIR: Respondent Views on Trade-off of Larger Awards for Fewer Awards (2011 Survey)

Should Phase II Award Size by Increased?	Percentage of Respondents
Yes	37
No	40
Not sure	22
Total	100

NOTE: N=179 Respondents.
SOURCE: 2011 Survey, Question 43.

agency's project manager. At NASA, the latter is called the contracting officer technical representative (COTR). The 2011 Survey asked a series of questions aimed at identifying ways in which this relationship might be improved.

We hypothesized that, in the absence of a NASA-wide standard, there might be wide variation in the degree to which COTRs actually engage with their awardee projects. When asked how often they engaged with their COTR, just under one-half of respondents reported monthly contact, while 38 percent reported quarterly contact (see Table 2-6).

Case studies of SBIR companies revealed that some COTRs had very positive effects on their awardee companies, while others were of little help. The 2011 Survey attempted to gauge the distribution of utility by asking respondents about their COTR's usefulness. As reported in Table 2-7, more than one-half of respondents scored COTR usefulness at 4 or 5 on a 5-point scale. Conversely, less than one-quarter scored COTR usefulness at 1 or 2. The details of the SBIR program are fairly complex, so a technically knowledgeable COTR has the potential to be of great use, especially to companies that are new to the program. The 2011 Survey therefore also asked respondents to share their views on the technical capacity of the COTR with regard to the SBIR program (see Table 2-8). Overall, respondents appeared satisfied; more than one-quarter indicated that their COTR was extremely knowledgeable about the SBIR program, while 3 percent indicated that the COTR was not at all knowledgeable.

TABLE 2-6 NASA SBIR: Frequency of Contact with COTRs, Reported by 2011 Survey Respondents

COTR Engagement	Percent of Respondents
Weekly	8
Monthly	47
Quarterly	38
Annually	7
Total	100

NOTE: N=178 Respondents.
SOURCE: 2011 Survey, Question 47.

TABLE 2-7 NASA SBIR: Usefulness of the COTR, Reported by 2011 Survey Respondents

Value of COTR to Company	Percentage of Respondents
Invaluable (5)	25
4	37
3	21
2	12
No help (1)	4
Total	100

NOTE: N=178 Respondents.
SOURCE: 2011 Survey, Question 48.

TABLE 2-8 NASA SBIR: COTR Knowledge About the SBIR Program, Reported by 2011 Survey Respondents

COTR Knowledge of SBIR	Percentage of Respondents
Extremely knowledgeable	28
Quite knowledgeable	46
Somewhat knowledgeable	23
Not at all knowledgeable	3
Total	100

NOTE: N=178 Respondents.
SOURCE: 2011 Survey, Question 49.

COTRs are the project managers, but they can also provide valuable support in a number of other areas, which the 2011 Survey attempted to flesh out. COTRs sometimes also provide help in introducing awardees to technical staff at universities who could provide critical technical support. However, only about 15 percent of respondents indicated that this was the case for their project.[17]

COTRs are also sometimes well positioned to provide useful connections to other firms—either other SBIR awardees or other firms with complementary interests or capabilities. Just over one-quarter of respondents indicated substantial support in this area (scores of 4 or 5 on a 5-point scale) (see Table 2-9).[18]

COTRs may also help connect SBIR companies to specific NASA programs. Although case studies of SBIR firms suggest that COTRs can effectively provide this connection, the 2011 Survey results generally suggest that effective help is not the norm. Twenty-seven percent of respondents scored their COTR at 4 or 5 on a 5-point scale in terms of providing connections to possible markets. Over one-half scored their COTR at 1 or 2 on the same scale (see Table 2-9). It was not possible to determine what type of training COTRs receive to connect awardees to market opportunities. This may reflect the fact that, to some extent, the responsibility of making this connection is also associated with NASA's technology infusion managers (see below for roles and activities).

In addition, the 2011 Survey asked SBIR companies about specific help received with connections to Phase III funding opportunities—Phase III emphasizing commercialization without the provision of additional SBIR funding. As reported in Table 2-10, about one-third of respondents indicated that they discussed an application in great detail with their COTR, or that their COTR provided substantial guidance during the application process, while more than 40 percent indicated that little support was provided.

[17]2011 Survey, Question 50.3.
[18]2011 Survey, Question 50.4.

TABLE 2-9 NASA SBIR: Amount of Help from COTR in COTR Help in Connecting NASA SBIR Awardees to Market Opportunities (Reported by 2011 Survey Respondents)

Amount of Help from COTR in making with Private Firm Connections	Percentage of Respondents
Most help (5)	6
4	21
3	18
2	20
Least help (1)	36
Total	100

NOTE: N=174 Respondents.
SOURCE: 2011 Survey, Question 50.5.

TABLE 2-10 NASA SBIR: Respondent Perspective on Working with COTR on Phase III Funding (2011 Survey)

How closely awardee worked with COTR	Percentage of Respondents
The officer provided a lot of guidance during the application process	10
We discussed the application in detail	22
Not much	23
Not at all	21
We did not apply for Phase III funding	24
Total	100

NOTE: N=177 Respondents.
SOURCE: 2011 Survey, Question 51.

The 2011 Survey also asked about the *effectiveness* of COTR help in acquiring Phase III funding, that is, non-SBIR funding received after the completion of SBIR Phase II. Case studies of SBIR companies suggest that COTRs have widely varied capabilities in this important area, with some focusing on the project's scientific and technical aspects and others providing connections to the acquisition programs that will use the research results. Forty-four percent of respondents indicated that their COTR was very helpful or somewhat helpful in connecting the company to sources of Phase III funding, while 58 percent thought the COTR was not very helpful or not at all helpful (see Table 2-11).

Company Relationship with the COTR

Beyond the specific areas related to Phase III funding, the 2011 Survey also sought to determine how easy it was for SBIR companies to reach the

COTR with questions or concerns, given that COTRs usually have many other duties to manage other than the project at hand. Table 2-12 shows that more than 90 percent of survey respondents found it easy or very easy to reach their COTR. Given other duties, some COTRs may simply not have enough time to work on projects that they are supposed to be managing. However, in general, respondents did not indicate this was the case—85 percent of respondents indicated there was sufficient or more than sufficient COTR time available.[19]

During the case study discussions, a number of principal investigators suggested that the replacement of a COTR during the course of an award could have devastating consequences for the long-term success of the project. However, among survey respondents, only about 10 percent of COTRs were replaced during the course of Phase II awards.[20]

TECHNOLOGY INFUSION MANAGERS

Although NASA has recently launched new initiatives that seek to connect SBIR companies with NASA opportunities, it does not provide

TABLE 2-11 NASA SBIR: Effectiveness of COTR in Connecting Awardee to Sources of Phase III Funding, as Reported by 2011 Survey Respondents

COTR Effectiveness in Connecting Awardee to Phase III Funding	Percentage of Respondents
Very helpful	17
Somewhat helpful	27
Not very helpful	29
Not at all helpful	29
Total	100

NOTE: N=151 Respondents.
SOURCE: 2011 Survey, Question 52.

TABLE 2-12 NASA SBIR: Ease with Which Respondent Could Contact COTR, as Reported by 2011 Survey Respondents

Ease of Reaching COTR	Percentage of Respondents
Very easy	33
Easy	59
Hard	6
Very hard	2
Total	100

NOTE: N=177 Respondents.
SOURCE: 2011 Survey, Question 53.

[19]2011 Survey, Question 55.
[20]2011 Survey, Question 54.

dedicated agency-level support for the commercialization of SBIR technologies using third-party commercialization support companies.[21]

NASA currently relies primarily on technology infusion managers (TIMs) to make connections between SBIR companies and the acquisition programs within the Mission Directorates. TIMs are in place at all of the NASA Centers. However, NASA has not developed metrics or data about the effectiveness of TIMs. Although they possess knowledge about opportunities within their own Center, TIMs are often not well connected to other NASA Centers and do not focus on commercialization outside of NASA.

NASA has provided support to a TecFusion™ program operated by the independent Technology Commercialization Center, which seeks to link large and small businesses, although not focused exclusively on SBIR.[22] The TecFusion™ program has evolved over time; it is currently on a 1-year extension of its previous contract to help NASA managers connect to companies (especially small companies) that can meet their technology needs.[23] It is a small program involving about five NASA officials.[24]

The SBIR program office relies primarily on NASA's Technology Transfer program to help SBIR companies find opportunities outside of NASA. However, the Technology Transfer program is not limited to SBIR. NASA did not provide data about the effectiveness of the Technology Transfer program in helping companies find commercialization opportunities either in general or specific to SBIR.

MENTORING PROGRAM

Two recent NASA initiatives have attempted to develop mentor programs for SBIR firms. One initiative arranges for large companies to mentor small companies. The other initiative pairs universities with less SBIR experience with universities with more SBIR experience.[25] Alabama ATT was recently assigned such a mentor. In yet another mentoring effort, NASA had encouraged tighter linkages between engineering and business students at the Georgia Institute of Technology.

All SBIR Phase II winners are automatically eligible for the Mentor Protégé Program (MPP).[26] (See Box 2-1.) Mentors from prime contractors receive an incentive to participate, such as a fee or a credit toward

[21]NASA has recently implemented two limited initiatives designed to enhance commercialization: the Phase II-E and the Phase II-X program. See Chapter 3 for a review of recent NASA initiatives with the SBIR and STTR programs.
[22]See Technology Commercialization Center website, http://www.teccenter.org/about, accessed January 28, 2015.
[23]Interview with Milt Holt, TeCC CEO, January 29, 2015.
[24]Interview with Milt Holt, TeCC CEO, January 29, 2015.
[25]Richard Leshner, Discussion, January 17, 2014.
[26]Information about the MPP is drawn primarily from the NASA description of the program at http://osbp.nasa.gov/mentor.html, accessed December 12, 2014.

subcontracting goals. Mentors and protégés find each other; NASA does not provide matchmaking services.[27] They are required to develop a formal development assistance agreement, which must commit at least 70 percent of the dollar value to technology transfer (the remaining 30 percent can be committed to business assistance). Proposed agreements must be approved at the center level and then by the Office of Small Business Programs at NASA headquarters, after which they must be formally added to contracts by the COTR. These agreements are subject to a full range of reporting requirements: semi-annual and annual reports, as well as a post hoc report. Despite the reporting requirements, the NASA SBIR office did not provide any data on take-up or outcomes for SBIR participants.

The energy and materials program at Glenn Research Center recently collaborated with a local entrepreneur support group called Launchhouse to identify NASA projects—including SBIR projects—that could be further developed in partnership with outside companies, organizations, or funders. Launchhouse worked in particular on customer validation and needs requirements, according to Matt Moran, Sector Manager, energy and materials at NASA Glenn.[28] Moran noted, however, that, in general, SBIR firms do not participate in the larger cooperative projects at NASA Glenn.

DATA, TRACKING, AND ANALYSIS

The NASA SBIR program exists primarily to serve NASA mission needs. However, efforts to track the extent to which these needs are, in fact, met have been limited. It is conceptually difficult to track a technology all the way from initial development to final infusion into a NASA mission or program.

BOX 2-1
The Mission of the Mentor-Protégé Program

"The NASA Mentor-Protégé Program encourages NASA prime contractors to assist eligible protégés, thereby enhancing the protégés' capabilities to perform NASA contracts and subcontracts, fostering the establishment of long-term business relationships between these entities and NASA prime contractors, and increasing the overall number of these entities that receive NASA contract and subcontract awards."

SOURCE: NASA Mentor-Protégé Program webpage. Available at http://osbp.nasa.gov/mpp/index.html.

[27]TecFusion™Program provides matchmaking role with regard to particular Phase II technology.
[28]Matt Moran, telephone interview, September 17, 2014. Moran's job is focused on creating new ventures and partnerships based on intellectual property and capabilities at NASA.

Often infusion of an SBIR technology occurs many years after the award date, and the technology is a small part of a much larger system of technologies developed by different companies under different contractual arrangements. In addition, infusion often comes through a contract held by a large company in the role of NASA prime.[29]

For the overall program, data and analysis issues can be divided into those related to data collection and those related to data utilization and analysis, as described below.

Data Collection

Outcomes Data

Until FY2012 NASA did not collect post-award outcomes data in a systematic way. NASA did not provide the committee with any data for the period preceding FY2012. More recently, NASA has begun to collect outcomes data via a new EHB module (see Chapter 3 for a more detailed description of the Electronic Handbook). The new data collection system is largely modeled on the DoD Company Commercialization Record (CCR), with some significant adjustments and improvements. The NASA system uses a more granular data structure which permits companies to enter information about multiple successes related to the same award, but according to discussions with agency staff, NASA SBIR companies are not required to certify that their records are updated before an award can be made, and, as a result, database coverage is likely not universal.[30]

Beyond the new EHB module, NASA does not have a contract-based system for tracking Phase III awards on a systematic basis. If awards are entered into the Federal Procurement Data System (FPDS) database correctly, then it should be possible to track Phase III awards through the contracting system. However, the NASA SBIR office does not have procedures in place to ensure that contracts are entered, or that the entries are correct. Therefore, although the EHB module offers the promise of better data, it is important to ensure that sufficient priority and resources are assigned to data collection.

Process Data

In addition to tracking outcomes, tracking activities at the Field Center level would provide information central to the program. TIMs undertake a wide range of activities that vary substantially by sector, and they track these activities themselves, using a range of tools. However, there are no mechanisms for tracking the activities of TIMs more centrally.

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[29]These tracking challenges and similar problems have been described at length in the recent report on the SBIR program at the DoD. National Research Council, *SBIR at the Department of Defense*, Washington, DC: The National Academies Press, 2014.

[30]Add a contrary point here from Fin/Holt, who offer a different view on requirements and utility.

The processes of formal NASA initiatives are also not closely tracked in some cases. For example, NASA has not been able to provide data about either the MPP take-up or outcomes.

Analytics

The limited data collection in the past has undoubtedly made it more difficult for NASA to develop a data-driven approach to program management. The data now emerging from the EHB should help to provide a basis for such an approach in the future.

Overall, NASA provided no documentation of past evaluation efforts—aside from the 2012 Economic Impact Report to suggest that the SBIR program is using process and outcomes data to drive program structure and to adjust the program based on experience. Otherwise, over the course of this study, NASA had offered to this committee little quantitative analysis of outcomes based on program data. It had provided little evidence that the program was meeting congressional goals—neither a systematic assessment of the overall take-up of SBIR technologies within NASA nor of the take-up of SBIR technologies outside of NASA via Phase III contracts.

There has been no analysis of the different approaches and resulting outcomes at the different Field Centers. These offer the potential for natural experiments as TIMs and Field Centers adopt different strategies to meet their objectives. Discussions with Field Center staff revealed that there is considerable communication among the TIMs at different Field Centers and that best practices are shared laterally among Field Centers but did not reveal similar communication between the Field Centers and the NASA SBIR office.

2012 NASA IMPLAN Assessment

In 2012 NASA hired a consultant to provide an economic impact assessment of the NASA SBIR program, based on an input-output framework and multipliers, and implemented using the IMPLAN input-output methodology[31] and software. A variety of agencies have used IMPLAN to assess the expected effects of a program change on measures such as employment, income, output, and taxes.

Although this mode of analysis can generate some interesting results, it is not an effective approach to assessing the extent to which the NASA SBIR program meets congressional objectives, because none of those objectives is measured using input-output analysis. Congressional objectives do not include jobs, economic growth, or return on investment. Furthermore, the assessment was not designed to provide formative guidance on process improvement—another useful application of program evaluation. However, the results have

[31]IMPLAN stands for Impact Analysis of PLANning. The methodology was implemented via software from Migs Inc.

been used for program accountability and to meet Administrative and Congressional requirements that federal agencies evaluate their programs.

NASA FIELD CENTERS AND SBIR

Each of the NASA Field Centers has an SBIR program that to some degree reflects its unique capabilities and history. To provide some insight into the differences among the Field Centers, this section addresses the activities of TIMs at Langley Research Center, Johnson Space Center, and the Jet Propulsion Laboratory.

Langley Research Center (LaRC)

LaRC was founded in 1917 as the nation's civil aeronautics laboratory, with competencies in aeronautic research, testing, and mechanical fabrication, and atmospheric and space science. Its SBIR/STTR annual portfolio averages 350 active Phase I, Phase II and Phase II enhancement projects.

LaRC SBIR/STTR infusion is driven by early identification of Mission Directorate customer needs, expressed in various NASA program and technology guidance—plus SBIR topics/subtopics—and by the need to connect these needs effectively with LaRC Engineering Directorate staff.

LaRC has developed new information technology (IT) infrastructure on which to build systems that can link Mission Directorate clients, LaRC engineering staff, and SBIR/STTR companies. By adapting a Salesforce™ "Sales Process Map" to Microsoft Project software, the LaRC TIM developed an IT backbone and database. The TIM then enriched the database with NASA customer information from the National Research Council's[32] *Visions and Voyages for Planetary Science in the Decade 2013–2022* report,[33] NASA's Technology Area Roadmaps, and the Aeronautics Research Plan. This enabled the TIM to map the LaRC SBIR program design to NASA Strategic Goals, LaRC's overall vision, and Strategic Focus Areas. Finally, the TIM devised specific SBIR infusion goals and objectives, which are aligned with Mission Directorate technology priorities.

The TIM markets SBIR technologies and companies to potential NASA customers through periodic web-based "Innovation Updates" on SBIR projects. The TIM also provides NASA customers with more detailed information about the benefits of Phase III SBIR contracting.

The TIM works to attract key Engineering Directorate staff to serve as COTRs. In particular, the TIM has enhanced COTR participation in Phase I and

[32]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council, or NRC, are used in an historic context identifying programs prior to July 1.

[33]National Research Council, *Visions and Voyages for Planetary Science in the Decade 2013–2022,* Washington, DC: The National Academies Press, 2011.

II project close-out discussions, as well as Phase II project midterm reviews, which are led by topic/subtopic sponsors from the Mission Directorates. Creating a solid personal and professional link between Mission Directorate and engineering staff is a core characteristic of LaRC infusion strategy.

Outside NASA, an external partnership management plan supports industry/university/laboratory partnerships with SBIR projects. The plan includes outreach via social and conventional media, and participation in regional small business promotional events.

Now that the IT tools are in place, the TIM has implemented an annual process improvement review to determine progress toward these goals and has made some program course corrections as a result. Key metrics cover Phase I and II proposal submissions, Phase II enhancement activity, and Phase III contracts; however, these data were not provided to the committee.

Johnson Space Center (JSC)

JSC opened in 1961 as NASA's primary center for design, development, and testing of spacecraft and associated systems for human flight. Unique among the Field Centers, JSC is owned and operated by the nonprofit Manned Space Flight Education Foundation, with a high-priority NASA public education mission that extends to its SBIR program. Historically, JSC has been at the heart of NASA outreach, which has also affected SBIR activities, as indicated below.

A range of pathways are employed to connect Mission Directorates, engineering staff, and SBIR companies. For example, TIMs participate in Mission Directorate activities at the Field Center and in Mission Support Division activities for the Mission Directorates. Participation in these activities generates detailed information about customer needs and demands, which the TIM can then pass on to SBIR companies.

Externally, the SBIR program actively piggybacks on Field Center regional outreach. The TIM participates in local/regional "speed-dating" events and small business technology markets with industry partners. In addition, while JSC has reached out to scientists and engineers at regional Historically Black Colleges and Universities (HBCUs) and Minority Serving Institutions (MSIs) by providing onsite technical briefings about NASA programs and Mission Directorate roadmaps, the TIM has provided professors and graduate students with information about SBIR as a pathway into NASA. It is notable that the TIM uses Phase I applications from HBCUs/MSIs as a metric for success.

The TIM also collaborates with other agencies' SBIR programs, such as the Missile Defense Agency and the Defense Advanced Research Projects Agency (DARPA), to expand customer opportunities, leverage SBIR funding, and provide technical assistance for SBIR awardees. Collaboration with foreign space programs, including Japan Aerospace Exploration Agency (JAXA), is designed to expand customer opportunities for SBIR projects.

Jet Propulsion Laboratory (JPL)

JPL is managed for NASA by the California Institute of Technology (Caltech) and is the leading U.S. center for robotic exploration of the solar system, focused on spacecraft payloads (not on rockets themselves).

JPL is also NASA's only Federally Funded Research and Development Center (FFRDC); unlike NASA's other nine field centers, which are staffed by government civil servants, JPL staff—including SBIR project technical monitors—consists almost entirely of Caltech researchers and engineers.

The JPL SBIR infusion strategy differentiates between near-term practices and longer-term customer (NASA program) engagement:

- Near-term infusions are purely technical and may be linked to Mission Design Reviews. They are focused on SBIR technology at Technology Readiness Level (TRL) 6 or higher.
- Longer-term infusions have less direct impact on mission programs. According to JPL staff, impacts include contribution to technical state-of-the-art or application to a priority technical trade space.

The TIM participates in bi-weekly meetings of the JPL Technology Working Group (TWG), a high-level strategic planning body at the Division/Directorate level. TWG's work aims to ensure that the SBIR program is aligned with JPL mission priorities, and it also allows senior staff input into and influence over topic/subtopic development, while strengthening the visibility of SBIR projects for senior Caltech scientists and engineers.

The TIM leverages the skills and connections of veteran JPL engineers by recruiting them as technical monitors (TMs):

- SBIR is positioned as an incentive to JPL engineers—it provides access to leading-edge research and development in exchange for limited hours of TM service.
- TMs are encouraged to communicate NASA mission requirements and the mission culture of specific programs to SBIR awardees.

JPL staff were reluctant to discuss further details of program management or of individual SBIR projects.

INTELLECTUAL PROPERTY AND DATA RIGHTS

The SBIR program is clear that the intellectual property (IP) rights developed under an SBIR award remain the property of the company.[34] Although the government—as with all federal contracts—retains "march in"

[34]Small Business Administration, http://www.sbir.gov/faq/data-rights. Accessed February 2, 2015.

rights whereby it can use the technology for its own purposes, the stated requirements of the program insist that companies retain all IP rights for a period of 4 years after the end of the Phase II award. The SBA website on SBIR data rights states: "SBIR/STTR Data are protected from disclosure by the participating agencies for a period of not less than 4 years from delivery of the last deliverable under the Phase I, II, or III award. The protection period is extended with each subsequent related award in order to avoid harmful disclosure of SBIR/STTR data related to on-going federally funded SBIR/STTR efforts."[35]

The SBA Policy Directive defines IP very broadly, explicitly not limiting this definition to patents only: "The separate and distinct types of intangible property that are referred to collectively as 'intellectual property,' including but not limited to: (1) patents; (2) trademarks; (3) copyrights; (4) trade secrets; (5) SBIR technical data (as defined in this section); (6) ideas; (7) designs; (8) know-how; (9) business; (10) technical and research methods; (11) other types of intangible business assets; and (12) all types of intangible assets either proposed or generated by an SBC as a result of its participation in the SBIR Program."[36]

NASA's approach to SBIR contracts rests, however, more on statutory regulations related to contracts, and in particular on provisions drawn from the Bayh-Dole act that focus on patents and patenting. NASA contracts require that all inventions be disclosed within 2 months, preferably via the agency's New Technology Reporting website.[37] According to NASA, registration provides the company with a free worldwide license to the technology. Failure to register is a violation of FAR 52.227-11 and can result in loss of IP protections.

This tension between SBIR regulations and federal contracting could lead to circumstances in which companies decline to seek patent protection and NASA subsequently steps in to patent an invention, potentially over-riding the data protection provisions of the SBIR legislation. However, companies contacted for case studies indicate that this scenario is, in practice, quite unlikely. Although there is a tension between the provisions, in practice this is unlikely to cause damage to an SBIR company.

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[35]Ibid.
[36]Small Business Administration Policy Directive, Section 3.s.
[37]FAR 52.227-11.

3

Program Initiatives

The National Aeronautics and Space Administration (NASA) has in recent years—and especially since the 2011 reauthorization—experimented with new initiatives within the Small Business Innovation Research (SBIR) program. These include the following:

- Electronic Handbook (EHB)
- Technology infusion managers (TIMs)
- Phase II Enhancement (PII-E) awards
- Phase II-Expanded (PII-X) awards
- Select Topics
- Commercialization Readiness Pilot (CRP) program
- Enhanced data collection

Three of these new initiatives (the EHB, TIMs, and Phase II-E awards) have been in operation for some time; others are just being implemented (the CRP program and enhanced data collection). Each of these initiatives is discussed in turn in the following sections—with the exception of enhanced data collection, which is discussed in a general way within the EHB section. That section relates that recent additions to the EHB have focused on incorporating data collection tools for outcomes to enhance data collection capabilities.

ELECTRONIC HANDBOOK (EHB)[1]

Introduction and EHB Overview

Originally developed with funding from a NASA SBIR Phase II contract in 1989, the EHB has evolved into a highly effective grants/contracts

[1]See background information at SBIR/STTR Awardee Firm Electronic Handbooks, https:/ehb8.gsfc.nasa.gov/contracts/public/firmHome.do. This is also the registration and login site.

and program management tool. First deployed in 1996, the EHB now provides NASA with a complete end-to-end paperless system for managing the SBIR program. Approximately 6,000 users are currently on the NASA system, and overall the system owner and manager, REI Systems, serves more than 250,000 users annually. An example of NASA best practices, the EHB is now in use at a number of federal agencies and other grant-giving organizations.

The EHB contains seven modules corresponding to the different phases of the SBIR program:

- **Solicitation.** The Solicitation Development module facilitates the collaborative development of the research topics and subtopics for the annual NASA SBIR solicitation. The final solicitation is published through the EHB.
- **Submission**. Small Business Concerns (SBCs) electronically submit their Phase I and Phase II SBIR proposals via the Proposal Submissions module.
- **Administrative screening.** Proposals are administratively screened using the Proposal In-processing module, which tracks proposal status, problems identified, and eventual resolution.
- **Review and selection**. The Review and Selection module is used for evaluation, ranking, recommendation, selection, and debriefing of Phase I and Phase II SBIR proposals.
- **Contract negotiation.** The Contract Negotiation and Award module supports the negotiation and award of NASA SBIR Phase I and II proposals selected for award and maintains current and archived contracts.
- **Contract administration.** The Contract Administration and Closeout module facilitates the contract administration and eventual closeout of NASA SBIR Phase I and Phase II contracts, including the submission, review, and acceptance of contract deliverables. The EHB is currently used to manage invoices and approve payments.
- **Tracking**. The Tracking, or Post Award Successes Module, provides collection and reporting capabilities of post-Phase II successes including Phase III, infusion, and commercialization. This module is a relatively new addition.

Figure 3-1 highlights the range and complexity of the processes managed within the EHB by illustrating the more than 50 different functional roles played by NASA staff, consultants, and company executives within the NASA SBIR process.

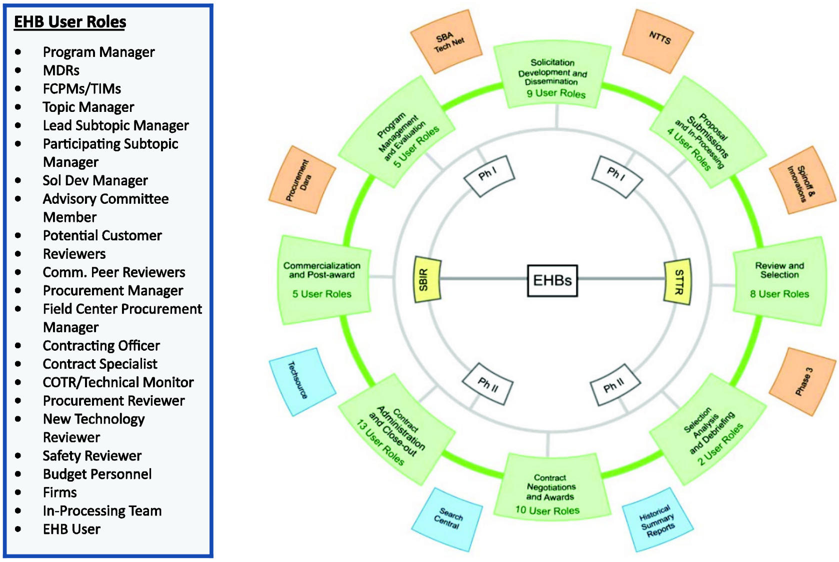

FIGURE 3-1 Distribution of roles within the NASA EHB.
Abbreviations: Ph I and Ph II denote SBIR Phase I and II, respectively; SBA Tech-Net denotes the Small Business Administration's SBIR database, which contains data on SBIR grants and contracts; TechSource is a scientific and technical consulting firm that provides services to organizations that develop, implement, operate, and manage high technology programs; and NTTS abbreviates NASA's Technology Transfer System.
SOURCE: NASA, March 2015.

Program and Process Dashboards

The EHB provides state-of-the-art tools for program management. It offers users a series of individually customizable dashboards through which to view data in the system, with drill-down capabilities. This dashboard allows program managers to easily review selected data covering applications and awards for a range of variables. These capabilities are more comprehensive than those available at any of the other SBIR programs, including the Department of Defense (DoD), where considerable efforts have been expended in this direction. Similar dashboards allow managers to closely track progress against defined milestones.

Because the system was designed from the start to be a tracking system for contracts, it provides both applicants/contractors and program managers with appropriately differentiated views into the process.

Reporting Tools

In addition to the detailed and customizable dashboards described above, the EHB has evolved an extensive set of reporting tools. These include both standard reports using a simple trigger and easily customized searches using a range of fields across a number of data sets. Table 3-1 describes the available search tools.

These search tools allow management to track program activities. They also enable companies and NASA officials to explore opportunities by finding technologies and their owners within the system. The TechSource search tool is publicly available on the NASA website; anyone can search using a range of keywords, categories, and filters.

TABLE 3-1 Search Tools Available Within the EHB

Tool	Description
Search Central	Allows customized "ad hoc" searches across solicitations for topics/subtopics, proposals, awards, firms; Reports on all historical data from 1983 to present; Detailed or graphical report options available
TechSource	Performs keyword searches on the following database fields and uploaded documents; Abstract, Project Title, PI and COTR, Firm Name, Taxonomy Mappings, Submitted docs: Proposal and Deliverable documents
Post Award Success Reports	Allows customized "ad hoc" searches across all post awards and success opportunities
Summary Reports	Canned reports with drill down capabilities: Proposal Statistics; Award Statistics; State-based Statistics; Women/Minority/HubZone; Firm-based Search Tool; Subtopic-based Search Tool; Proposal Info Tool Commercial Metrics Survey Tool
Website Search	Searchable site, solicitations, and awards
EHB Quick Search	Searchable proposals, awards, firms

SOURCE: REI Systems.

Utilization of the EHB

The EHB is a state-of-the-art system for managing and capitalizing on the NASA SBIR program.[2] Discussions with NASA staff within the Research Centers suggest that Field Center and Headquarter (HQ) SBIR staff use the EHB extensively as a management tool and as a resource. The EHB is also used to manage the SBIR program on an operational level. The EHB provides tools through which standard tasks can be accomplished with minimal effort, while facilitating a constant flow of information across the program.

It is concluded that the EHB is an example of best practice that SBIR programs at other agencies should consider for adoption (and indeed that other programs that offer grants or contracts beyond SBIR also should consider). The EHB is currently in use at the Department of Homeland Security SBIR program and the Small Business Administration (SBA). It is in itself an important SBIR success story.

That said, NASA SBIR staff are not taking full advantage of the EHB capabilities to develop a data-driven approach to program management. The EHB tools have become much more useful for this purpose since the agency started collecting outcomes data in 2012, while reaching back to awards in previous years. (The data are collected in ways that also capture the current commercialization status of projects funded in earlier years.) NASA currently has on file outcomes data for about 2,000 SBIR and Small Business Technology Transfer (STTR) projects dating back to the 1990s. Additional records are being added.

Data Collection Related to Outcomes

In 2012, NASA adopted a version of the process used at DoD to collect outcomes data for SBIR and STTR awards. Companies are required to enter data on all known SBIR awards (at NASA and at other agencies); however, entering these data is not a prerequisite for applying for or receiving additional awards from NASA, as it is at DoD. The EHB is similar to DoD's Company Commercialization Record (CCR): data are similar in kind, and the collection procedures are similar in process,[3] but the EHB incorporates a number of changes and possible improvements over CCR. These changes and improvements include more detailed data collection within the EHB.

Several more detailed fields in the EHB specifically address infusion into NASA programs. They describe Technology Readiness Levels (TRLs), the specific technology involved, agency components, and other aspects of the

[2]The Navy Program Manager's database is perhaps the closest match as an electronic toolkit for program management.

[3]See National Research Council, *SBIR Program at the Department of Defense*, Washington, DC: The National Academies Press, 2014, p. 68, for a description of the CCR and related procedures.

infusion process. This is a thorough and well-designed effort to help measure the extent to which SBIR technologies are indeed being used by NASA.

Additional fields also relate to matching funds for some programs such as Phase II-E (discussed below). Once again, these adaptations could help provide managers with a more detailed understanding of matching fund sources and commitments.

The development of this module for the EHB represents an important step toward the creation of a data-driven management culture within the NASA SBIR program. It provides a set of tools with which management can work to identify patterns and thereby opportunities for improvement.

EHB Challenges and Opportunities

As with all information technologies, the need for standardization generates tension with the need for flexibility. The EHB has evolved over time. Table 3-2 shows how new capabilities have gradually been added in response to user and agency needs. Recent additions have focused on the addition of data collection tools for outcomes.

Despite this evolution, there is evidence that several of the new initiatives (such as technology infusion managers, discussed in detail in the next subsection) have not fully adopted the EHB for tracking their activities. Not only has one TIM developed an alternative information system based on Salesforce (a popular cloud Customer Relationship Management (CRM) software), but also another TIM uses a 300-page Word document for the same purpose. Both TIMs find these preferable to the EHB, which suggests that the needs of the TIMs are not being fully met by the EHB.

TABLE 3-2 Addition of Capabilities to EHB—Timeline

	Program Year Data Collection Started	
Type of Data	Phase I	Phase II
Solicitation Topics/Subtopics	1998	1998
Proposals	1997	2000
Technical Evaluations	1998	1998
Contracts	1997 (1998 for STTR)	1997 (1998 for STTR)
Contract Deliverables	2001 (more complete over time)	2000 (more complete over time)
Technology Taxonomy Mapping	2005	2005
STR Technology Area Mapping	2011	2011
TRL	2007 (required in 2008)	2007 (required in 2008)
Recommendation Quad Charts	2006	2007
Briefing Charts	2001 (Required in 2007)	2000 (Required in 2007)
Post Award Successes (Phase II-E, Phase III, Infusion, Commercialization)	APG metrics from FY12 plus Commercialization Metrics data from Firms	APG metrics from FY12 plus Commercialization Metrics data from Firms

SOURCE: REI Systems.

The Academies[4] discussions with NASA staff indicated that program management were not currently using these capabilities to guide the program. These discussions indicated that NASA had not developed (or planned) analytics to link outcomes data with possible explanatory variables or applications with outcomes, and NASA has not provided analytics that compare outcomes, for example by Mission Directorates, Center, technology, type of topic, and companies and projects, based on a range of other possible causal factors such as firm size, demographics, technology, or location. Such analyses can help NASA to develop better topics, identify problems within the process, and find firms and projects that are more likely to be successful.

In sum, the NASA EHB is an example of best practice: The EHB has been adopted by other agencies and programs outside of NASA SBIR, including the SBIR program at the Department of Homeland Security and the SBA. It is in itself an important SBIR success story that can be more widely adopted by other SBIR programs, as well as by other grant and contract programs across the federal government.

However, NASA SBIR staff are not yet taking full advantage of the EHB capabilities to develop a data-driven approach to program management. The EHB tools have the potential to become much more useful for this purpose, particularly since NASA started collecting outcomes data in 2012, and have reached back to collect the outcomes (i.e., current commercialization status) of awards funded in previous years).

NASA SBIR program managers can do more with the EHB to guide the program. They can develop analytics to link outcomes data with possible explanatory variables or applications with outcomes. They can compare outcomes, for example by Mission Directorate, Center, and companies and projects based on a range of possible causal factors such as firm size, demographics, technology, or location.[5] These and other analyses can help NASA to develop better topics, identify problems within the process, and find firms and projects that are more likely to be successful.

TECHNOLOGY INFUSION MANAGERS (TIMS)

One potentially important long-running initiative at NASA is the provision of Technology Infusion Managers (TIMs) at each Center. A recent document from Glenn Research Center described the core activities of TIMs:

- **Help for NASA program/project managers**: TIMs conduct searches of Phase I and Phase II awards, identifying technologies to support a

[4]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.
[5]Academies discussions with NASA SBIR staff.

particular technology interest or the specific needs/requirements of a program/project.

- **Help for SBIR small businesses:** TIMs facilitate dissemination of information about an SBIR technology of potential interest to program managers.
- **Help putting these parties together:** TIMs facilitate meetings and web-based teleconferences between NASA program/project managers and SBIR companies. They also provide guidance on seeking post-Phase II funding.[6]

TIMs are expected to connect with Center technologists, help plan and implement infusion strategies, identify applications and funding sources, report successes, inform prospective users about available and developing technologies, and motivate SBIR advocates. Discussions with TIMs and their supervisors indicate that the implementation of these roles differs among Centers because the Centers have slightly different operations and the Mission Directorates have slightly different needs. Successful TIMs rely on a broad network of contacts that are active in SBIR technology infusions.

Discussions with TIMs and their supervisors also reveal that TIMs generally tend to come from within NASA and to have worked on the operational side, for example as an engineer. They have different levels of knowledge related to commercialization depending on the kind of activity involved. Figure 3-2 provides a schematic illustration: TIM knowledge and understanding declines as the relevant area shifts away from the home center to other centers and then attenuates even further for private-sector entities.

A limited scope of Phase III commercialization expertise is understandable, because TIMs primarily focus on connecting SBIR projects to NASA programs. However, it underscores some of the limitations of the TIM model. Discussions with TIMs and other agency staff suggested that the effectiveness of TIMs varies substantially, but this variation is not substantiated with metrics. NASA did not describe or share metrics for assessing the individual or collective success of TIMs, because it does not have tools in place for tracking TIM activities effectively across Centers or to identify or transfer best practices. This is unfortunate because TIMs develop different strategies and tools, and these natural experiments have the potential to improve operations for the program as a whole if they are appropriately analyzed and transferred effectively.

[6]SBIR/STTR Program Office, Glenn Research Center, "Opportunities to Infuse SBIR Technology into NASA Programs: Funding and Strategic Alignment Guidance for the Science Mission Directorate," 2015.

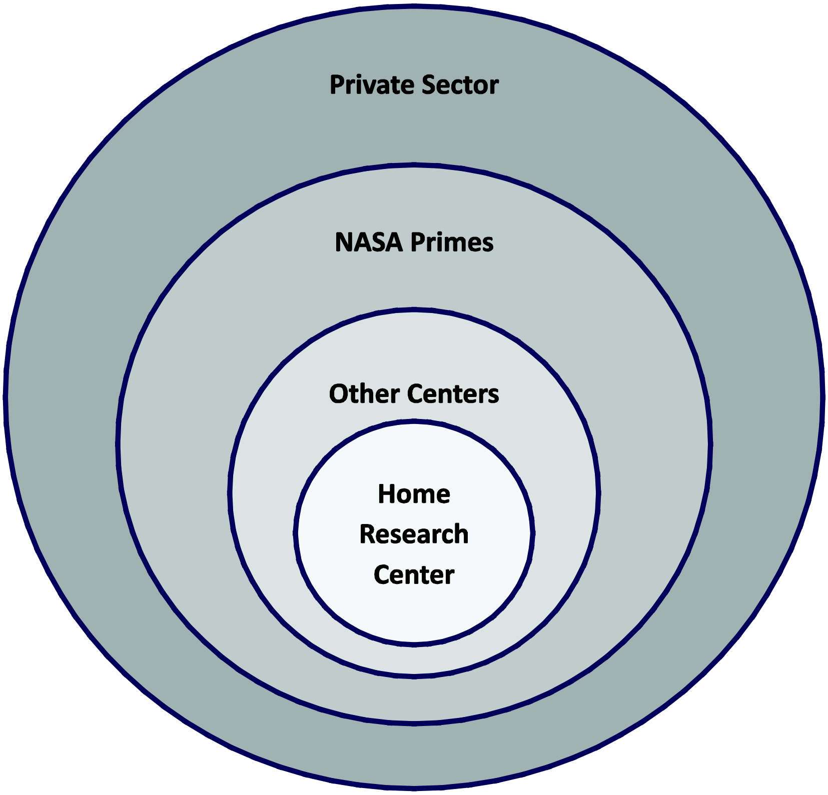

FIGURE 3-2 Schematic: Attenuation of TIM relevant commercialization experience and knowledge as a function of distance from the home research center

PHASE II ENHANCEMENT (PII-E) AWARDS

Overview

Established in FY2007, the objective of the PII-E program is to "further encourage the advancement of innovations developed under Phase II via an option of R/R&D efforts underway on current Phase II contracts."[7] Firms that can attract an external investor can apply to NASA for matching funds up to a pre-set limit. By using the matching funds approach, NASA can ensure that

[7]NASA Phase II-E description, http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives, accessed March 7, 2015.

there is either commercialization or investment interest from a third party. The PII-E program requires that the matching funds come from a third party (external to the NASA SBIR program, though potentially from other sources within NASA).

The PII-E program has evolved somewhat since its inception. The maximum program contribution was $250,000 until 2011, and has been $150,000 since then. The maximum amount of agency funding counting both Phase II and Phase II-E is now $900,000, down from $1 million in 2007-2011 (see Table 3-3). Reasons for these changes were not provided. Select Topics can be funded at a higher level (see Select Topics section, below).

Phase II-E Award Patterns

From 2007 to 2011, NASA made 94 PII-E awards, using about $12.5 million in NASA SBIR funding and attracting about $16.0 million in matching funds (see Table 3-4). Data for 2013 and 2014 are not yet available from NASA (as of May 2015).

TABLE 3-3 Evolution of the NASA Phase II-E Program

Applicable Period/Solicitation	Minimum Non-SBIR/STTR Funding Required	Corresponding SBIR/ STTR Program Contribution	Maximum Cumulative Award (Phase II + Phase II-E Match)
April 2016 – onwards	$25,000	1:1 match to a maximum of $150,000	$900,000 (SBIR and STTR) $1,650,000 (SBIR Select)
2012 Solicitation	$25,000	1:1 match to a maximum of $125,000	$875,000 (SBIR and STTR) $1,625,000 (SBIR Select)
2011 Solicitation	--	1:1 match to a maximum of $250,000	$1,000,000

SOURCE: NASA Phase II-E description, http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives, accessed March 7, 2015.

TABLE 3-4 SBIR PII-E Awards at NASA, 2007-2011

Year	Number of PII-E SBIR Awards	SBIR Phase II-E Funding (Dollars)	Matching Contribution (Dollars)
2007	24	2,945,947	3,419,370
2008	18	2,245,140	2,565,989
2009	16	1,832,780	4,041,954
2010	25	3,130,073	3,484,236
2011	11	2,334,973	2,385,000
Total	94	12,488,913	15,896,549

SOURCE: Awards data provided by NASA.

In the context of the NASA SBIR program, these are relatively modest numbers. During the same time period, NASA made a total of 1,605 awards, so Phase II-E awards accounted for only 5.8 percent of NASA awards. The SBIR program provided $53.7 million in funding during this period, and PII-E awards accounted for 2.8 percent of SBIR program expenditures. The 94 PII-E awards were distributed to 76 different companies, with the two most prolific companies each receiving four awards and $600,000 in SBIR funds.

Phase II-E—Sources of Matching Funds

The PII-E program is designed in part to help Phase II awardees connect to other funding sources, especially within NASA. Figure 3-3 shows the distribution of matching funds and confirms that NASA is the largest single source of funding for the 94 PII-E projects at 55 percent, followed by the private sector at 27 percent and DoD at 10 percent.

Phase II-E Outcomes

Although Phase II-E projects account for less than 6 percent of all NASA SBIR Phase II contracts from 2007 to 2011, they account for 155 out of 735 projects, or 21.1 percent, in the commercialization database. For Phase II

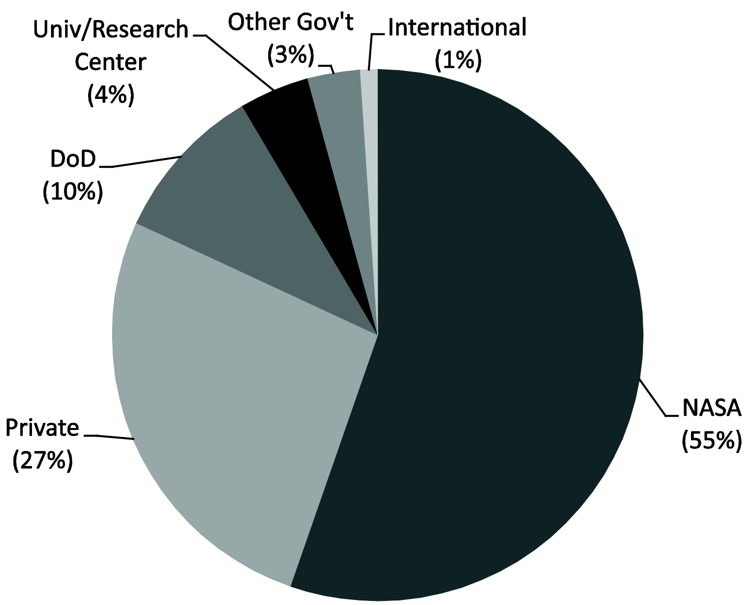

FIGURE 3-3 NASA SBIR/STTR Phase II-E awards: Sources of matching funds.
SOURCE: NASA SBIR/STTR data.

projects awards in 2005-2009 (the corresponding years for the subsequent PII-E award, which comes at the end of Phase II), the 155 PII-E accounts come from 400 Phase II projects, or 38.8 percent, in the EHB database. This suggests that Phase II-E is to some degree aligned with commercialization.

These numbers should, however, be treated with some caution. The outcomes data collected so far from the EHB are incomplete, and there is no way to determine the biases that affect this reporting. During the same period, NASA initiated a total of 789 Phase II SBIR awards, so only about 51 percent of all NASA awards reported outcomes through the EHB. Even with these caveats, it is still striking that 20 percent of Phase II awards accounted for about 39 percent of the records in the new commercialization database. Further exploration of these data—viewed against the backdrop of the Great Recession and the recovery—would be potentially fruitful. With better data in the EHB, such broader analysis would be possible.

Phase II-E funding is limited in several ways, aside from the relatively short time horizon (4 months). First, new work proposed under Phase II-E must "build upon and demonstrably advance" the technology developed under Phase II, which suggests that more ambitious expansions of the technology may not be funded. On the other hand, Phase II-E is supposed to "lead to new outcomes not achievable with Phase II funding alone."[8] Second, there is a tight window for Phase II-E applications, between the 12th and the 15th month of the Phase II award.

External funding can come from a range of investors, including not only private investors, but also a NASA program, a NASA contractor, or a non-SBIR/non-STTR government program. Government matching funds from outside the SBIR program are not limited because they are regarded as a Phase III event and hence not subject to Phase II limits. Discussions with NASA staff indicate that NASA does not include sales revenues as a potential match. A precise match may change by solicitation (i.e., annually).

PHASE II-EXPANDED (PII-X)

Launched in 2014, the Phase II-Expanded (Phase II-X) program represents a new effort to create better bridges between the SBIR/STTR program and the NASA Mission Directorates (MDs) who have acquisition funds. Effectively, the program operates in ways quite similar to the Phase II.5 (or Phase 2.5) program recently implemented in some components at DoD[9]: the SBIR program provides additional funding against a match specifically provided by the NASA Mission Directorates as a bridge toward commercialization and use by NASA MDs.

[8]NASA, NASA SBIR/STTR Participation Guide, 2015, p.4.
[9]National Research Council, *SBIR at the Department of Defense*, Washington DC: The National Academies Press, 2014.

The PII-X program aims to "establish a strong and direct partnership between the NASA SBIR/STTR program and other NASA projects undertaking the development of new technologies or innovations for future use."[10] The program adds an option to all NASA Phase II contracts, which can be exercised under appropriate circumstances.[11] The option provides for a 2:1 match by the SBIR program against funding from other NASA sources. To participate, eligible firms must secure a *NASA program or project* (other than the NASA SBIR/STTR program) as an investment partner funding further research or infusion activities. A minimum of $75,000 in NASA non-SBIR/non-STTR funding is required, and the SBIR program will match up to a maximum expenditure of $500,000. If fully exercised, then this funding would take the maximum award (Phase II + PII-X) to $1.25 million for standard topics and $2 million for Select Topics (see Table 3-5). Contributions from other NASA programs or projects are not limited, because they are not regulated under SBIR guidelines.

The PII-X program started too recently for outcomes to be available for analysis. However, this effort does indicate that NASA continues to explore initiatives that will connect the SBIR program more effectively to other programs at NASA. Agency staff indicated that Phase II-X funds account for about 5 percent of SBIR/STTR program funds.

SELECT TOPICS

Starting in 2012, NASA has identified a small number of topics as Select Topics. Similar to standard topics in many respects, these topics attract additional SBIR/STTR funding. In 2015, these Select Topics were limited to the Human Exploration and Operations Mission Directorate and the Science Mission Directorate.[12]

TABLE 3-5 NASA Phase II-X Program

Minimum NASA Non-SBIR/ STTR Funding Required	Corresponding SBIR/ STTR Program Contribution	Maximum Cumulative Award (Phase II + Phase II-X Match)
$75,000	2:1 match to a maximum of $500,000	$1,250,000 (SBIR and STTR) $2,000,000 (SBIR Select)

SOURCE: NASA, "Post Phase II Initiatives and Opportunities, Phase II-X", http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives#Phase-II-x, accessed July 23, 2015.

[10]NASA, Post Phase II initiatives, http://sbir.gsfc.nasa.gov/content/post-phase-ii-initiatives, accessed March 8, 2015.

[11]Note: companies may apply for Phase II-E or Phase II-X but not both (presumably because Phase II-X is a subset of Phase II-E, excluding non-NASA partners). Applications windows for both programs are tight. Companies must provide notice of intent to apply by the 13th month of the Phase II award. The submission window is the 4th month of the second year of a Phase II award.

[12]Discussion of Select Topics draws in part on the NASA 2015 Select Topic Solicitation, http://sbir.gsfc.nasa.gov/solicit/54565/detail?l1=55463, accessed March 8, 2015.

Select Topics are run as a separate solicitation in parallel with the standard solicitation. Awards are capped at a higher level—$125,000 for Phase I and $1.5 million for Phase II. The performance time period is unchanged at 6 months for Phase I and 2 years for Phase II. NASA also imposed additional company limits on the FY 2015 Select SBIR Solicitation: acceptance of no more than three proposals from any one firm and award of no more than two Select Topic SBIR contracts to any applicant under the solicitation.[13]

As shown in Table 3-6, NASA made 26 Phase I Select awards and 10 Phase II Select awards totaling about $18.7 million in 2012. The number of Phase I awards increased by almost 40 percent in 2014, from 26 to 36 (data for Phase II awards had not yet been tabulated for 2014 at the time of writing).

Select Topics are a NASA initiative to place additional funding on topics that MDs consider to be of particular significance or priority for their operations. It remains to be seen whether this approach is more successful than standard solicitations, but it does represent another potentially important initiative aimed at improving program outcomes. NASA expects that end-of-project Technology Readiness Levels (TRLs) will be significantly higher than those for standard topics.[14]

COMMERCIALIZATION READINESS PILOT PROGRAM (CRP)

NASA is now engaging with opportunities presented under reauthorization through the Commercialization Readiness Pilot (CRP) program.[15] A limited pilot in 2014 expanded in 2015, aimed at increasing the infusion of SBIR-/STTR-developed technology into NASA's broader programs. Under the CRP program, other NASA programs will act as sponsors, who will show how proposed activities result in risk reduction and bridge the "TRL gap" discussed in Box 3-1. Increasing TRL levels will help commercialization. The SBIR/STTR program will then offer matching funds to support these activities.

TABLE 3-6 NASA SBIR Awards Made Under Select Topics, 2012-2014

Year	Number of Select Topic Phase I SBIR Awards	Select Topic Phase I SBIR Funding ($)	Number of Select Topic Phase II SBIR Awards	Select Topic Phase II SBIR Funding ($)
2012	26	5,175,601	10	13,537,022
2014	36	4,484,590		
Total	62	9,660,191	10	13,537,022

SOURCE: Awards data provided by NASA.

[13]NASA 2015 Select Topic Solicitation, http://sbir.gsfc.nasa.gov/solicit/54565/detail?l1=55463, accessed July 23, 2015.

[14]Carol Lewis, FAQ: NASA SBIR Technology Infusion and Post Phase II Opportunities, NASA internal memo, November 2013.

[15]Information on the CRP program is drawn from Joseph Grant, SBIR/STTR, Presentation to the National SBIR/STTR conference, 2014, and discussions with agency staff.

BOX 3-1
The Valley of Death at NASA: Bridging the TRL Gap

The funding crunch for small innovative companies comes at different times and in different circumstances at different agencies. At NASA, although SBIR Phase II awards fund development to approximately TRL 4-5, agency acquisitions managers fear the remaining technology risks and strongly prefer to fund projects at TRL 6-7. Because NASA technologies tend to be highly NASA-specific, it is difficult for companies to find non-NASA funding to continue development to a point at which NASA will deliver a Phase III contract.[a] Figure Box 3-1 is drawn from a NASA document that illustrates NASA views on the funding gap, as aligned with TRL development within the SBIR/STTR program.

		TRL Level	Qualifier/Development Hurdle
SBIR Phase I & II	Basic Research	1	Basic scientific/engineering principles observed and reported
	Feasibility Research	2	Technology concept, application, and potential benefits formulated (candidate system selected)
	Feasibility Research	3	Analytic and/or experimental proof-of-concept completed (proof of critical function or characteristic)
	Technology Development	4	System concept observed in laboratory environment (breadboard test)
Technology Demonstration "Valley of Death"	Technology Development	5	System concept tested and potential benefits substantiated in a controlled relevant environment
	System Development	6	Prototype of system concept is demonstrated in a relevant environment
System Development	System Development	7	System prototype is tested and potential benefits substantiated more broadly in a relevant environment
	Operational Verification	8	Actual system constructed and demonstrated, and benefits substantiated in a relevant environment
	Operational Verification	9	Operational use of actual system tested, and benefits proven

FIGURE BOX 3-1 NASA description of TRL levels in relation to SBIR/STTR.
NOTE: The "Valley of Death" signifies that many companies fail when their technologies are in the range of TRLs 5-6. SBIR Phase I applications are usually TRL 1, and by the time Phase II is complete, projects are expected on average to have reached TRL4.
SOURCE: NASA.

[a]See SBIR/STTR Program Office, Glenn Research Center, "Opportunities to Infuse SBIR Technology into NASA Programs: Funding and Strategic Alignment Guidance for the Science Mission Directorate," 2015, p. 2. Accessed March 8, 2015. Information on the CRP program is drawn from Joseph Grant, SBIR/STTR, Presentation to the National SBIR/STTR conference, 2014, and discussions with agency staff.

The CRP program is designed to focus specifically on bringing technologies through TRL 5-6 so that they can be funded by NASA development contracts, because that is the stage where many small companies fail (the so-called "Valley of Death").[16] The program requires that the related Phase II SBIR contract be awarded no earlier than 2008 and provides up to $1.5 million from the SBIR/STTR program over 24 to 36 months.

CONCLUSIONS

The NASA SBIR program has put in place several promising initiatives. The EHB is an important and potentially powerful electronic management tool that provides a mechanism for enhanced data collection.[17] TIMs can play a useful role in connecting SBIR companies, potential customers, and Center priorities. The Phase II-E, Phase II-X, and CRP initiatives all have potential to help link the SBIR program to downstream agency programs. The concept of Select Topics seems an appropriate mechanism for identifying and funding projects that are especially important from the agency's perspective to bring them to the desired higher TRL level, but the results of its employment should be monitored for effects on the broader SBIR program at NASA.

The larger questions for the NASA SBIR program revolve around implementation, follow-through, and tracking of these initiatives. NASA has developed enhanced data collection tools for a data-driven approach—one that can permit ongoing evaluation of the current initiatives and the identification and implementation of appropriate adjustments—however, previous NASA initiatives such as the NASA Alliance for Small Business Opportunities (NASBO)—which sought to link NASA SBIR companies with commerce-ready technologies to small business service providers, large contractor firms, and investors—lacked consistent implementation. Although the EHB has great potential, our research shows further effort is needed for this potential to be realized.

[16]Other studies in science have noted the TRL gap and the need to address it. See, e.g., National Research Council, *New Worlds, New Horizons in Astronomy and Astrophysics*, Washington, DC: The National Academies Press, 2010, Table ES.1 and Chapter 5.
[17]Our analysis focused only on the use of the Electronic Handbook in relation to the NASA SBIR Program, but it has great potential outside the program and is used elsewhere.

4

SBIR Awards

This chapter provides a summary analysis of application and award patterns for the National Aeronautics and Space Administration (NASA) Small Business Innovation Research (SBIR) program for fiscal years (FY) 2005-2014. It addresses Phase I and Phase II awards and breaks out patterns by state and by company. The chapter annex provides a more detailed presentation of the data in tables and figures, several of which are included in the chapter body.

The analyses in this chapter are based on data provided to the committee by NASA. These data are not always complete, and their quality is sometimes uneven.

SBIR PHASE I

Applications and Awards

Overall, the number of NASA SBIR Phase I applications declined during the study period. There were more than 1,900 Phase I applications in 2005 but only 942 in 2014. Although the numbers of applications declined at all agencies, this was a relatively large decline and could signal that the program is becoming less attractive to promising companies. However, as was noted in Chapter 2 (Program Management), in FY2007-2008, NASA imposed a limit of 10 applications per company per solicitation, and the number of applications promptly declined by about 20 percent.[1]

Despite this decline, the number of awards remained at approximately 300 per year. The higher rate of application acceptance need not imply deterioration in the quality of awards, because limiting the number of applications per company is expected to result in an improvement on average in

[1]National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Washington, DC: The National Academies Press, 2009, Chapter 2, pp. 2-11.

the quality of applications submitted as companies choose their better proposals to submit. FY 2014 saw a slight increase in the number of awards, perhaps reflecting growth in the mandated size of the program after reauthorization. Funding for Phase I awards expanded at NASA during the study period (see Figure 4-1), implying that the average size of Phase I awards increased.

Applications and Awards by State

Consistent with other SBIR agencies—and indeed with science and technology funding in general—NASA SBIR applications and awards are clustered geographically, generally correlated with population size. Not surprisingly, states with more scientist and engineers and more companies apply more often—and receive more awards. However, after normalizing by population size, a large spread remained between the most and least successful states, in terms of the number of Phase I awards per 1 million people. As shown in Table 4-2, seven states (Massachusetts, Colorado, New Hampshire, New Mexico, Virginia, Montana, and Maryland) generated 35 or more awards per 1 million people during FY2005-2014, while 33 states generated fewer than 10 awards per 1 million people during the same time period. Of these, Arkansas, Nebraska, North Dakota, and the District of Columbia generated none. Unadjusted for population, California had by far the greatest number of applications and awards. As discussed below, this is consistent with the concept of regional clusters of innovation generating relatively large rates of applications and awards to national competitions such as SBIR provides.

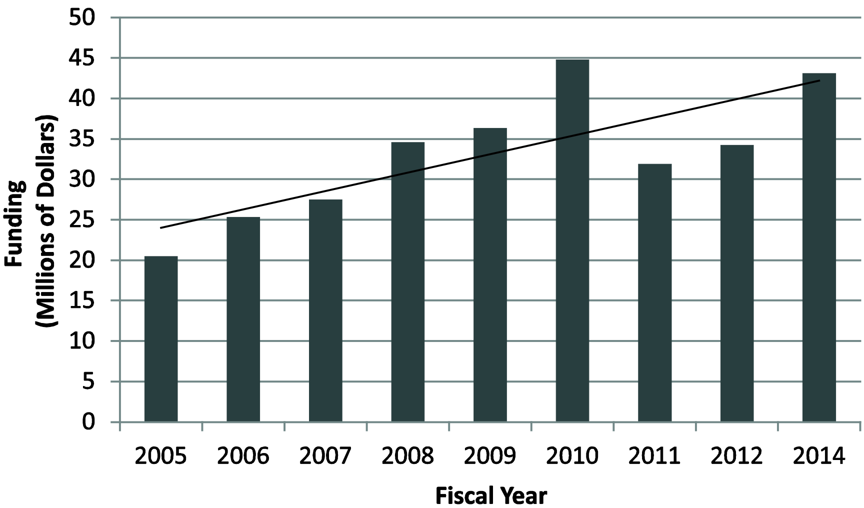

FIGURE 4-1 NASA funding for SBIR Phase I awards, FY2005-2014.
SOURCE: NASA awards and applications database.

As has been noted by the Government Accountability Office (GAO), the distribution of science-related awards tends to follow the distribution of scientists and engineers in the workforce, with geographical clusters of science and engineering talent generating proportionately more awards.[2] The geographical distribution of applications and awards is also affected by the awareness of the program. Small businesses in some states are less aware of the SBIR program and, for this reason, apply less often. By like token, small businesses located in states with NASA Field Centers (or in regions surrounding NASA Field Centers) are more aware of the NASA SBIR opportunity and more likely to apply. This difference in awareness raises a question of whether NASA is receiving a full complement of innovative proposals.

Recent efforts led by the Small Business Administration to sponsor a traveling road show on the SBIR program across a number of under-served states is a public policy response that may help businesses across the nation become more aware of the SBIR opportunities. To the extent that lack of awareness is the reason for a low participation rate, this effort may boost participation rates.

Awards by Company

Previous reports by the Academies[3] have examined claims that awards cluster within a few companies, effectively giving rise to "SBIR mills."[4]Analysis of NASA SBIR Phase I awards reveals that the awards were not highly concentrated within companies. Table 4-4 lists the top 20 NASA SBIR Phase I awardees and the number of awards received by those companies during FY2005-2014. The most prolific winner (Creare) received 42 SBIR and STTR Phase I awards during FY2004-2014, or about 4 per year, which was well under the limits set by NASA.[5] Combined, the top 20 awardees accounted for about 18.4 percent of Phase I awards. Conversely, firms new to the program received about 15 percent of Phase I awards in FY2014, although they submitted

[2]Government Accountability Office, *Federal Research: Evaluation of Small Business Innovation Research Can Be Strengthened*, GAO/RCED-99-114, Washington, DC: Government Accountability Office, June 1999, p. 17.

[3]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.

[4]"SBIR mill" is a pejorative term that refers to a company that lives off SBIR awards and does not have a separate business function or true commercial objectives. It is inconsistent with the goals of the SBIR program to create and perpetuate "mills". At the same time, it should be recognized that some companies in the technology creation and development business are positioned legitimately to apply for and receive multiple SBIR awards. In many cases, firm with multiple SBIR awards usefully meet the mission needs of NASA and operate within the spirit of the program.

[5]According to the NASA 2014 program description, in addition to limiting the number of applications to 10 from any one firm, NASA also does not plan to award more than 5 SBIR contracts and 2 STTR contracts to any offerer under the solicitations described. NASA SBIR/STTR 2014 Program Solicitation, http://sbir.gsfc.nasa.gov/solicit/52896/detail?l1=52931. It is not clear whether this policy extends beyond the 2014 solicitations.

more than one-quarter of all applications. Over time, new firm shares of both applications and awards declined (see Figure 4-2).

SBIR PHASE II

The patterns of applications and awards for Phase II are largely driven by Phase I awards because until 2014 only Phase I awardees were permitted to apply for a Phase II award. This summary therefore only highlights areas where results are somewhat unexpected or deserve to be highlighted. A full analysis of Phase II is contained in the Annex at the end of this chapter. Because NASA Phase II data were not available for FY2014 as of March 2015, when the analysis was performed, and because there were no awards in FY2013[6], the most recent Phase II data shown are for FY2012.

During FY2005-2011, the number of Phase II awards declined somewhat on average, but finished in 2012 at about the same level as in 2005. The average may have declined further were it not for the additional funding made available through the American Recovery and Reinvestment Act of 2009

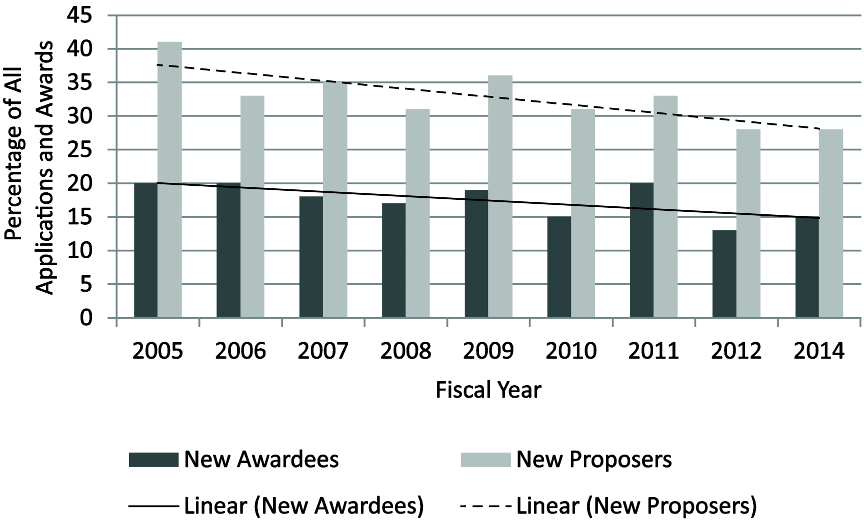

FIGURE 4-2 NASA application and award rates for new participants in the NASA SBIR Phase I program, FY2005-2014.
SOURCE: NASA awards and applications database.

[6]Because of a change in the solicitation dates, there was no competition in FY2013, and, hence, no awards were made in FY2013.

(ARRA)[7] in FY2009-2011. Total funding for Phase II SBIR awards followed a similar pattern because NASA rarely departs from stated per project award amounts.

As shown in Figure 4-3, Phase II success rates (i.e., the share of Phase II applications that resulted in Phase II awards) were quite high during the early part of the period, peaking at 65 percent in 2007. The rates declined sharply to 21 percent in 2010 and recovered to near the overall average success rate of 45 percent in 2012.

As business success in the larger economy is highly variable among companies, it should be no surprise, that companies varied widely in the extent of their success in transitioning Phase I awards into Phase II awards. Among the top 20 recipients of Phase I contracts, two converted more than 90 percent of Phase I into Phase II, while the least successful company converted only 37 percent. All the top 20 recipient-companies comfortably surpassed the new 25 percent benchmark imposed by NASA in response to new requirements in the

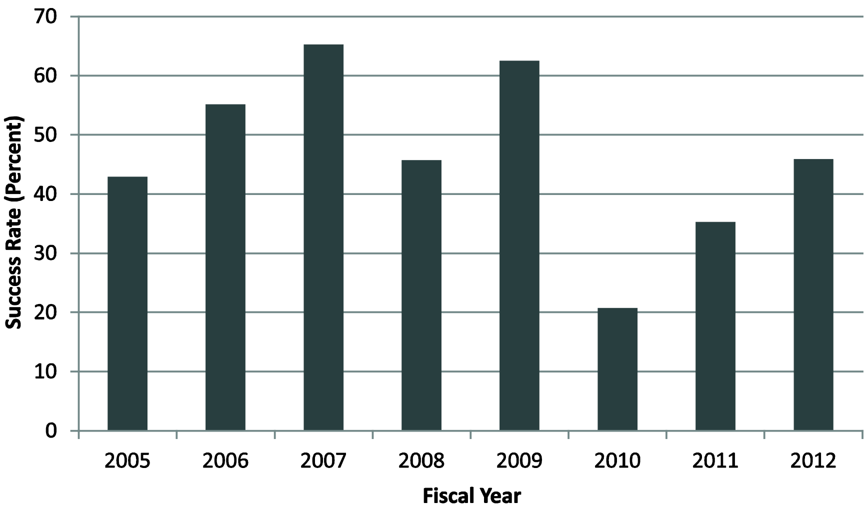

FIGURE 4-3 Success rates for NASA Phase II SBIR applications, FY2005-2012.
NOTE: Phase II success rate reflects the share of Phase II applications that resulted in Phase II awards.
SOURCE: NASA awards and applications database.

[7]The American Recovery and Reinvestment Act of 2009 (ARRA; P.L. 111-4) provided economic stimulus funds, a portion of which was allocated through the SBIR/STTR programs.

reauthorization legislation.[8] The implication is that the 25 percent benchmark does not appear to constrain on companies from receiving multiple NASA contracts.

As a general note, some NASA SBIR/STTR companies may experience confusion between different NASA centers on value or requirement to produce a concept demonstration prototype in Phase I as compared to producing a rigorous technical study/evaluation. This confusion with small business concerns may have effect on number and quality of proposals submitted. Improved communication to potential small business submitters as to its specific preference for given topics can address this issue. A small business concern can learn which centers are prototype-focused and which are not. Better communication would allow for higher success rates for NASA and the small business concern.

ANNEX: AWARDS AND APPLICATIONS FOR THE NASA SBIR PROGRAM, FY2005-2014

This annex addresses the number and distribution of SBIR awards. It reviews Phase I and Phase II awards and discusses each in terms of the distribution of awards by component, state, and company. (Data on the participation of women and minorities is presented in Chapter 6.)

To focus attention on the most recent data, the timeframe for analysis is the 10 years from FY2005 to FY2014 inclusive. In some cases, the data series does not extend beyond FY2012. FY2005 provides the starting point of the data analysis, because pushing the data to earlier years is of only limited additional value for policy assessment purposes.

The analyses in this chapter are based on data provided to the committee by NASA. These data are not always complete, and their quality is sometimes uneven.

Phase I SBIR Awards

The number of SBIR Phase I awards by NASA is presented in Figure 4-4. Award numbers per year were largely stable, as shown by the trend line, but this was in part affected by the years of additional awards under ARRA, especially in FY 2010. Because of a change in the solicitation dates, there was no competition in FY2013.

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[8] As is explained in the section on "Company Eligibility" in Chapter 2 (Program Management), to be eligible for a Phase I award, applicants that have previously won more than 20 Phase I SBIR/STTR awards over the past 5 years must have at least a 25 percent Phase I to Phase II successful transition rate. (Based on interview with Rich Leshner, former NASA program director, January 17, 2014.)

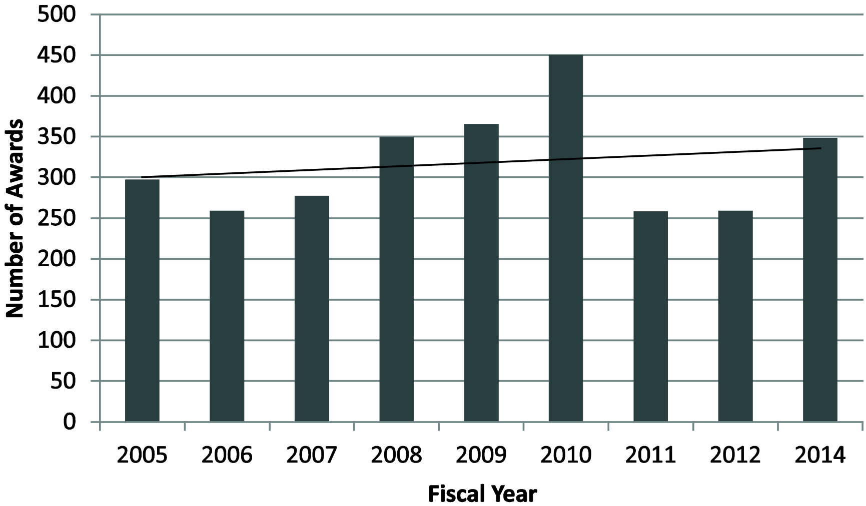

FIGURE 4-4 Phase I SBIR awards at NASA, FY2005-2014.
SOURCE: NASA awards and applications database.

A declining number of Phase I applications and a flat number of awards resulted in a larger share of applications receiving a Phase I award: In FY2014, more than 35 percent of applicants received an award, compared to 15 percent in FY2005. Thirty-five percent is a very high rate, both historically and in comparison with SBIR programs at other agencies.[9]

Funding for NASA SBIR Phase I awards grew steadily from the base year FY2005 to peak at about $45 million in FY2010, drop back to about $30 million in FY2011, and then increase again to $43 million in FY2014. The FY2011 amount reflects ARRA funding, while the FY2014 amount reflects the increase in the size of awards and overall SBIR funding after reauthorization (see Figure 4-5).

Phase I SBIR Applications and Success Rates

Data for Phase I applications at NASA are displayed in Figure 4-6. Overall, the number of applications declined from more than 1,900 in FY2005 to 942 in FY2014. Given that funding increased during that period and that small businesses experience well-known difficulties in raising funds, this trend is somewhat surprising. Application numbers remained relatively constant at about 2,000 during the FY1997-2005 period covered by the preceding study by the

[9]As was noted previously, a restriction on the number of applications per company was believed to have raised the quality, contributing to the higher success rate.

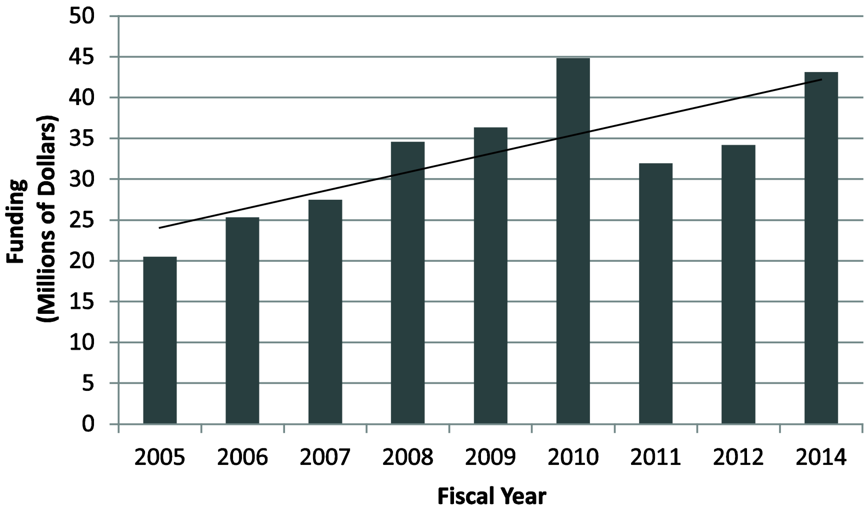

FIGURE 4-5 NASA Phase I SBIR award funding, FY2005-2014.
SOURCE: NASA awards and applications database.

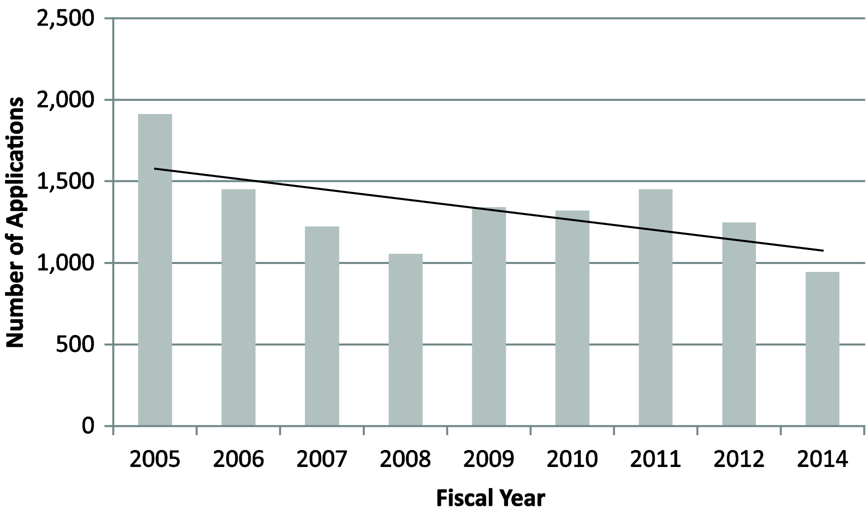

FIGURE 4-6 Phase I SBIR applications at NASA, FY2005-2014.
SOURCE: NASA award and applications database.

Academies.[10] The declining number of applications and growing numbers of awards have driven up success rates (i.e., the share of applications that result in awards). Success rates for Phase I applications are shown in Figure 4-7. If NASA finds a decrease in quality of awarded Phase I projects, it does have internal flexibility to shift money to Phase II awards.

One likely factor contributing to the precipitous decline between 2005 and 2008 in the number of Phase I applications is the limit of 10 applications per company imposed by NASA in FY2007-2008. Other possible factors are NASA's increasing focus on internal mission needs rather than a broader array of technologies, and possible rigid contracting practices, and long funding gaps. However, these possible explanations have not been explored in any depth and are lacking in hard evidence.

Phase I SBIR Awards by State

Several factors can affect the shares of SBIR awards by state, including the overall population of the state, the strength of its science and engineering workforce, and the number of SBIR award applications received from small businesses in a given state. For FY2005-2014, five states collectively received

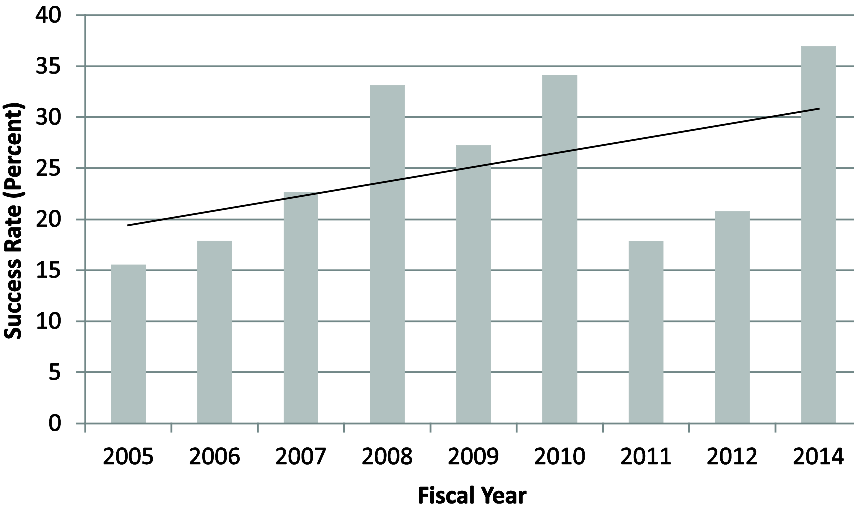

FIGURE 4-7 Success rates for Phase I SBIR applications, FY2005-2014.
NOTE: Phase I success rate reflects the share of Phase I applications that resulted in Phase I awards.
SOURCE: NASA awards and applications database.

[10] National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, p. 43.

51.1 percent of Phase I awards, a very slight increase from the time period analyzed in the previous Academies' report.[11] Conversely, three states (Alaska, Nebraska, and North Dakota) and Puerto Rico received no Phase I award during this period. Massachusetts and Virginia were the two larger states with higher shares of awards than applications, accounting in combination for 19 percent of awards and 16 percent of applications. Table 4-1 shows the distribution of NASA SBIR Phase I awards and applications by state for FY2005-2014.

Given the variation in the distribution of SBIRs across states, it is important to normalize for population and to underscore the scientific and engineering strength of some states and the weakness of others. Table 4-2 shows awards by state per 1 million people. Seven states (Massachusetts, Colorado, Virginia, Maryland, Montana, New Hampshire, and New Mexico) generated at least 35 Phase I awards per 1 million people. Thirty-three states generated fewer than 10 awards per 1 million people; of these, four generated none.

These findings suggests that population alone does not completely predict the distribution of SBIR awards. The GAO has noted that the distribution of SBIR awards tends to follow the general distribution of government science and engineering awards, which in turn tends to follow the distribution of science and engineering talent in the workforce.[12] Using data from the National Science Foundation, we found that the Pearson r score for the percentage of scientists and engineers in the population and the number of NASA SBIR Phase I awards per 1 million people were highly correlated (Pearson r=0.7).[13] By like token, small businesses located in states with NASA Field Centers (or in regions surrounding NASA Field Centers) are likely more aware of the NASA SBIR opportunity and more likely to apply, and this could raise a question of whether NASA is receiving as innovative proposals as it can be.

Another way to evaluate state success in attracting NASA SBIR awards is to examine success rates, which varied substantially (see Table 4-3). NASA data indicate that for FY2005-2014, for states with at least one award, success rates varied from greater than 40 percent in New Hampshire and Louisiana to less than 10 percent in six states. This variability is rooted in the complex differences in state industry focus and the locations of key firms, as well as other potential variables, including the large variability often associated with small numbers where one application and one award means a 100 percent success rate and one application and no award means a 0 percent success rate.

Phase I SBIR Awards by Company

The number of NASA SBIR Phase I awards was not highly concentrated by company. The top 20 companies accounted for 18.4 percent of

[11] Ibid, p. 56.
[12] Government Accountability Office, *Federal Research,* p. 17.
[13] National Science Board, *Science and Engineering Indicators 2014*, Arlington, VA: National Science Foundation, 2014.

NASA SBIR Phase I awards. Table 4-4 summarizes NASA SBIR and STTR Phase I awards for the top 20 awardees during the study period. The top awardee, Creare, received an average of four Phase I awards per year, a number very similar to that of other top winners, CFD Research, Aurora Flight Sciences, and Intelligent Automation.

Phase II SBIR Awards

To a considerable extent, the pattern of NASA SBIR Phase II awards closely follows that for Phase I. This is not surprising because receipt of a Phase I award, until the 2011 reauthorization, has been a prerequisite for receipt of a Phase II award.

Although the overall number of Phase II awards apparently exhibits no substantial long-term trend over the study period (see Figure 4-8), if the additional funding added through ARRA in 2009-2011 is excluded, then the numbers drift down somewhat from an average of 124 awards in FY2005-2007 to 101 in FY2012-2014. The FY2012 figure rebounded from those in FY2010 and FY2011, and it is not yet known if the rebound continued in FY2014, which was the year of the next solicitation.

Funding for Phase II awards fluctuated considerably during the period, even excluding 2009 when ARRA funding contributed to the higher number (see Figure 4-9). NASA sticks closely to the funding limits for individual awards. During the study period, NASA made 26 SBIR non-Phase I awards greater than standard funding ($600,000 until FY2011, $700,000 until 2014, and $750,000 currently).[14] Of these, 22 were made in FY2012, utilizing funds allocated through the 2010 solicitation, which may again reflect the impact of ARRA funding. In addition, in FY2014 NASA introduced a program to add funds for "Select Topics" awards (described in more detail in Chapter 3 [Initiatives]).

Phase II SBIR Applications and Success Rates

If ARRA funding years are excluded, the number of Phase II applications to NASA trended down slightly (see Figure 4-10). Although it is somewhat surprising that applications grew rapidly to meet that additional funding, these applicants were already in the program (with Phase I funding) and were likely to know that additional funding was available (this was, after all, public knowledge at the time). Phase II success rates remained at about 45 percent, except for an unexplained decline in FY2010 (see Figure 4-11).

[14]Awards data show that in FY2011 16 awards were made at approximately $750,000, suggesting that new limits were implemented part way through FY2011.

TABLE 4-1 NASA SBIR Phase I Awards and Applications, FY2005-2014

State	Number of Phase I Awards	Number of Phase I Applications	Percentage of all Phase I Awards	Percentage of all Phase I Applications
AK		1	0.0	0.0
AL	132	450	3.1	2.7
AR	18	77	0.4	0.5
AZ	119	492	2.8	3.0
CA	898	3,460	20.8	20.8
CO	282	1,063	6.5	6.4
CT	99	301	2.3	1.8
DC	1	12	0.0	0.1
DE	20	129	0.5	0.8
FL	107	597	2.5	3.6
GA	27	140	0.6	0.8
HI	2	30	0.0	0.2
IA	8	26	0.2	0.2
ID	10	60	0.2	0.4
IL	74	363	1.7	2.2
IN	29	102	0.7	0.6
KS	7	29	0.2	0.2
KY	11	71	0.3	0.4
LA	8	20	0.2	0.1
MA	483	1,572	11.2	9.4
MD	207	826	4.8	5.0
ME	8	39	0.2	0.2
MI	88	349	2.0	2.1
MN	49	195	1.1	1.2
MO	14	63	0.3	0.4
MS	8	47	0.2	0.3
MT	41	110	1.0	0.7
NC	18	95	0.4	0.6
ND		4	0.0	0.0
NE		9	0.0	0.1
NH	72	179	1.7	1.1
NJ	124	446	2.9	2.7
NM	91	340	2.1	2.0
NV	5	66	0.1	0.4
NY	134	518	3.1	3.1
OH	165	736	3.8	4.4
OK	1	38	0.0	0.2
OR	72	268	1.7	1.6
PA	135	607	3.1	3.6
PR		3	0.0	0.0

State	Number of Phase I Awards	Number of Phase I Applications	Percentage of all Phase I Awards	Percentage of all Phase I Applications
RI	9	36	0.2	0.2
SC	4	23	0.1	0.1
SD	1	6	0.0	0.0
TN	27	108	0.6	0.6
TX	188	813	4.4	4.9
UT	24	102	0.6	0.6
VA	337	1,052	7.8	6.3
VT	5	18	0.1	0.1
WA	82	341	1.9	2.0
WI	50	175	1.2	1.0
WV	8	32	0.2	0.2
WY	10	31	0.2	0.2
Total	4,312	16,670	100.0	100.0

SOURCE: NASA awards and applications database.

TABLE 4-2 NASA SBIR Phase I Awards by State, Normalized for State Population, FY2005-2014

State	Number of Phase I Awards per 1 Million People	State	Number of Phase I Awards per 1 Million People	State	Number of Phase I Awards per 1 Million People
AK	0	MA	73.8	PA	10.6
AL	27.6	MD	35.9	RI	8.6
AR	6.2	ME	6.0	SC	0.9
AZ	18.6	MI	8.9	SD	1.2
CA	24.1	MN	9.2	TN	4.3
CO	56.1	MO	2.3	TX	7.5
CT	27.7	MS	2.7	UT	8.7
DC	0.0	MT	41.4	VA	42.1
DE	22.3	NC	1.9	VT	8.0
FL	5.7	ND	0.0	WA	12.2
GA	2.8	NE	0.0	WI	8.8
HI	1.5	NH	54.7	WV	4.3
IA	2.6	NJ	14.1	WY	17.7
ID	6.4	NM	44.2		
IL	5.8	NV	1.9		
IN	4.5	NY	6.9		
KS	2.5	OH	14.3		
KY	2.5	OK	0.3		
LA	1.8	OR	18.8		

SOURCE: NASA awards and applications database.

TABLE 4-3 NASA SBIR Phase I Success Rates, FY2005-2014

Firm State	Phase I Success Rate (Percent)	Firm State	Phase I Success Rate (Percent)	Firm State	Phase I Success Rate (Percent)
AK	0.0	MA	30.7	PA	22.2
AL	29.3	MD	25.1	PR	0.0
AR	23.4	ME	20.5	RI	25.0
AZ	24.2	MI	25.2	SC	17.4
CA	26.0	MN	25.1	SD	16.7
CO	26.5	MO	22.2	TN	25.0
CT	32.9	MS	17.0	TX	23.1
DC	8.3	MT	37.3	UT	23.5
DE	15.5	NC	18.9	VA	32.0
FL	17.9	ND	0.0	VT	27.8
GA	19.3	NE	0.0	WA	24.0
HI	6.7	NH	40.2	WI	28.6
IA	30.8	NJ	27.8	WV	25.0
ID	16.7	NM	26.8	WY	32.3
IL	20.4	NV	7.6		
IN	28.4	NY	25.9		
KS	24.1	OH	22.4		
KY	15.5	OK	2.6		
LA	40.0	OR	26.9		

NOTE: Phase I success rate reflects the share of Phase I applications that resulted in Phase I awards.
SOURCE: NASA awards and applications database.

TABLE 4-4 Top 20 NASA Phase I SBIR/STTR Award Recipients, FY2005-2014

Company Name	Number of Phase I Awards
Creare	42
CFD Research	40
Aurora Flight Sciences	38
Intelligent Automation	37
Honeybee Robotics	33
NanoSonic	28
Lynntech	27
Orbital Technologies	26
Physical Sciences	25
Physical Optics	24
Busek Company	22
UMPQUA Research Company	22

Company Name	Number of Phase I Awards
Los Gatos Research	21
Pioneer Astronautics	21
TRACLabs	21
Advanced Cooling Technologies	20
Luna Innovations	20
Mosaic ATM	20
TDA Research	20
ZONA Technology	20
Total	527
Percentage of all NASA SBIR and STTR Phase I awards	18.4

NOTE: For the purposes of assessing company involvement, the table includes both SBIR and STTR awards.
SOURCE: NASA awards and applications database.

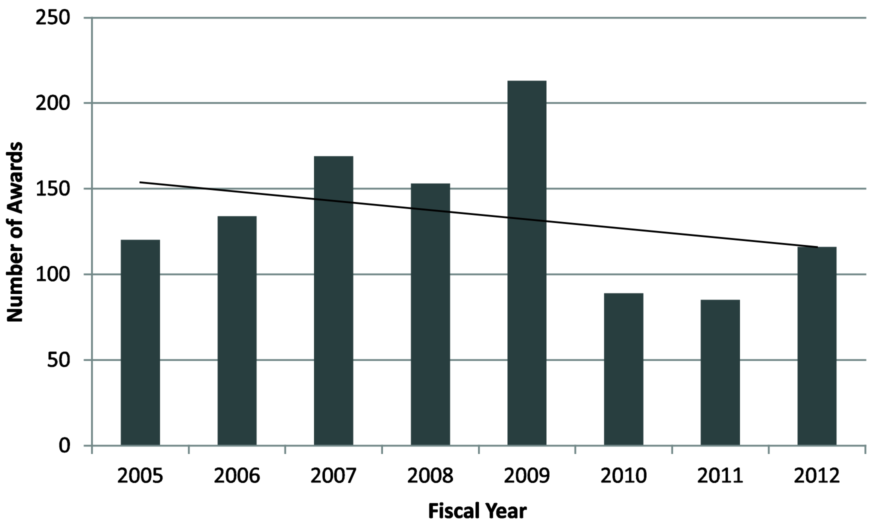

FIGURE 4-8 Number of NASA SBIR Phase II awards, FY2005-2012.
NOTE: Data on NASA Phase II awards for 2014 were not available as of March 16, 2015, and because of a change in the solicitation date, no awards were made in 2013.
SOURCE: NASA awards and applications database.

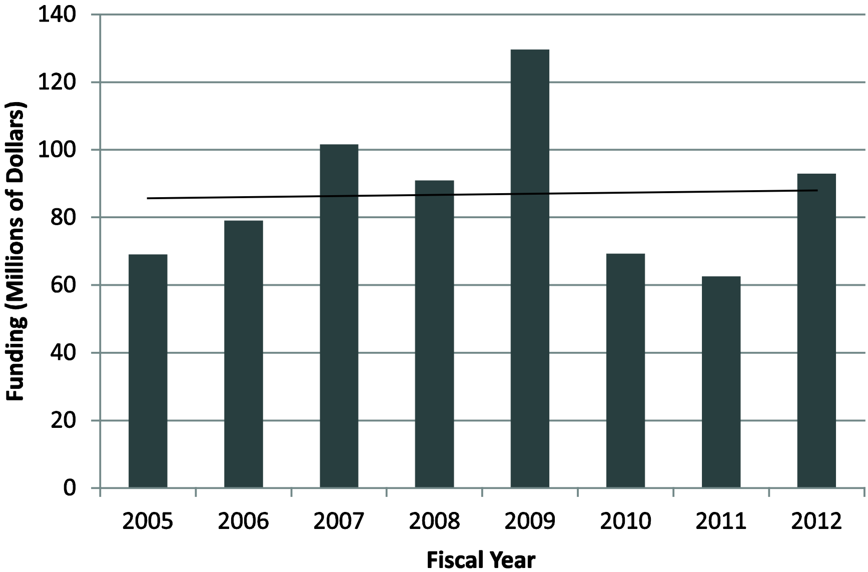

FIGURE 4-9 NASA SBIR Phase II funding, FY2005-2012.
SOURCE: NASA awards and applications database.

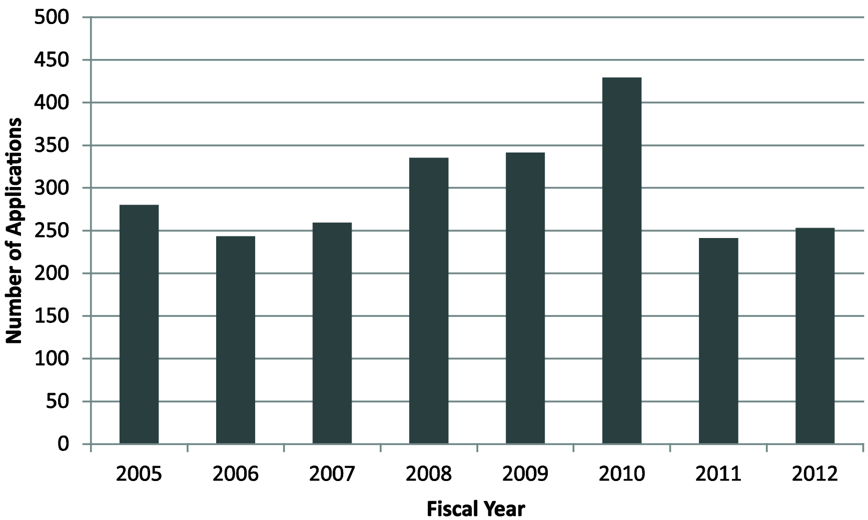

FIGURE 4-10 NASA SBIR Phase II applications, FY2005-2012.
SOURCE: NASA awards and applications database.

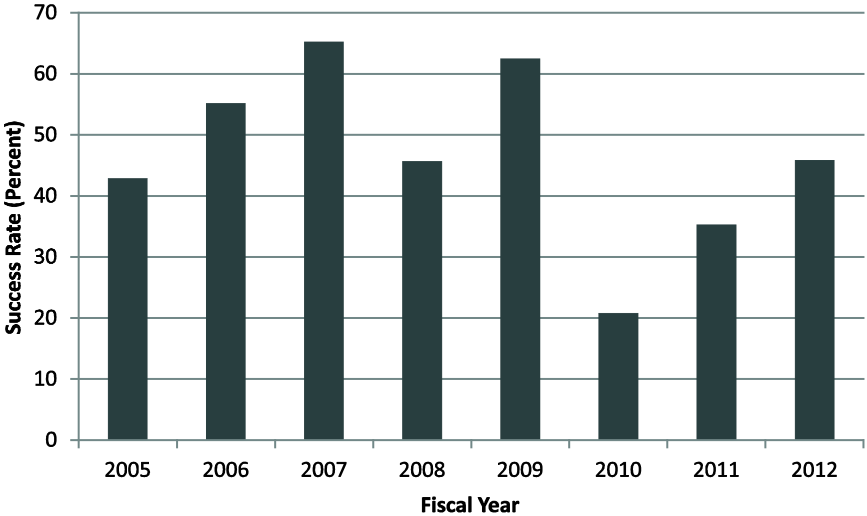

FIGURE 4-11 Success rates for NASA SBIR Phase II applications, FY2005-2012.
NOTE: Success rate reflects the share of Phase II applications that resulted in Phase II awards.
SOURCE: NASA awards and applications database.

Phase II SBIR Awards by State

As with Phase I awards, companies in some states had a consistently stronger record in receiving Phase II awards. Some states generated no applications, in part because a Phase I award was required for Phase II application and these states received no Phase I awards. For other states, the data reveal considerable differences in the quality of Phase II applications—overall 46 percent of Phase II applications were funded. Tennessee's success rate was 77 percent (10 out of 13 applications) (see Table 4-5).

Phase II Awards by Company

Given that receipt of a Phase I award is a requirement for receipt of a Phase II award, it is not surprising to see many of the same company names on the list of top 25 Phase II awardees (see Table 4-6). What is quite striking, however, is the extent to which these companies' Phase II success does not rely solely on the volume of Phase I awards that they win: for most of the top 20 awardees, the share of Phase I awards that are transitioned to Phase II (i.e., the

TABLE 4-5 NASA Phase II SBIR Applications and Awards, FY2006-2012

State	Number of Phase II Applications	Number of Phase II Awards	Percent of all Phase II Applications	Percent of all Phase II Awards
AK	0	0	0.0	0.0
AL	67	23	2.5	1.9
AR	17	6	0.6	0.5
AZ	77	41	2.9	3.4
CA	525	261	20.0	21.6
CO	178	75	6.8	6.2
CT	65	26	2.5	2.2
DC	0	0	0.0	0.0
DE	14	6	0.5	0.5
FL	63	29	2.4	2.4
GA	16	4	0.6	0.3
HI	1	0	0.0	0.0
IA	6	4	0.2	0.3
ID	7	3	0.3	0.2
IL	56	25	2.1	2.1
IN	17	8	0.6	0.7
KS	5	2	0.2	0.2
KY	8	3	0.3	0.2
LA	4	0	0.2	0.0
MA	281	135	10.7	11.2
MD	127	50	4.8	4.1
ME	8	3	0.3	0.2
MI	61	24	2.3	2.0
MN	33	10	1.3	0.8
MO	7	2	0.3	0.2
MS	4	1	0.2	0.1
MT	30	19	1.1	1.6
NC	11	5	0.4	0.4
ND	0	0	0.0	0.0
NE	0	0	0.0	0.0
NH	44	28	1.7	2.3
NJ	80	37	3.0	3.1
NM	53	22	2.0	1.8
NV	2	1	0.1	0.1
NY	89	41	3.4	3.4
OH	97	37	3.7	3.1

State	Number of Phase II Applications	Number of Phase II Awards	Percent of all Phase II Applications	Percent of all Phase II Awards
OK	0	0	0.0	0.0
OR	43	20	1.6	1.7
PA	85	48	3.2	4.0
PR	0	0	0.0	0.0
RI	6	1	0.2	0.1
SC	2	0	0.1	0.0
SD	1	0	0.0	0.0
TN	13	10	0.5	0.8
TX	112	46	4.3	3.8
UT	9	4	0.3	0.3
VA	214	105	8.1	8.7
VT	1	1	0.0	0.1
WA	53	21	2.0	1.7
WI	24	15	0.9	1.2
WV	6	3	0.2	0.2
WY	7	3	0.3	0.2
Total	2,629	1,208	100.0	100.0

SOURCE: NASA awards and applications database.

conversion rate[15]) is higher than the average success rates for all awards and reaches more than 90 percent for Paragon Space Development Corporation and Busek. CFD Research had the lowest conversion rate at 37.5 percent, but even this rate is comfortably above new benchmarks imposed as a result of reauthorization.

Overall, the top 20 winners (i.e., the companies with the most Phase II awards) accounted for 25.6 percent of all awards. Their Phase II share was higher than their Phase I share (18.4 percent) because top 20 winners generated Phase I projects that were converted to Phase II at a slightly higher than average rate.

New Participants in the NASA SBIR Program

NASA maintains data on the participation of new firms in the program, defined as firms that have not proposed or do not own awards from the NASA SBIR program. Over time, new firm shares of both applications and awards declined, which suggests substantial value in the relationships that previous winners established over time. It may also suggest that the NASA SBIR program is exhausting the supply of potential new program applicants.

[15]The conversion rate is the number of Phase II awards received by a company expressed as a percentage of the number of Phase I awards received by that company.

TABLE 4-6 NASA Top 25 Phase II Companies (plus ties), FY2005-2012: Awards and Conversion Rates

Firm Name	Number of Phase I Awards	Number of Phase II Awards	Phase I – Phase II Conversion Rate (percent)
Creare	42	27	64.3
Intelligent Automation	37	21	56.8
Busek Company	22	20	90.9
Orbital Technologies	26	18	69.2
Aurora Flight Sciences	38	17	44.7
Los Gatos Research	21	16	76.2
CFD Research	40	15	37.5
Honeybee Robotics	33	15	45.5
TRACLabs	21	13	61.9
ADVR	19	12	63.2
Fibertek	18	12	66.7
Lynntech	27	11	40.7
Advanced Cooling Technologies	20	11	55.0
Optimal Synthesis	18	11	61.1
Deployable Space Systems	17	11	64.7
Barron Associates	15	11	73.3
Physical Sciences	25	10	40.0
Physical Optics	24	10	41.7
Luna Innovations	20	10	50.0
ZONA Technology	20	10	50.0
Plasma Processes	19	10	52.6
Combustion Research and Flow Technology	18	10	55.6
Giner	18	10	55.6
Paragon Space Development	11	10	90.9
Total	569	321	56.4

NOTE: The conversion rate is the number of Phase II awards received by a company expressed as a percentage of the number of Phase I awards received by that company.
SOURCE: NASA awards and applications database.

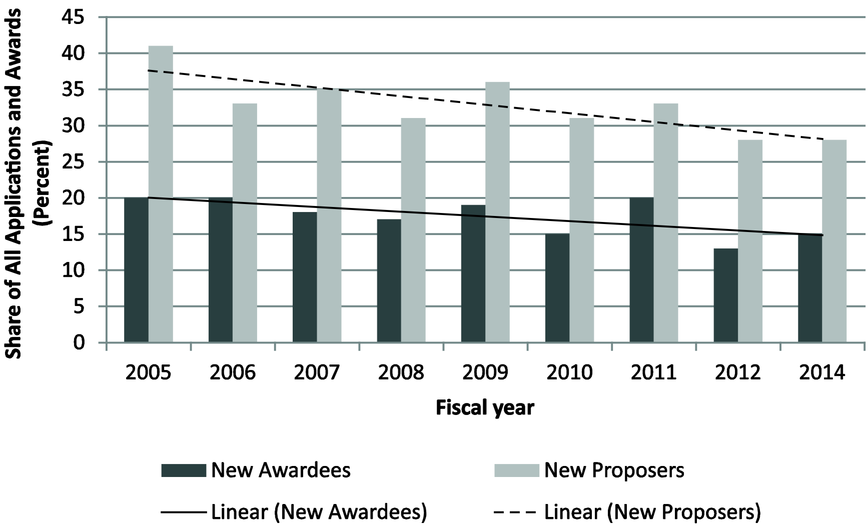

FIGURE 4-12 NASA application and award rates for new participants in the SBIR Phase I program.
SOURCE: NASA awards and applications database.

5

Quantitative Outcomes

As was noted in Chapter 1 (Introduction), Congress mandated four goals for the Small Business Innovation Research (SBIR) 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.[1] This chapter provides an analysis of program outcomes related to the first, second and fourth goals: stimulating technological innovation, using small business to meet Federal research and development needs, and increasing private-sector commercialization of federally funded research.[2] The approach analyzes outcomes as revealed primarily by the performance of National Aeronautics and Space Administration (NASA) Phase II awards from fiscal year (FY) 1998 to FY2007 (the period covered by the 2011 Survey). The focus is on Phase II awards rather than Phase I awards because Phase II-funded projects are expected to have business plans and to have progressed toward commercialization.

Although NASA was among the earliest agencies to adopt a fully electronic submission and project management system, the agency has not led the way on tracking outcomes. NASA has recently begun to track outcomes using firm-completed surveys as part of its Electronic Handbook, but these records currently cover less than one-half of the awards made from FY2003-2012 (596 of 1,362 Phase II awards). Although some highly visible anecdotes have emerged about SBIR technologies being used to great effect by NASA—for example, several SBIR technologies were used with the Mars Rover—NASA does not have systematic data to describe the transition of SBIR

[1]Small Business Innovation Development Act of 1982, P.L. 97-219, July 22, 1982.
[2]The second goal of using small businesses to meet federal research and development needs was also discussed to some extent in Chapter 2 (Program Management). The third goal of fostering the participation of women and minorities is the focus of Chapter 6.

technologies within NASA into the Mission Directorates and then into space or other agency applications, nor does it have systematic data on the take-up of SBIR-funded technologies outside NASA.

Therefore, the analysis of outcomes in this report is based primarily on the 2011 Survey, for the period FY1998-2007. The survey methodology is described in detail in Appendix A and a description of the survey response rate and non-respondent bias[3] is provided in Box 5-1. The overall target population for the survey reported in this chapter is NASA Phase II awards made FY1998-2007,[4] and most response data is reported at the project-level. Some survey questions, however, collect company-level information (such as number of employees). In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged. Tables and figures with company-level data are marked as reporting the number and percentage of responding companies. Not all survey recipients completed every survey question; as a result, the number of respondents and the number of responding companies varies.[5]

The survey data have limitations that signal the need for caution. The response rate for NASA was lower than for some other agencies,[6] and the number of responses—although sufficient to provide useful data—was also lower than for other agencies. In addition, the 2011 Survey inevitably captured outcomes at a specific point in time: many projects had not yet generated maximum commercial returns—some were just entering their commercialization phase, while other more mature projects may not generate revenues for many years to come. These caveats are important to bear in mind while reviewing the data in this chapter. As a result, the study findings reported in Chapter 8 are based on not only the 2011 Survey data, but also the case studies and interviews presented in Chapter 7 (Insights).[7]

COUNTERFACTUALS

It is always difficult to tightly determine the impact of a given SBIR award. Many factors affect the success and failure of companies and projects, and it is often difficult to determine whether a specific factor was a

[3]Multiple sources of bias in survey response are discussed in Box A-1 of Appendix A.
[4]See Box 5-1 and Appendix A for a description of filters applied to the starting population.
[5]Not all questions were applicable to all respondents, depending on their answers to particular questions. For example, questions 36 and 37, which address sales outcomes, were directed only to respondents reporting sales in response to question 35. In other cases, respondents did not answer particular questions. The reasons for these non-responses are unknown.
[6]The reason for the lower response rate is not known. See Box 5-1 for a discussion of potential non-respondent bias in the survey.
[7]See Appendix A for a detailed description of the survey methodology. The 2011 Survey questionnaire is reproduced in Appendix C.

BOX 5-1
Survey Response Rate and Non-Respondent Bias

As noted in the introduction to this report, and described in detail in Appendix A, the committee recognizes the limitations of the survey effort underlying the data presented in this chapter.

The Academies' 2011 Survey was sent to every principal investigator (PI) who won a Phase II award from NASA, FY1998-2007 (not to the registered company point of contact (POC) for each company). Each PI was asked to complete a maximum of 2 questionnaires, which as a result excludes some awards from the survey.

The preliminary population was developed by taking the original set of SBIR Phase II awards made by NASA during the study period and eliminating on a random basis awards to PIs who received more than two awards (to limit the burden on respondents).The resulting preliminary population was 1,131 awards. PIs for 641 of these awards were determined to be not contactable at the SBIR company listed in the NASA awards database. The remaining 490 awards constitute the effective population for this study. From this effective population, we received 179 responses. As a result, the response rate in relation to the preliminary population was 15.8 percent and in relation to the effective population was 36.5 percent.

The committee acknowledges that because it was not possible to collect information from non-respondent PIs, and because the agencies have minimal information about PIs which could be used to track potential non-respondent biases, we can conclude only that the data are likely to be biased toward PIs who are still working at companies that are still in business as corporate entities (i.e. have not failed or been acquired).

In addition, we note that some questions focused on company-level activities (e.g. employment, or company acquisitions and mergers) are best addressed by developing company-level responses. Accordingly, for these questions (which are clearly identified in the text), we use an average of all the responses received for a given company.

The committee suggests that, where feasible, future assessments of the SBIR program include comparisons of non-awardees, such as in matched samples (Azouley et al., 2014) or regression discontinuity analysis (Howell, 2015).[a] In addition, future assessments should document the root cause of non-responsiveness. For example, determining whether the company is still in business even if the PI is no longer with the firm could provide useful evidence about the effectiveness of the SBIR award.

[a]Pierre Azoulay, Toby Stuart and Yanbo Wang, Matthew: Effect or Fable? *Management Science,* 60(1), pp. 92-109, 2014. Sabrina Howell, "DOE SBIR Evaluation: Impact of Small Grants on Subsequent Venture Capital Investment, Patenting, and Achieving Revenue," Paper presented at the National Academy of Sciences, Engineering, and Medicine Workshop on the Economics of Entrepreneurship, June 29, 2015.

necessary condition for success. Worse still, the large number of factors and the multiple paths to success and failure mean that it is unusual to be able to state with confidence that a particular intervention—in this case an SBIR award—constitutes a *sufficient* condition for a project's success.

Still, it is worth considering what would have occurred absent SBIR funding from the perspective of those most likely to have detailed knowledge and understanding of their particular projects: the principal investigators (PIs). Accordingly, the 2011 Survey asked a series of questions focused on the likely effect of the absence of SBIR funding. Of course, asking recipients about the impact of funding raises possible conflicts of interest, so results should be interpreted with some caution. However, these are awards some years in the past now, and many respondents no longer apply for SBIR funding for a variety of reasons.

PROJECT GO-AHEAD ABSENT SBIR FUNDING

One approach has been to ask recipients for their own views on the program's impact on their project or company. In particular, the survey asked respondents whether the project would have been undertaken absent receipt of the SBIR award and whether the scope and timing would have been affected. Responses are summarized in Table 5-1. Seven percent of the respondents indicated that the project probably or definitely would have proceeded without program funding. In contrast, 75 percent thought the project probably or definitely would not have proceeded absent SBIR funding. Nineteen percent of respondents were uncertain.

These data have interesting wider implications for debates about early-stage funding: they suggest a weakness in the "crowding out" hypothesis, as it would appear that awardees at least—presumably those with the closest knowledge of funding prospects for the project—overwhelmingly believed it to be unlikely that alternative funding would be found.

TABLE 5-1 Project Undertaken in the Absence of this SBIR Award

Question: In your opinion, in the absence of this SBIR award, would the company have undertaken this project?	Percentage of Respondents	Number of Respondents
Definitely yes	2	3
Probably yes	5	9
Uncertain	19	34
Probably not	41	73
Definitely not	34	60
Total	100	179

SOURCE: 2011 Survey, Question 24.

The small number of respondents (12) who believed the project might have proceeded without SBIR funding were asked additional questions about the impact on project scope, duration, and timelines. They indicated the following:

- Project scope would have been narrower (67 percent)
- Project would have been substantially delayed (75 percent)
- Project would have taken longer (75 percent)
- Project would not have hit necessary milestones (75 percent)

Overall, these views indicate that SBIR funding was important not only for the go/no-go decision but also for the eventual shape and indeed likely impact of the project. Delay in bringing projects to conclusion—and hence to the point of potential market entry—can have a disastrous effect, as the window for market entry can be a narrow one.

CHAPTER OUTLINE

The remainder of this chapter is broken into two sections: (1) Quantitative Survey Evidence that NASA Increased Commercialization and (2) Quantitative Survey Evidence that NASA Stimulated Technological Innovation. Commercialization is discussed first, where it is treated as inclusive of both technology infusion into NASA (i.e., meeting federal R&D needs, which was also treated to some extent in Chapter 2) and private-sector commercialization. These sections are preceded by a chapter overview.

Two annexes to this chapter, contained in appendixes F and G of this report, offer supplemental data. Appendix F contains a range of 2011 Survey data on SBIR effects on companies that is not reported in this chapter. Appendix G provides data from the Department of Defense on NASA SBIR awards.

OVERVIEW

Increasing Commercialization

Each agency has its own priorities for the SBIR program, and SBIR-supported technologies can be infused into agency programs or commercialized in the private sector or both. At NASA, the overwhelming emphasis has been on the adoption of SBIR-funded technologies for use within the agency in support of the agency mission, yet not all SBIR funding goes to areas in which NASA has acquisition activity, such as aeronautics, and evidence of commercialization outside NASA was also found as part of the committee's research as noted below.

NASA contracts for SBIR-funded technologies tend to be relatively small. It appears that small companies whose mission is to work on space technologies for NASA are likely to remain small, and their projects are unlikely to generate huge commercial outcomes. NASA SBIR companies responding to the 2011 Survey had a median of 10 employees at the time the surveyed award was made and a median of 15 employees at the time of the survey. In some cases, spinoffs from the mission technologies led to contracts and successes outside NASA. Forty-six percent of survey respondents reported some sales, and an additional 26 percent reported that they anticipate future sales. At the same time, the scale of commercialization was limited: one percent of respondents reported project-related sales of over one million dollars.

Just over one-third of projects with sales reported sales to domestic private-sector customers. Only 17 percent of respondents reported that their products were in use at NASA. Almost as many reported use at the Department of Defense (DoD). About 9 percent reported sales to export customers, and 2 percent report sales to NASA prime contractors.

Survey results suggest that subsequent investment in an SBIR project generates potential commercial value even if the project has not yet reached the market. Sixty-five percent of respondents reported additional investment funding. Non-SBIR federal funding was overwhelmingly the most likely source of additional funding (71 percent). No other source was used by more than 10 percent of respondents. About 2 percent reported U.S. venture capital (VC) funding.

Stimulating Technological Innovation

Regarding the first goal, there is ample quantitative evidence that NASA is using its SBIR program to stimulate technology development, enhance science and technology, and add to the scientific knowledge base. Among the evidence are data showing linkage of survey respondents to a university (nearly one-third). Among respondents: 21 percent reported that a research university or college was a subcontractor; 15 percent reported that university faculty worked on the project (not as Principal Investigator [PI]); and 14 percent reported that graduate students worked on the project. Seventy-seven different universities were identified as project partners. Sixty-three percent of respondents reported at least one academic founder, and 29 percent of responding companies reported that the most recent prior employment of the founder was at a university.

Survey results show that SBIR projects generate substantial knowledge-based outputs such as patents and peer-reviewed publications—widely used metrics of the creation and dissemination of technical knowledge. Forty-five percent of responses reported receipt of at least one patent related to the surveyed project. Fourteen percent of responding companies reported receipt of 10 or more patents for all SBIR-funded technologies.[8] Eighty-two percent of respondents reported at least one peer-reviewed publication resulting from the

[8]N=64 companies.

surveyed project. Thirty-one percent reported more than three peer-reviewed publications.

Technological innovation can be stimulated by fostering innovative companies, thereby expanding the nation's capacity for innovation. Forty percent of respondents reported that the company was founded entirely or in part because of the SBIR program (not necessarily just the NASA SBIR program). The receipt of the award targeted by the survey had a "transformative" effect according to 25 percent of respondents and a "substantial positive long term effect" according to 56 percent of respondents.

At the same time, survey results show that NASA program participants in general are not overly dependent on SBIR awards. More than one-quarter of respondents reported that they received no SBIR funding during the most recent fiscal year. Less than one-quarter reported that SBIR accounted for more than 50 percent of company revenues during the most recent fiscal year.

QUANTITATIVE SURVEY EVIDENCE THAT NASA INCREASED COMMERCIALIZATION

This section presents the quantitative survey results related to the success of the NASA SBIR program in meeting its commercialization-related goals, both through the take-up of technology by NASA and commercialization outside NASA. Commercialization is among the more measurable outcomes of the SBIR program and has become a primary benchmark for program performance. [9]

The priority of the NASA SBIR program is to serve the agency's mission by providing technology not otherwise available for use by the agency. Sales to commercial non-agency buyers are considered to be an important but secondary goal from the perspective of NASA.[10] Although similar to DoD in this respect, the program's impact on quantitative outcomes is different because NASA represents a much smaller market than DoD for SBIR outputs, making the opportunities to generate sales to NASA fewer and on a much smaller scale.

Therefore, the structure of the program itself limits the commercial opportunities for program participants. On the one hand, the program is explicitly designed to provide tools and capabilities for use by NASA; on the other hand, NASA's needs for some technologies are of insufficient scale to provide a viable and sustainable commercial market for those same tools and capabilities.[11]Moreover, the time from technology development in SBIR to

[9]The focus on commercialization, however, should not be allowed to obscure the requirement that the program meet all four congressionally mandated objectives.

[10]This perspective is drawn from numerous discussions with agency program managers, Center SBIR directors, and other agency staff.

[11]Yet it is possible to overstate the uniqueness of NASA relative to other generators of research. While many NASA SBIR projects are in technical domains – e.g., hypersonic vehicles, scramjets, in-situ use of lunar or Martian materials – for which related commercial markets may have not emerged (and may never emerge), many others – e.g., project management software, sensors, heat

eventual acquisition for a program may span years, a decade, or longer, presenting further challenges to small businesses and few market opportunities. That said, SBIR program participants at NASA are small for-profit companies (as for other agencies), and they need to proceed in ways that provide a sustainable path forward. The extent to which they achieve this is the subject of this section.

Defining "Commercialization"

Several important conceptual challenges emerge when seeking to define "commercialization" for the purposes of the SBIR program. Like many apparently simple concepts, commercialization becomes progressively more difficult and complex as it is subjected to further scrutiny.[12] For example:

- Should commercialization include just sales or other kinds of revenue, such as licensing fees and funding for further development?
- What is the appropriate benchmark for sales? Is it any sales whatsoever, sufficient sales to cover the costs of awards, sales that lead to breaking even on a project, or sales that reflect a commercial level of success and viability? The latter at least would likely be different for each project in each company.
- Should commercialization include license fees and sales by licensees, which may be many multiples of the sales by the licensors?
- Should commercialization metrics focus only on formally recognized Phase III contracts,[13] or should they more widely cover follow-on sales and development activities even when not formally recognized as Phase III?

NASA-supported technologies and program have long development cycles (see Box 5-2). For the purposes of this study, the committee deployed a broad net to capture a range of data. Once acquired, these data were analyzed in a variety of ways to provide insights into this complex topic.[14]

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and energy management systems, aeronautics, unmanned systems, processing and inspection of composite materials, etc. – have markets outside of NASA programs.

[12]Measurement of commercialization also raises questions about time needed to commercialize new technologies. For a discussion of this "commercialization lag," see Box A-1 in Appendix A. As noted separately in Appendix A, limiting the 2011 Survey to Phase II awards from no later than FY2007 allowed two years for completion of the Phase II awards and an additional two years for commercialization, and this timeframe was consistent with the 2005 Survey.

[13]"Phase III" is in the context of DoD a technical term for contracts that are officially recognized as following from an SBIR or Small Business Technology Transfer (STTR) Phase II award. Not all follow-on contracts are so recorded.

[14]For an overview of the commercialization metrics and survey used in this study, see Appendix A (Methodology).

Sales and Other Revenues

Perhaps the most used metrics for assessing commercial outcomes for SBIR-type programs are revenues and licensing fees. Although we are cautious about the overuse of these metrics—which the committee has acknowledged by using a wide range of metrics in the current assessment—sales and licensing revenues remain important considerations.

Reaching the Market

The first survey question in this area concerns reaching the market: Did the project generate sales, and if not, are sales expected? The second part of this question is necessary given the long life cycle of some projects. Responses are summarized in Table 5-2. Forty-six percent of respondents reported some sales, and 26 percent expected sales in the future. Although the percentage reporting sales remained flat from the 2005 Survey to the 2011 Survey, which itself is notable given the economic downturn that occurred, the percentage expecting sales in the future increased from 14 percent in 2005 to 26 percent in 2011.

BOX 5-2
Development Cycles of NASA-supported Technologies and Programs

The NASA program needs are often highly specific and are characterized by long development cycles. These can pose a challenge to small innovative companies that seek to integrate their technology with the execution of the NASA project.

- Long Lifecycles: NASA projects often have extremely long lifecycles making the utilization of technologies developed by small companies with limited funds and short horizons under the SBIR program a challenge.
- Limited Commercial Application: NASA's needs and goals often do not have a direct relation to products or technologies with broader potential in commercial markets. Moreover, applications of NASA technologies typically require significant additional development and modifications to be successful in commercial markets.

Of course, even tightly targeted mission-oriented programs can and do produce technologies with sometimes significant non-NASA market potential. In the main, however, these factors do impact the management of the NASA SBIR program and the manner and quality of its success metrics.

TABLE 5-2 NASA SBIR Sales and Licensing Revenues Reported by 2011 Survey Respondents

Sales Status for the Surveyed Project	Percentage of Respondents		Number of Respondents	
No sales to date	54		97	
No sales to date, nor are sales expected.		*28*		*50*
No sales to date, but sales are expected.		*26*		*47*
Any sales to date	46		82	
Sales of product(s)		*35*		*63*
Sales of process(es)		*3*		*6*
Sales of services(s)		*17*		*30*
Other sales (e.g., rights to technology, licensing, etc.)		*3*		*6*
Total	100		179	

NOTE: Respondents could report multiple different types of sales for a single project, so the types of sales do not sum to "Any sales to date."
SOURCE: 2011 Survey, Question 35.

Amount of Sales and Licensing Revenues

The percentage of projects reaching the market is an important metric, but it is not a sufficient determinant of success. It is also important to understand the distribution of sales. Of the 179 responses to the survey, 80 reported sales. The 80 respondents who reported sales to also reported the amount of sales, grouped into tiers. These data are summarized in Table 5-3. Most sales are at the lower end of the scale: 54 percent or respondents reported less than $500,000. Only one percent reported sales of at least $10 million, while about four percent reported sales of $5 million to <$10 million. Overall, 33 percent reported sales of at least $1 million. This compares with 18 percent from the 2005 Survey, which suggests that the scale of commercialization is growing at NASA, although due to the low response rate, the data must be considered with caution.

Markets by Sector

For those projects with sales, the survey asked respondents about the market sectors in which sales were made. As shown in Table 5-4, respondents reported an average of 19 percent of project sales to NASA or NASA prime contractors. But a closer look at the data, reveals that only an average of 2 percent of sales were to a NASA prime contractor. Given that most core NASA programs have a significant share of work performed by prime contractors, this low percentage is deserving of attention if SBIR programs are going to play a larger role in meeting NASA core program needs. As noted in Chapter 2, while nearly three-quarters of survey respondents indicated that the assigned COTR

TABLE 5-3 Distribution of Total Sales Dollars, by Range, Reported by 2011 Survey Respondents Reporting Sales Greater than Zero Dollars

Total Sales	Percentage of Respondents that Reported Sales	Number of Respondents
Some sales under $100,000	28	22
$100,000-$499,999	26	21
$500,000-$999,999	14	11
$1,000,000-$4,999,999	28	22
$5,000,000-$9,999,999	4	3
$10,000,000-$19,999,999	1	1
$20,000,000-$49,999,999	0	0
$50,000,000 or more	0	0
Total	100	80

NOTE: This question was directed only to those respondents reporting sales in response to 2011 Survey question 35.
SOURCE: 2011 Survey, Question 36 B1.

was either quite or extremely knowledgeable about the SBIR program, over one-half of respondents gave a low rating of COTR assistance in finding market opportunities (1 or 2 on a 5-point scale), and 58 percent indicated that their COTR was either not very helpful or not at all helpful in connecting the firm with sources of Phase III funding.[15]

The leading market overall, as shown by Table 5-4, was the domestic private sector (35 percent), followed by DoD and its contractors (24 percent). Nine percent were exports. These results suggest strong crossover between the NASA and DoD market sectors and provide further evidence of the limited market available within NASA, even though take-up within NASA is a primary objective of the NASA SBIR program.

Employment

As with prior surveys, 2011 Survey respondents were asked both about the size of the company at the time of the award and the current size, in terms of number of employees.

The data in Table 5-5 show that, at the time of the award, NASA SBIR Phase II awardees were in general far below the 500 employee limit defining a small company for Small Business Administration (SBA) purposes. Nearly one-third (30 percent) of companies reported fewer than 5 employees; overall, about two-thirds reported fewer than 20 employees at the time of award, up slightly from the 2005 Survey. The number of companies with 100 or more employees

[15]See section on "Working with the Contracting Officer Technical Representative," especially tables 2-8 and 2-9, in Chapter 2: Program Management and 2011 Survey questions 49, 50, and 52 in Appendix C.

decreased from 13.6 percent in 2005 to 7 percent in 2011. The mean and median numbers of employees were 26 and 10, respectively.

TABLE 5-4 Average Percentage of Project Sales by Market Sector, Reported by 2011 Survey Respondents

Market Sector	Mean Value (Percent) Reported by Respondents that Reported Sales
Domestic private sector	35
NASA	17
Department of Defense (DoD)	14
Export markets	9
Prime contractors for DoD	10
Other federal agencies	4
Prime contractor for NASA	2
State or local governments	1
Other (Specify)	8
Total	100

NOTE: Number of respondents = 82. This question was directed only to those respondents reporting sales in response to 2011 Survey question 35. For this question, each respondent reported a percentage distribution. The values above are calculated by deriving the mean value for all the responses received for each category.
SOURCE: 2011 Survey, Question 37.

TABLE 5-5 Number of Company Employees at Time of Award and at Time of Survey, Reported by 2011 Survey Responding Companies

	At Time of Award		At Time of Survey	
Number of Employees	Percentage of Responding Companies	Number of Responding Companies	Percentage of Responding Companies	Number of Responding Companies
Under 5	30	23	24	18
5 to 9	18	14	12	9
10 to 19	19	15	19	14
20 to 49	20	15	23	17
50 to 99	6	5	11	9
100 or more	7	5	11	8
Total	100	77	100	75
Mean	26		46	
Median	10		15	

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged.
SOURCE: 2011 Survey, Questions 18A and 18B.

Respondents also provided the current number of employees (at the time of the survey). Although the results report information from surviving companies, the comparisons are useful. Table 5-5 shows that the smallest firms accounted for the largest percentage of awards, with 24 percent of companies having fewer than five employees, a decrease of 6 percentage points from the time of the award. These results indicate that one-fifth of the smallest Phase II companies grew out of this category (or ceased operations). Median employment grew from 10 to 15. The percentage of companies with 100 or more employees increased from 7 percent at the time of award to 11 percent currently, while the percentage of companies with fewer than 20 employees decreased from 67 percent to 55 percent. This distribution is broadly similar to that drawn from the 2005 Survey, except for the percentage of larger firms, defined as 100 or more employees (22 percent in 2005 compared to 11 percent in 2011) and suggests that Phase II awards are associated with increasing firm size.

Further Investment

The ability of SBIR projects and companies to attract further investment has traditionally been a defining metric for SBIR outcomes.[16] Sixty-five percent of the respondents had received additional investment,[17] an increase from 52 percent in the 2005 Survey.

As with prior surveys, the amount of additional investment is substantially skewed. Table 5-6 summarizes responses from the 50 respondents who reported receipt of additional investment from non-SBIR federal sources. In most cases, the amount of extra investment was quite modest: 64 percent of respondents reported additional funds of less than $500,000, while only two percent of respondents reported additional funds of $50 million or more.

Respondents also reported the sources of additional investments. The funding distribution was dominated by federal non-SBIR sources. Consistent with earlier evidence of strong commercial markets for both NASA and DoD, 71 percent of the average (mean) additional investment of $1.5 million came from federal non-SBIR sources. The dependence on federal non-SBIR funding increased from 2005, when the percentage was 51 percent (see Table 5-7). Other sources individually accounted for less than 10 percent of additional investment, and U.S. venture funding accounted for about 2 percent.

Company-level Commercialization through Mergers and Acquisitions

SBIR companies sometimes commercialize their technology through mergers or other company-level activities. As shown in Table 5-8, 16 percent of responding companies reported that their company had spun off one or more

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[16] See National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, 2008.
[17] 2011 Survey, Question 33.

TABLE 5-6 Additional Investment by Amount to Surveyed Projects for which Additional Funds were Received, Reported by 2011 Survey Respondents

Amount of Additional Investment	Percentage of Respondents that Reported Additional Project Investment	Number of Respondents
Some investment under $100,000	24	12
$100,000-$499,999	40	20
$500,000-$999,999	12	6
$1,000,000-$4,999,999	20	10
$5,000,000-$9,999,999	2	1
$10,000,000-$19,999,999	0	0
$20,000,000-$49,999,999	0	0
$50,000,000 or more	2	1
Total	100	50

NOTE: This question was directed only to those respondents reporting additional project investment in response to 2011 Survey question 33.
SOURCE: 2011 Survey, Question 34.1.

TABLE 5-7 Distribution of All Reported Additional Project Investments by Source of Funds, Reported by 2011 Survey Respondents

Source of Additional Investment	Percentage of Total Funding Reported by Respondents that Received Additional Project Investments
Non-[SBIR/STTR] federal funding	71
U.S. venture capital	2
Foreign investment	5
Other private equity (including angel funding)	2
Other domestic private company	7
State or local governments	0
Colleges or universities	0
Your own company (including money you borrowed)	9
Personal funds	3
Total	100
Average additional funding (mean) ($000s)	1,488
N = Number of Respondents	116

NOTE: This question was directed only to those respondents reporting additional project investment in response to 2011 Survey question 33. Values reported are percentages of total funding reported.
SOURCE: 2011 Survey, Question 34.

TABLE 5-8 Company-level Changes, Resulting from the SBIR Program, Reported by 2011 Survey Responding Companies

Company-level Activity	Percentage of Responding Companies	Number of Responding Companies
Established one or more spin-off companies	16	11
Been acquired by/merged with another firm	9	6
Made an initial public offering	3	2
Planning to make an initial public offering in 2011-2012	2	1
None of the above	75	53

NOTE: Number of Responding Companies = 71. In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged. Percentages do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 Survey, Question 10.

new companies. Greater than 9 percent of responding companies indicated that the awardee company had been acquired or merged with another firm. Five percent indicated that the company had made or planned to make an initial public offering (IPO). Three-quarters of responding companies indicated that their companies had not been acquired, had not implemented or planned an IPO, and had not established a spin-off company.

Respondents reported on a range of market-related activities involving agreements between their company and other organizations, which can again be taken as an indication of commercial activity. About 25 percent of respondents identified at least one market-related activity undertaken by their company as a result of the technology developed during the surveyed project.[18] Of those companies, 61 percent completed at least one research development (R&D) agreement; 30 percent entered into licensing agreements; and 26 percent entered into customer alliances (see Table 5-9).

Commercialization Training and Marketing

Federal agencies have in recent years provided more commercialization training for SBIR awardees. In some cases this training has been mandatory. NASA does not provide formal commercialization training. However, 22 percent of respondents nonetheless claimed to have received agency-sponsored training related to the surveyed award.[19]

[18]Respondents may have finalized agreements with U.S. companies and investors that are unrelated to the technology developed during the surveyed project.
[19]2011 Survey, Question 17.

TABLE 5-9 Market-oriented Activities Resulting from Project Technology, Reported by 2011 Survey Respondents—Finalized agreements with U.S. companies and investors

Market-oriented Activity	Percentage of Respondents	Number of Respondents
R&D agreement(s)	61	26
Licensing agreement(s)	30	13
Customer alliance(s)	26	11
Marketing/distribution agreement(s)	19	8
Manufacturing agreement(s)	21	9
Sale of technology rights	12	5
Joint venture agreement	9	4
Sale of company	5	2
Partial sale of company	5	2
Company merger	0	0
Other	5	2

NOTE: Number of Respondents = 43. Percentages do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 Survey, Question 38.1.

The 2011 Survey asked whether the company has at least one full-time staff person for marketing. This new question provides another metric to gauge the extent to which the company has focused on marketing. Only 40 percent of respondents reported that their company had at least one full-time marketing staff, a figure likely explained by the high percentage of very small firms among the respondents.[20]

Conclusions: Commercialization at the Company Level

Evidence from the 2011 Survey provides useful insight into the commercialization record of SBIR companies at NASA, on a number of dimensions. The data confirm that *a substantial percentage of projects do indeed commercialize through sales of products or services and/or advance toward commercialization through the receipt of additional development funding.*

Forty-six percent of respondents indicated that their company had already recorded sales of products or services derived from the awarded project. A further 26 percent of respondents were expecting sales in the future (a substantial increase from data collected in the 2005 Survey). (NASA does not have independent data against which the validity of the survey responses can be cross-checked.)

In light of the highly specialized fields in which NASA companies

[20]2011 Survey, Question 12.

operate, which in many cases means that the available market is small, it is not surprising that *the scale of commercialization is limited*. About two-thirds of respondents reporting project-related sales indicated total sales of $1 million or less. Only 1 percent of respondents reported sales of more than $10 million, and zero percent reported sales of $20 million or more.

SBIR commercialization is also in part associated with take-up by NASA. An average of 19 percent of project sales reported by 2011 Survey respondents were to NASA or NASA primes. This percentage is slightly lower than the average percentage of sales to DoD or DoD primes (24 percent), suggesting strong crossover between the NASA and DoD markets sectors. The 19 percent figure is also considerably lower than the average percentage of sales to the domestic private sector (35 percent). These data reflect a tension within the NASA SBIR program, whose design and operations primarily aim to service the needs of NASA Mission Directorates, which compels NASA small business contractors to sell elsewhere to achieve sufficient scale for financial viability. [21] (The report did not ascertain which NASA SBIR topics/subtopics/technologies were linked to higher and lower rates of commercialization within and without NASA, though such analysis would be useful in making program adjustments.)

Additional investment is another important metric for commercialization. Many Phase II projects are not yet ready for the marketplace at the end of the award period, especially at NASA (like DoD), where careful technology readiness assessment must occur and specific levels of readiness must be achieved before interest emerges from acquisitions groups. Sixty-five percent of survey respondents reported that the project received additional investment, mostly for amounts of less than $1 million.

Of the subset of respondents that received additional investment, 71 percent of the average (mean) additional investment of $1.5 million came from federal non-SBIR sources. Other sources individually accounted for less than 10 percent of additional investment, and U.S. venture funding accounted for about 2 percent. The percentages for funding from own company and personal resources were substantially lower than for the 2005 Survey.

QUANTITATIVE SURVEY EVIDENCE THAT NASA STIMULATED TECHNOLOGICAL INNOVATION

Did the NASA SBIR program stimulate technological innovation? Although the committee was unable to develop an appropriate control group to analyze against SBIR awardees, it is at least possible to examine—as have previous Academies and GAO surveys—what the company believed might have happened absent SBIR funding. This counterfactual question presented in the

[21]As with previous surveys, respondents reported whether the funded project was currently in use by a Federal System or Acquisition Program. Twenty-one of respondents reported this to be the case.2011 Survey, Question 57.

opening to this chapter is of course subjective and hypothetical, but the company is best placed to provide some answers.

Given the small commercial market for NASA-specific projects, it is not surprising that only 7 percent of respondents believed that the project would definitely or possibly have proceeded without the SBIR award. Conversely, the majority—three-quarters—of respondents said that the project would likely or definitely not have proceeded without the SBIR award.[22] The remainder were uncertain.

This section of the chapter examines a number of measures to examine how the NASA SBIR program has stimulated technological innovation—first examining knowledge outcomes such as patents and then returning the broader topic of fostering innovative companies.

Knowledge Outcomes

Although patents and peer-reviewed papers are not the only metrics of knowledge development and dissemination by small high-tech companies, they offer a useful starting point. Table 5-10 shows the overall number of patents that responding companies reported as being related to any SBIR awards they have received (not just NASA SBIR awards).[23] Over three-quarters of respondent companies received at least one such patent, and 14 percent received 10 or more.

Patenting activity is often used to measure innovation, but it does not capture the entire story: patenting is important, but it is also expensive, and SBIR funds cannot legally be used for the purpose of patent filing or patent defense. Many companies interviewed for this report and others in this series indicated that they preferred to keep their technology secret or to rely on first-mover advantages and other market-based leverage to defend their technologies. Finally, patenting matters most when potential competitors may seek to utilize a company's intellectual property (IP); for many NASA companies, their work and their market is so small and so specialized that this threat is limited.

Standard Intellectual Property (IP) metrics and bibliometrics provide at least a starting point for quantitative analysis of knowledge outcomes. The survey addressed patents, trademarks, copyrights, and peer-reviewed papers.[24]

Patents are to some degree the life blood of high-tech firms. Because patents at small companies often result from multiple contracts in multiple

[22]2011 Survey, Question 24.

[23]Non-responding companies may have patents that are unrelated to any SBIR award(s) that they have received.

[24]The values of these knowledge repositories vary. Any unique item, painting, photo, music score, can be copy-written for a modest fee. Trademarks include more processing, as registered trademarks need to be unique in their field so as not to impinge on another prior trademark's domain. A patent can be valuable IP, and patents have been correlated with prosperity. Refereed journal articles as a metric are generally not as valued outside of academia, where there is no tenure track requirement to publish such articles. The university professors who participate in SBIR may be responsible for production of many of the articles, although case studies have shown that company researchers also publish.

projects, it is important to capture patents related to the surveyed project as well as patents more generally attributable to SBIR-funded research. Seventy-six percent of responding companies reported the award of at least one patent by the time of the 2011 Survey related to any SBIR-funded technology; and 14 percent reported at least 10 related patents.

With regard to IP related to the specific award being surveyed. Table 5-11 shows that about 45 percent of respondents that responded to the relevant survey question reported receipt of at least one patent specifically related to the surveyed award, compared to 20 percent in the 2005 Survey. This result reflects a high degree of technical success, given the cost of patent applications (which provides disincentives to filing) as well as the burden of novelty that a successful application must meet. Four percent of respondents reported receipt of more than three patents specifically related to the surveyed award, compared to zero in the 2005 Survey.

TABLE 5-10 Number of Patents per Company Related to All Company SBIR Awards, Reported by 2011 Survey Responding Companies

Number of Patents Resulting, at Least in Part, from the Company's SBIR Awards	Percentage of Responding Companies	Number of Responding Companies
0	24	15
1 or 2	39	25
3 or 4	13	8
5 to 9	11	7
10 or more	14	9
Total	100	64
At least 1	76	49

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged.
SOURCE: 2011 Survey, Question 11.

TABLE 5-11 Patents Awarded Related to Surveyed Project, Reported by 2011 Survey Respondents

Patents Submitted for Technology Developed as a Result of the Project	Percentage of Respondents	Number of Respondents
0	55	58
1	25	26
2	11	12
3	5	5
More than 3	4	4
Total	100	105
At least 1	45	47

SOURCE: 2011 Survey, Question 39.1.2.

Copyrights and Trademarks

Eleven of the 13 respondent companies who applied for copyrights related to the surveyed project received at least one copyright.[25] The survey revealed a similarly limited interest in project-related trademarks, with only 12 respondent companies (less than 10 percent) having applied for at least one. Similar percentages were reported for receipt of trademarks.[26]

Peer-reviewed Publications

Publication in peer-reviewed journals and conference proceedings are a standard method for disseminating scientific knowledge. As with the first-round Academies assessment, several case study interviewees noted that publication in peer-reviewed journals was an essential part of the firm's work.

For the purposes of this assessment, peer-reviewed publications are important for two reasons:

- They validate the quality of the research being conducted with program funds.
- They are the primary mechanism through which knowledge is transmitted within the scientific community.

Eighty-two percent of respondents that responded to the relevant survey question indicated that an employee of the surveyed company had published at least one related scientific paper. This was a significantly larger percentage than in the 2005 Survey results (40 percent). Almost one-third reported publication of more than three related papers (see Table 5-12). The existence of articles based

TABLE 5-12 Peer-Reviewed Scientific Publications Related to the Surveyed Project, Reported by 2011 Survey Respondents

Number of Scientific Publications Published for the Technology Developed as a Result of the Project	Percentage of Respondents	Number of Respondents
0	18	23
1	20	26
2	19	24
3	12	16
More than 3	31	40
Total	100	129
At least 1	82	106

SOURCE: 2011 Survey, Question 39.4.1.

[25] 2011 Survey, Question 39.2.1 and Question 39.2.2.
[26] See 2011 Survey, Question 39.3.1 and Question 39.3.2.

on SBIR projects is 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.

Links to Universities

The survey asked a number of questions about the use of university staff and facilities on the surveyed project. Overall, nearly one-third of respondents reported a university connection of some kind.[27] The most reported types of linkages were a university or college as a subcontractor; a faculty member working on the project but not as a principal investigator (PI); and graduate students employed on the project (see Table 5-13). Box 5-2 describes a workshop that the committee convened to address a range of issues related to university-SBIR linkages. Linkages to university is an important component in examining evidence that NASA "stimulated technological innovation," Goal 1 of the SBIR Program. University connections can also benefit SBCs by giving access to technical expertise.

BOX 5-2
Workshop on Improving University-SBIR Linkages

On February 5, 2014, the committee convened a workshop on universities and the SBIR/STTR program.[a] Participants at this workshop considered a range of issues including—

- Improving linkages between SBIR programs at agencies and the universities,
- Aligning with university accelerator initiatives,
- Supporting improved links between state and local innovation and entrepreneurship programs and the universities, and
- Supporting shifts in culture at universities to incentivize faculty to pursue SBIR/STTR funding.[b]

[a] National Academies of Sciences, Engineering, and Medicine, "Workshop on Commercializing University Research: The Role of SBIR and STTR," Washington, DC, February 5, 2014. Agenda found at http://sites.nationalacademies.org/PGA/step/sbir/PGA_086819.htm.
[b] These issues and others related to the SBIR/STTR program and universities will be addressed in detail in the upcoming report on the STTR program.

[27] 2011 Survey, Question 60.

TABLE 5-13 Project Links to Universities, Reported by 2011 Survey Respondents

	Percentage of Respondents	Number of Respondents
A university or college was a subcontractor on this project	21	37
Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI	15	26
Graduate students worked on this project	14	25
The technology for this project was originally developed at a university or college by one of the participants in this project	5	8
The PI for this project was at the time of the project an adjunct faculty member	2	4
The technology for this project was licensed from a university or college	2	3
The PI for this project was at the time of the project a faculty member	1	1
Any of the above	31	55
None of the above	69	122

NOTE: Number of Respondents = 177. Respondents could select more than one answer.
SOURCE: 2011 Survey, Question 60.

Respondents were also asked to identify the universities with which they worked in various capacities on this project. Although the type of work varied widely, some universities were mentioned by a number of respondents. Overall, 77 different universities and colleges were identified. Those mentioned by two or more respondents are listed in Table 5-14 (see Appendix D for the complete list of university mentions). Some of the names on this list are large state universities, a number of which have in recent years focused on technology transition as well as basic research. We believe these data provide a preliminary indication of the connections between specific universities, university systems, and the NASA SBIR program.

Finally it is worth observing that 63 percent of companies that responded to 2011 Survey question 4 reported that at least one founder had an academic background (see Table 5-15), and 29 percent of companies that responded to 2011 Survey question 5 reported that at least one founder was most recently employed by a college or university (see Table 5-16).

Fostering Innovative Companies

Technological innovation can be stimulated by fostering innovative companies. SBIR programs have a range of effects on companies that affect their ability to work within the innovation ecology of the agency or indeed more

TABLE 5-14 University Participants Mentioned by Two or More 2011 Survey Respondents

College or University Name	Number of Mentions
Pennsylvania State University	4
Purdue University	4
Stanford University	4
University of California, Berkeley	4
Georgia Institute of Technology	3
Massachusetts Institute of Technology	3
The Ohio State University	3
Rutgers University	3
University of Alabama	3
University of Central Florida	3
University of Houston	3
University of Illinois at Urbana-Champaign	3
Dartmouth College	2
Rensselaer Polytechnic Institute	2
Texas A&M University	2
University of Arizona	2
University of Colorado	2
University of Florida	2
University of Maryland	2
University of Minnesota	2
University of Notre Dame	2
Virginia Polytechnic Institute	2

SOURCE: 2011 Survey, Question 60a.

TABLE 5-15 Number of Academic Founders, Reported by 2011 Survey Responding Companies

Number of Academic Founders	Percentage of Responding Companies	Number of Responding Companies
None	37	27
1	42	30
2	11	8
3	6	4
4	3	2
5 or more	1	1
Total	100	72
At least 1	63	45

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged.
SOURCE: 2011 Survey, Question 4.

generally. In addition, data about companies can help to define the technological space in which the SBIR programs operate. Finally, a review of the SBIR share of overall company activities can provide insights into the degree of dependence on the SBIR program for individual companies.

SBIR Share of R&D Effort and Company Revenues

Respondents estimated how much of their company's total R&D effort (defined as man-hours of work for scientists and engineers) was devoted to SBIR-funded projects. Overall, 40 percent of companies that responded to the relevant survey question indicated that 10 percent or less of total effort was devoted to SBIR activities during the most recent fiscal year (at the time of the survey), and 28 percent indicated more than one-half (see Table 5-17).

TABLE 5-16 Most Recent Founder Employment, Reported by 2011 Survey Responding Companies

Most Recent Founder Employment	Percentage of Responding Companies	Number of Responding Companies
Other private company	69	50
College or University	29	21
Government	9	6
Other	11	8

NOTE: Number of Responding Companies = 72. In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged. Percentages do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 Survey, Question 5.

TABLE 5-17 Percentage of R&D Effort Funded by SBIR for Most Recent Fiscal Year (Reported at Time of 2011 Survey by Responding Companies)

Percentage of S&E Hours on SBIR	Percentage of Responding Companies	Number of Responding Companies
0	25	18
1-10	15	11
11-25	13	9
26-50	21	14
51-75	13	9
76-100	15	11
Total	100	72

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged.
SOURCE: 2011 Survey, Question 7.

These data correspond fairly closely to responses from another survey question, which (again from the perspective of the time of survey) asked what percentage of company revenues during the most recent fiscal year was accounted for by SBIR awards. As Table 5-18 indicates, 28 percent of companies that responded to the relevant survey question reported having zero SBIR revenues for the most recent fiscal year, while nearly one-quarter reported receiving more than 50 percent of revenues from SBIR. The data are consistent with some companies using SBIR awards to launch and then switching to other sources of funding, and with some companies either continuing to use SBIR awards or returning to seek SBIR awards as a means of engaging with NASA and its technology needs; however, they do not give any indication of how these data may have changed over the life of the responding company.[28]

Prior SBIR Awards

Although the idealized view of the SBIR program is that ideas are tested in Phase I, prototyped in Phase II, and commercialized in Phase III, real-world efforts typically require multiple iterations. Often projects must restart with an earlier phase, or multiple efforts are needed to meet specific problems.

The 2011 Survey asked respondents to indicate how many prior SBIR Phase I awards they had received that were related to the project and technology

TABLE 5-18 Percentage of Company Revenues from SBIR for Most Recent Fiscal Year (Reported at Time of 2011 Survey by Responding Companies

Percent of Company Revenues from SBIR at the Time of the Survey	Percentage of Responding Companies	Number of Responding Companies
0	28	20
1-10	15	11
11-25	14	10
26-50	21	15
51-75	10	7
76-100	13	9
Total	100	72

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged. Because survey sample includes inactive awards, some respondents reported zero SBIR revenues for the most recent fiscal year.
SOURCE: 2011 Survey, Question 9.

[28]Future research of the program could measure outcomes against firm type (those formed in response to an SBIR award solicitation and established firms) and explore more deeply the strategic uses of SBR by firms.

TABLE 5-19 Prior SBIR or STTR Phase I Awards Related to the Surveyed Project, Reported by 2011 Survey Respondents

Number of Awards	Percentage of Respondents	Number of Respondents
0	21	33
1	41	63
2	19	29
3	10	15
4	5	7
5 or more	5	7
Total	100	154
1 or more	80	

SOURCE: 2011 Survey, Question 40.1.1 and Question 40.1.2.

being surveyed. Table 5-19 shows that more than three-quarters of respondents reported prior Phase I awards related to the project surveyed, and more than a third reported more than 1 prior Phase I awards. These data strongly supports the view that innovative products emerge from clusters of activity, rather than from simple straight line development from Phase I to Phase II to commercialization.

Long-term Impacts on Companies Receiving SBIR Awards

Although SBIR awards have direct effects on specific projects, they can have a longer-term effect on the trajectory of company development, creating capacity and in some cases providing a critical input that transforms long-term outcomes. The survey asked respondents about this directly. The results for those companies that responded to the relevant survey question are summarized in Table 5-20.

Respondents to the survey report an overwhelmingly positive impact. Twenty-five percent of respondents indicated that SBIR had had a transformative effect on their company, and a further 56 percent reported a strongly positive effect. Only one percent of respondents reported negative long-term effects.

Conclusions: Stimulating Technological Innovation

What emerges from these data is a picture of companies that are dynamic centers of technological innovation, a considerable amount of which is protected through the patent system. Seventy-six percent of responding companies reported that their company had received at least one patent based on its work under SBIR contracts, while 45 percent reported at least one patent related to the surveyed project only.

TABLE 5-20 Long-term Impacts of the SBIR Funding on Recipient Companies, Reported by 2011 Survey Responding Companies

	Percentage of Responding Companies	Number of Responding Companies
Had a transformative effect	25	20
Had a substantial positive long-term effect	56	46
Had a small positive effect	15	12
Had no long-term effect	2	2
Had a negative long-term effect	1	1
Total	100	81

NOTE: In cases where company information, as opposed to individual projection information, was collected, multiple responses from the same company were averaged.
SOURCE: 2011 Survey, Question 45.

SBIR companies participate at a high level in the standard form of technical knowledge dissemination: publishing in peer-reviewed journals. Eighty-two percent of respondents reported publication of at least one article based on the SBIR-funded work, and almost one-third reported publication of more than three such papers.

Finally, some SBIR companies are closely connected to the universities. Nearly one-third of respondents reported a university connection on the surveyed project, across a number of different modalities, and 12 universities were specifically mentioned as playing a role in at least three reported projects. This suggests that SBIR plays an important role in supporting the practical implementation of university research.

Data from companies responding to the 2011 Survey provide evidence regarding the program's effects on fostering innovative companies. Forty percent of respondents indicated that 10 percent or less of total company R&D effort was devoted to SBIR activities in the most recent fiscal year, and 28 percent of responding companies indicated that zero percent of company revenues came from SBIR for the most recent fiscal year. Still, more than three-quarters of survey respondents reported prior Phase I awards related to the project surveyed, and more than a third reported more than one prior Phase I awards. Together these data suggest that innovative products emerge from clusters of activity, and that some companies receiving SBIR awards are using them to launch their firms before moving on to other sources of funding.

6

Participation of Women and Minorities

One of the four primary Congressional objectives for the Small Business Innovation Research (SBIR) program is "to foster and encourage participation by minority and disadvantaged persons in technological innovation."[1] The 1992 reauthorization reaffirmed that the purpose of the SBIR program is "to improve the Federal Government's dissemination of information concerning the Small Business Innovation Research Program, particularly with regard to program participation by woman-owned small business concerns and by socially and economically disadvantaged small business concerns."[2] Within the SBIR program, disadvantaged persons are defined as those who are either women or are members of a disadvantaged group as identified by the Small Business Administration (SBA).[3] Although participation can encompass more than ownership, available agency data did not support detailed analysis of participation of disadvantaged persons beyond company ownership. The Academies'[4] 2011 Survey of National Aeronautics and Space Administration (NASA) SBIR awardees enabled for the first time a disaggregation of participants by minority status as well as information on participation of women and minorities as principal investigators in addition to company owners. In the committee's related report on the Small Business Technology Transfer Program, it recommends that the SBA change its definitions to address congressional intent with regard to minorities (see Box 6-1).

This chapter reviews the participation by women and minorities in the NASA SBIR program, using agency data and the 2011 Survey of NASA SBIR award recipients. It finds that current efforts have not been sufficient to meet the

[1]P.L. 97–219, § 2, July 22, 1982, 96 Stat. 217.
[2]P.L. 102-564, October 28, 1992, 106 STAT 4249.
[3]For the SBA definition of disadvantaged persons, see https://www.sba.gov/category/navigation-structure/eligibility-requirements. Accessed August 4, 2015.
[4]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.

BOX 6-1
Changing SBA Definitions with Regard to Minorities

The Academies'[a] 2011 Survey of National Aeronautics and Space Administration (NASA) SBIR awardees enabled for the first time a disaggregation of participants by minority status. In the committee's related report on the Small Business Technology Transfer Program, its recommends that the SBA change its definitions to address congressional intent with regard to minorities. Recommendation B reads—

SBA should change its definitions to address congressional intent with regard to minorities.[b]

1. *SBA translates "minorities" in the governing legislation into "socially and economically disadvantaged groups" in the Policy Guidance for SBIR. Asian Americans are designated as one of the included groups.*
2. *Asian Americans are well represented as founders of innovative small businesses. Research shows that they have in recent years accounted for a significant number of all startups in Silicon Valley and other innovation clusters.*[c]
3. *Including Asian Americans has the direct effect of underplaying the low participation for African American, Hispanic American, and Native American entrepreneurs and principal investigators.*
4. *SBA should act immediately to change its definitions to ensure that efforts in this area are focused on activities that meet congressional intent.*
5. *SBA should also require that agencies collect data—and report annually—on the participation of each SBA subgroup in the SBIR and STTR programs.*

[a]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.
[b]See Finding D.
[c]See, for example, Anuradha Basu and Meghna Virick (2015), "Silicon Valley's Indian diaspora: networking and entrepreneurial success," *South Asian Journal of Global Business Research*, 4(2):190-208.

SOURCE: National Academies of Sciences, Engineering, and Medicine, *STTR: An Assessment of the Small Business Technology Transfer Program*, Washington, DC: The National Academies Press, 2016.

Congressional objective. The committee recognizes that small businesses often introduce the radical ideas that can transform industries and markets, and that mobilizing all skilled individuals, regardless of race/ethnicity or gender, strengthens the economy and the nation. To this end, the committee convened a workshop to draw attention to participation of women, minorities, and both older and younger scientists, engineers, and entrepreneurs in the SBIR program and to identify mechanisms for improving their participation rates.[5] The workshop also drew attention to the fact that improving the participation of women and minorities in the SBIR program is a part of a broader national challenge of promoting the effective participation of women and minorities in science, technology, engineering, and mathematics (STEM) (see Box 6-2).

Participants in the workshop examined broad demographic trends in the science and engineering workforce and statistical measures from the SBIR program for women and minorities, and searched for pragmatic solutions to boost SBIR awards to women and minorities. The workshop highlighted the fact that women comprise 51 percent of the U.S. population and 27 per cent of

BOX 6-2
Expanding Participation of Women and Minorities in STEM

The issue of expanding the participation of women and minorities in the SBIR program is a part of a broader national challenge. The National Research Council 2011 report, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at a Crossroads*, notes that underrepresented minorities (defined as Hispanics, African Americans, Native Americans/Alaska Natives) comprise a small percentage at each step of the science, technology, engineering, and mathematics (STEM) education process.[a] The percentages of African Americans and Hispanics interested in STEM undergraduate majors are similar to those of white and Asian Americans, but their completion rates are much lower.[b] At the graduate school level for science and engineering (S&E), underrepresented minorities receive only 14.6 percent of master's degrees and 5.4 percent of doctoral degrees.[c] Data from the National Science Board indicates that women earn roughly one-half of S&E degrees at the bachelor's, master's, and Ph.D. levels, but they earn "fewer than one-third of the doctorates awarded in physical sciences, mathematics and computer sciences, and engineering" and less than one-quarter of engineering master's degrees.[d]

[a]National Research Council, *Expanding Underrepresented Minority Participation,* 37-38.
[b]Ibid., 38-39.
[c]Ibid., 38. Here, underrepresented minorities are also defined as African Americans, Hispanics, and Native Americans/Alaska Natives.
[d]National Science Board, *Science and Engineering Indicators 2014*, Arlington, VA: National Science Foundation, 2014, pp. 2-26, 2-29, 2-32, and appendix table 2-29.

[5]National Academies of Sciences, Engineering, and Medicine, *Innovation, Diversity, and the SBIR/STTR Programs: Summary of a Workshop,* Washington, DC: The National Academies Press, 2015, p.5.

STEM graduates, but woman-owned companies have received only about 6 percent of SBIR awards. Hispanics, African Americans, Asian Americans, and Native Americans together comprise 36 percent of the U.S. population and 26 percent of STEM graduates, but less than 10 percent of all SBIR awards.

DEFINING THE ISSUE

NASA and other federal agencies use definitions provided by the SBA. However, for the purposes of this analysis—and for determining whether agencies are meeting the congressionally mandated objective—neither the SBA's definition nor related metrics is adequate. In implementing the statute, the SBA has transformed "minority and disadvantaged persons" into "socially and economically disadvantaged small businesses (SDBs), and […] women-owned small businesses (WOSBs)."[6] Although this formulation has been traditional among SBIR stakeholders, it has several unintended consequences:

- It focuses attention entirely on company ownership, rather than the "participation" described in the statute. There are many different ways to participate in the SBIR program, and only one of them is ownership.
- It replaces "minority and disadvantaged persons" with "socially and economically disadvantaged small businesses," which aligns the program not with the minority needs apparently at the forefront of Congressional objectives but instead with SBA definitions of socially and economically disadvantaged and with businesses rather than persons.

As a result, all participation other than via ownership is disregarded by agencies—including NASA. For example, no data appear to be maintained by any SBIR-awarding agency on female and minority principal investigators. And as we shall see, SBA definitions of "socially and economically disadvantaged" have the effect of largely obscuring agency performance in addressing the Congressional objective.

To analyze the role of women and minorities in NASA's SBIR program, the committee relied primarily on agency data, survey data, and a workshop convened by this committee on the issue of diversity, taking each in turn. The analysis begins with examination of what agency data tells us about the participation of women and minorities.

AGENCY DATA ON WOMEN AND MINORITIES

The data cited below on the participation of woman- and minority-owned firms have been provided by NASA directly. These data are summarized below and discussed in more detail in the chapter annex.

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[6]SBA SBIR/STTR Policy Directive, February 24, 2014, p. 3.

Phase I Applications, Awards, and Success Rates

Phase I: Woman-owned Small Businesses (WOSBs)

Phase I applications from woman-owned small businesses (WOSBs) declined fairly steadily across the study period, fiscal year (FY) 2005-2014.[7] In FY2014 there were 179 applications from WOSBs, down from a peak of 286 in FY2005. However, there was no decline in WOSB applications as a percentage of all applications because the decline in WOSB applications matches the overall broad decline in Phase I SBIR applications to NASA.

"Success rates" measure the percentage of applications that result in awards. At NASA, Phase I success rates for WOSB have been consistently lower than for non-WOSB firms. During the study period, success rates for WOSB applications fluctuated substantially, with a peak at 22 percent in FY2008 and a low of 11 percent in FY2011 (see Figure 6-1), but in every one of the 9 years of data provided, WOSB success rates were lower than those for all

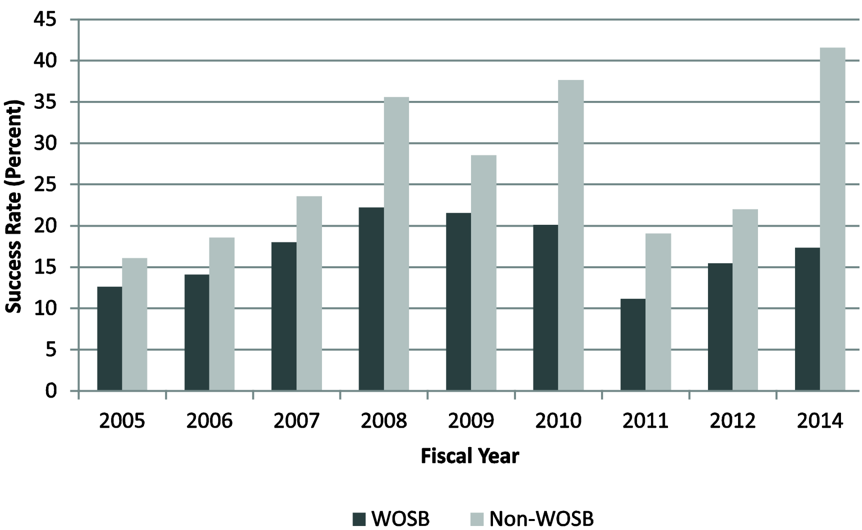

FIGURE 6-1 NASA Phase I SBIR success rates for WOSB and non-WOSB applications, FY2005-2014.
SOURCE: NASA applications and awards database.

[7]NASA utilizes the definition of woman-owned provided by the SBA in its policy guidance for the SBIR/Small Business Technology Transfer (STTR) program. http://www.sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf. Accessed March 17, 2015.

applicants. Overall, the WOSB success rate was 16.8 percent, while the non-WOSB success rate was 25.5 percent. As a result of the lower success rates, the WOSB share of Phase I awards declined over the study period, from about 12 percent of awards in the early part of the period to less than 9 percent in FY2014.

Phase I: Minority-owned Small Businesses (MOSB)

Phase I applications from minority-owned small businesses (MOSBs) declined fairly steadily during the study period, from a peak of nearly 350 in FY2005 to 132 in FY2014.[8] This decline was somewhat steeper than the overall decline in applications to NASA during the study period.

Success rates for MOSB application were lower than those for non-MOSB applications for every year during the study period—by more than one-half in 2 years (including FY2014). Across the study period, the average success rate was 25.5 percent for non-MOSBs and 14.5 percent for MOSBs. The average MOSB success rate was also lower than the average WOSB success rate for the same time period (14.5 compared with 16.8).

Reflecting a sharper than average decline in applications together with lower success rates, the MOSB share of Phase I SBIR awards declined across the study period, from a peak of almost 14 percent in FY2007 to a new low of

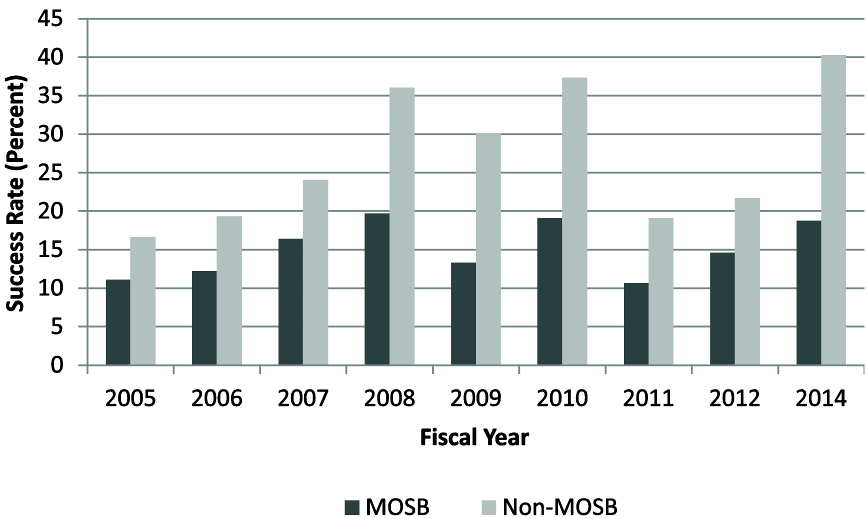

FIGURE 6-2 NASA Phase I SBIR success rates for MOSB and non-MOSB applications, FY2005-2014.
SOURCE: NASA applications and awards database.

[8]NASA utilizes the SBA definition as the basis for this tabulation.

7.8 percent in FY2014. These results include within the MOSB category awards to companies that are majority owned by Asian-Americans as well as those owned by groups more traditionally included in minority groups, such as African-Americans, Native Americans, and Hispanic-Americans. While the existing data reveal the dual problems of lower application rates and lower success rates, they do not provide the details of cause and effect needed to design solutions.

Summary: NASA data on Phase I Awards to Minority- and Woman-owned Small Businesses

For Phase I, there is strong evidence that MOSBs are not improving their access to the SBIR program; to the contrary, during the study period, for almost every relevant metric, access appeared to decline:

- The share of Phase I applications from MOSBs declined from about 15 percent to less than 12 percent of the total.
- For every year, MOSB success rates were lower than non-MOSB success rates. In FY2014 the gap was more than 10 percentage points.
- Declining applications and flat or declining success rates inevitably led to declining numbers of awards to MOSB.
- The percentage share of SBIR awards to MOSBs fell steadily beginning in FY2008, a function of both declining applications and relatively low success rates. At study end, MOSBs accounted for about 8 percent of NASA Phase I SBIR awards.

WOSBs had somewhat more success than MOSBs in Phase I, and overall there was a small upward trend in the share of awards to WOSBs:

- Applications from WOSB, although declining over the period, broadly reflected the patterns for applications as a whole. There was no substantial change in the percentage of applications received from WOSBs.
- Overall, success rates were lower for WOSBs than for non-WOSBs, although the average gap was considerably less than that for MOSBs. In 1 year (FY2011) WOSB applications enjoyed a slightly higher success rate than did all other applicants. Most recently, in FY2014 the gap in success rates between WOSB and all others widened, with WOSB success rates about 25 percentage points lower than that for all others.

Phase II Applications, Awards, and Success Rates

Participation of WOSBs and MOSBs in Phase II was largely, but not entirely driven, by their limited and lower participation in Phase I, compared to non-WOSBs and non-MOSBs. For instance, the Phase II success rates for WOSBs were lower than those for non-WOSBs in every year of the study period except for FY2005 (see Figure 6-3). Overall, the WOSB success rate was 4 percentage points lower than the non-WOSB success rate. And as a result of these factors, the WOSB share of Phase II awards declined to below 8 percent in FY2011 and FY2012.

Falling applications and lower success rates resulted in a decline in the number of MOSB Phase II awards, and in their share of all awards. The largest number of Phase II awards to MOSBs in FY2010, FY2011, and FY2012 was six awards, and MOSBs' share of all awards fell to a low of 5 percent in FY2012, the most recent year for which data were available.

Summary: Phase II Awards to Minority- and Woman-Owned Small Firms

Phase II participation is highly dependent on the number of firms winning NASA Phase I awards, because only Phase I winners could apply for Phase II until 2012. Beyond this overarching effect, other findings are important to note:

- Unlike Phase I, Phase II success rates showed no consistent pattern.
- The number of MOSB Phase II awards declined sharply during the study period, especially toward the end. After peaking at 18 in FY2009, awards dropped to 4 by FY2014.

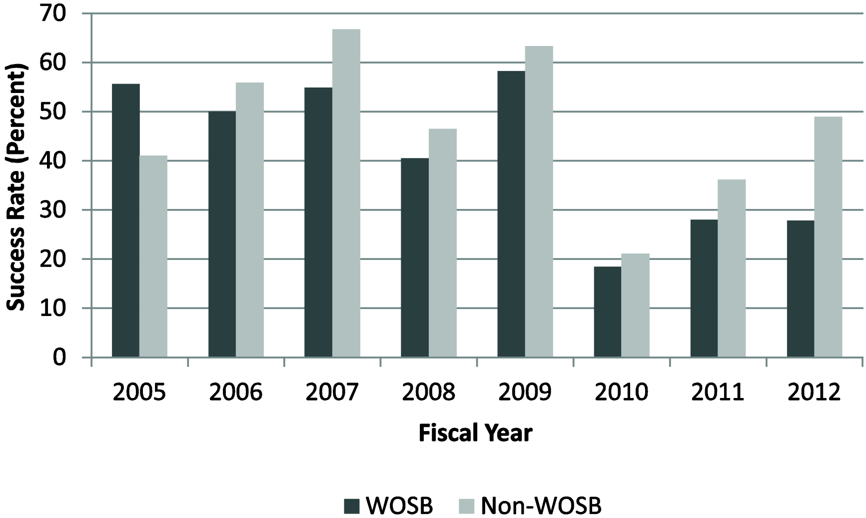

FIGURE 6-3 NASA Phase II SBIR success rates for WOSB and non-WOSB applications, FY2005-2012.
SOURCE: NASA applications and awards database.

- Overall the MOSB share of Phase II awards fell by more than half, from 13 percent in FY 2006 to 6 percent in FY2014.
- The trend in the number of Phase II applications from WOSBs tracked closely with that for all applicants.
- NASA awarded 8 or 9 Phase II awards to WOSBs in each of the 3 most recent years reported.
- Although the WOSB share of Phase II awards grew from FY2005 to FY2010, peaking at greater than 14 percent, it declined sharply since FY2010. In FY2014, WOSBs accounted for less than 9 percent of all Phase II awards.
- WOSB results are somewhat skewed by the presence of two especially successful WOSB companies. Two firms (Intelligent Automation and Paragon Space Development) accounted for more than one-quarter of all Phase II awards to WOSBs. There are no comparable MOSB companies.

Overall, these data overall suggest that NASA has not been effective in increasing applications from WOSBs and MOSBs. At a minimum, NASA should seek an explanation for these observed differences and search for appropriate remedies.

The data collected and provided by NASA do not address other forms of participation of women and minorities in the program—notably as PIs. In addition, the data are not disaggregated by minority status, which has the effect of camouflaging particularly serious problems around participation of Black-, Native American-, and Hispanic-owned firms. These issues are addressed via data drawn from the 2011 Survey.

SURVEYING MINORITY GROUPS

The 2011 Survey addressed the participation of women and minorities in the NASA SBIR program. It is the first to the committee's knowledge to probe beneath the SBA definition of "socially and economically disadvantaged groups" (SEDGs).[9] That is, previous SBIR surveys by the Academies and other organizations such as the Government Accountability Office (GAO)[10]—as well as agency data collection—have all simply sought to determine whether the company is majority-owned by members of a SED group (as defined by the SBA). The results below should be examined with some caution because the numbers of responses are too small to draw definitive conclusions. At the same time, these are the only available data on the demographics of PIs and on the

[9]Different agencies use different terminologies, which also change over time. Both "minority-owned" and "socially or economically disadvantaged" are widely used.

[10]Government Accountability Office, *Small Business Innovation Research Shows Success but Can Be Strengthened*, RCED-92-37, March 30, 1992.

participation of firms owned by Blacks, Hispanics, and Native Americans, and, as such, are of keen interest.

Minority Principal Investigators

Like the 2005 Survey, the 2011 Survey asked whether the PI for the surveyed project was a minority. Fourteen percent of Phase I[11] and 11 percent of Phase II respondents indicated this was the case for their project (see Table 6-1).

The 2011 Survey also asked respondents to provide details about the PI's ethnic background. Detailed categories were drawn from SBA definitions, with the addition of a category for "other" to ensure that all respondents who wish to claim SED status had an appropriate category. Answers to this detailed question revealed that more than three-quarters of the SED PIs were Asian-Pacific or Asian-Indian. No Phase II respondent indicated that the PI was African-American. Eighteen percent of Phase I PIs and 5 percent of Phase II PIs were Hispanic. Although the raw numbers are very small, the absence of Black PIs in Phase II and the sharp decline in Hispanic PIs across phases are causes for concern (see Table 6-2).

These data can be placed in the further context of the 2011 Survey population as a whole. Overall, of the 298 Phase I and Phase II respondents, over 1 percent reported that the project PI was Hispanic, and less than 1 percent reported that the project PI was Black. One percent reported that the Phase II PI was Native American (see Table 6-3).

Minority Company Ownership

Turning from the ethnicity of PIs to the ethnicity of company owners, approximately 10 percent of Phase I respondents and 7 percent of Phase II respondents indicated that the company was majority-owned by minority individuals at the time of the award.[12]

TABLE 6-1 Minority PIs in NASA SBIR Projects, Reported by 2011 Survey Respondents, as Percentage of Total Respondents, by Phase

Minority PI	Percentage of Phase I Respondents	Percentage of Phase II Respondents
Yes	14	11
No	86	89
Total	100	100
N=Number of Respondents	119	177

SOURCE: 2011 Survey, Question 14B.

[11]Phase I data were originally collected as a part of an effort to add statistical analysis to the assessment. This effort was later shelved, but the data were retained. It should be noted that the Phase I respondents in this case all came from companies that did not receive a Phase II award in FY1998-2007 from NASA, the National Science Foundation (NSF), or the Department of Defense (DoD).

[12]2011 Survey, Question 19B.

TABLE 6-2 NASA SBIR: Composition of Minority PIs by Ethnicity, Reported by 2011 Survey Respondents, as a Percentage of Respondents Reporting a Minority PI, by Phase

Ethnicity of Minority PI	Percentage of Phase I Respondents Reporting a Minority PI	Percentage of Phase II Respondents Reporting a Minority PI
Asian-Indian	41	37
Asian-Pacific	29	47
Hispanic	18	5
Black	12	0
Native American	0	5
Other	0	5
	100	100
N= Number of Respondents Reporting a Minority PI	17	19

SOURCE: 2011 Survey, Question 14C.

TABLE 6-3 NASA SBIR Composition of Minority PIs by Ethnicity Reported by 2011 Survey Respondents, as Percentage of All Respondents, by Phase

Ethnicity of Minority PI	Percentage of Phase I Respondents	Percentage of Phase II Respondents
Asian-Indian	6	4
Asian-Pacific	4	5
Hispanic	3	1
Black	2	0
Native American	0	1
Other	0	1
	14	11
N= Number of Respondents	119	179

SOURCE: 2011 Survey, Question 14C.

Probing more deeply into the ethnic distribution of minority company ownership allows for identification of further issues. Overall, this distribution is quite similar to that for minority PIs, in that responses from 75 percent of both Phase I and Phase II respondents reported majority owners of Asian-Indian and Asian-Pacific ethnicity.[13] Again, the percentages should be viewed with some caution, because the numbers involved are very small indeed: the 2011 Survey reported two Phase I awards and one Phase II award to Black-owned companies, and one Phase I award to a Hispanic-owned firm, out of 298 awards surveyed. Nonetheless, the fact remains that even among this very small sample, three-quarters of firms identifying as minority-owned are Asian-owned.

[13]2011 Survey, Question 19C.

Female Principal Investigators

Women have traditionally been viewed as socially and economically disadvantaged in the context of the SBIR program, and therefore expanding opportunities for women has been one of the congressionally mandated goals of the SBIR program since its inception. In most cases, analysts have focused on the participation of woman-owned firms. However, being a PI is thought by some to be a stepping stone toward company ownership, so the 2011 Survey captures the extent to which SBIR awarded projects had female PIs.

Respondents reported that about 11 percent of Phase I projects and 5 percent of Phase II projects had a female PI (see Table 6-4). The data show that overall there are relatively few female PIs in the NASA SBIR program. Furthermore, female PIs were less likely to receive a Phase II award than a Phase I award, at levels that were less than half. Although the raw numbers are small, these results warrant further analysis and possibly agency action.

Woman-owned Businesses

The 2011 Survey also addressed the extent to which SBIR awards are made to WOSBs. These data are provided in Table 6-5 and indicate that, although the percentage of WOSBs in the sample was not large, it was overall somewhat higher than the percentage of female PIs for Phase II projects. NASA provided data that show somewhat higher shares for WOSBs than does the 2011 Survey for the study period. Surprisingly, the NASA data show higher shares for WOSBs in Phase II than in Phase I.

NASA OUTREACH ACTIVITIES TOWARD WOMEN AND MINORITIES

Box 6-3 provides an excerpt from the 2013 NASA annual report to the SBA on efforts to enhance the participation of women and minorities in the SBIR program. This text shows that NASA's SBIR Program Office has passed primary responsibility for outreach to women and minorities to its Office of Small Business Programs (OSBP). OSBP staff undertake the outreach, and OSBP staff at the Field Centers are responsible for implementation. However, this outreach is not focused on the small target audience of potential SBIR applicants: it includes all other small businesses.

In 2013, the NASA SBIR program participated in several workshops, two of which were led by other organizations and were not SBIR-focused. There is no evidence that any concrete actions emerged from any of these activities.

The NASA SBIR program office does not track outreach to woman- and minority-owned firms in any systematic way and did not provide any data connecting outreach to applicants.

TABLE 6-4 NASA SBIR: Female PIs in NASA SBIR Projects, Reported by 2011 Survey Respondents, as Percentage of All Respondents, by Phase

Female PI	Percentage of Phase I Respondents	Percentage of Phase II Respondents
Yes	11	5
No	89	95
	100	100
N=Number of Respondents	119	177

SOURCE: 2011 Survey, Question 14A.

TABLE 6-5 NASA SBIR: Woman-owned Small Businesses Reported by Respondents, as a Percentage of All Respondents, by Phase

WOSB at Time of Award	Percentage of Phase I Respondents	Percentage of Phase II Respondents
Yes	7	9
No	93	91
	100	100
N=Number of Respondents	118	177

SOURCE: 2011 Survey, Question 19A.

PERSPECTIVES ON IMPROVING DIVERSITY

To further examine the participation of women, minorities, and other underrepresented groups in the SBIR/STTR programs and to identify ways to increase that participation, the committee convened a workshop on February 7, 2013, titled “Innovation, Diversity, and Success in the SBIR/STTR Programs.”[14] The workshop examined broad demographic trends in the science and engineering workforce and the need for more female and minority representation within that workforce, as well as pragmatic solutions to boost SBIR awards to women and minorities.

Personal experiences shared at the Academies’ workshop illustrated how diversity can advance innovation; the blending of multiple viewpoints often casts a new lens on old problems, leading to innovative solutions. Eric Adolphe of CenterScope Technologies, who is a 17-time SBIR awardee, credited the diversity of his team for his first SBIR award. He described the experience of writing code overnight for a National Aeronautics and Space Administration (NASA) Phase II award. By thinking outside the box, his team not only won the contract but also garnered the NASA SBIR of the Year Award. “We were able to solve complex problems because we all thought differently,” he said.

[14]For a review of these perspectives, see National Academies of Sciences, Engineering, and Medicine, *Innovation, Diversity, and the SBIR/STTR Programs: Summary of a Workshop*, Washington, DC: The National Academies Press, 2015. This section draws from the text of this report.

BOX 6-3
Excerpt from NASA Annual Report:
Efforts to Reach Out to Women and Minorities

"In general, outreach efforts are led by NASA's Office of Small Business Programs (OSBP). Since calendar year 2012 NASA's SBIR/STTR program has been working in partnership with the OSBP to conduct outreach events to disadvantaged-, veteran-, and women-owned businesses. These events are conducted at NASA Centers and rotate quarterly. The OSBP Small Business Specialist (SBS) at each Center is tasked with personal outreach to the target groups mentioned (as well as to businesses in HUBZones,[a] for those states that have both a HUBZone and a NASA Center) and is graded on the success of their efforts. Each quarter the SBS gives a report on their activity based on agreed to, measurable goals established by NASA Headquarters. The goals are negotiated on an annual basis. Additionally, the Small Business Administration (SBA) and the Office of Management and Budget (OMB) give grades to agencies with respect to their outreach; for the past three years NASA has received an "A" grade from SBA and OMB.

"The SBIR/STTR Program participated in four additional events in 2013 beyond those organized by OSBP: a workshop hosted with Alabama A&M University on the subject of mentor-protégé relationships for minority-owned businesses; participation in a workshop led by NIH on the subject of outreach to Historically Black Colleges and Universities (HBCUs) and other Minority Servicing Institutions; a workshop at the NASA Langley Research Center that included participation from faculty from several local area HBCUs on the subject of outreach to minority business communities and universities; and a meeting with personnel from the National Hispanic University in San Jose California to discuss outreach to the Latin-American community."

[a]HUBZones are Historically Underutilized Business Zones, in which the SBA encourages economic development and employment growth by providing access to more federal contracting opportunities.

SOURCE: NASA, Annual SBIR/STTR Report to SBA, 2013.

Although greater participation of women and minorities in U.S. science and engineering can help ensure a stable pipeline of talent to weather U.S. demographic and global economic shifts, workshop speakers noted how the addition of women and minorities enriches America's science and technology innovation in a more qualitative manner. For example, Peggy Wallace of Golden Seeds noted that research shows companies with women on their boards are more profitable than other companies.[15]

[15]See presentation by Peggy Wallace in Chapter 4 of National Academies of Sciences, Engineering, and Medicine, *Innovation, Diversity, and Success in the SBIR/STTR Programs*. It is recognized that

Individual workshop participants made a number of suggestions for addressing the participation of women and minorities in the SBIR and STTR programs. These suggestions spanned a wide range but broadly fell within three categories—expanding the pool of applicants, eliminating barriers in grant applications and selection, and providing greater education and support for entrepreneurship training and commercialization efforts. Participants also saw the need to align and leverage resources and programs at the state level that aim at providing access and support to woman- and minority-owned businesses; and to team with other federal and state/local programs which are addressing this issue.

BOX 6-4
Considering the Impact of Quotas

The Committee considered the question of whether quotas could be effective if assigned to applications from woman- and minority-owned firms. It concluded that while quotas might increase the number of awardees that are women and from minority population in the short-term, this approach could undermine the underling concept of SBIR.

In particular, committee members were concerned that the merit-based character and reputation of the program would be damaged, and that high-quality applicants might be discouraged as a result. The committee believes that non-merit based selection would dilute the signal of technical quality and commercial promise that SBIR awards now telegraph to potential investors, a factor that is key to helping SBIR companies to grow and bring new innovations to the market.

They further noted that such quotas might open the door for future set-asides—for example based on geographic location—that could balkanize the program. And they noted the technical and practical difficulties in implementing such a scheme: Would quotas be set for Phase II as well as Phase I, for example? And how would some components at DoD and NIH, which offer only a few awards annually, effectively implement a quota scheme?

As a result, the Committee decided that quotas would not be an appropriate solution to the problems described in the report, particularly as the report also notes that the agency has not yet made a concerted effort to attract more applicants from these companies.

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an observation differs from a statement of causality, with the latter generally requiring control groups to establish proof. For example, it may be that companies are more profitable because they have women on their boards, or that more profitable companies are more likely to emphasize diversity and appoint women to their boards.

SUMMARY

Data from both NASA and the 2011 Survey show that access for women and minorities to the SBIR/STTR program is not expanding. Not only are the shares of awards to woman- and minority-owned businesses continuing to decline, recently reaching historic lows in some cases, but also the same is true of opportunities for female and minority PIs.

Delving further into the details of minority participation, the 2011 Survey results also established that the percentages of Black- and Hispanic-owned firms and Black and Hispanic PIs are small and vanishing.

Finally, there is no evidence that NASA has undertaken any significant or effective initiatives to address this Congressional objective for the SBIR program. There are no documented outreach programs of any size or duration.

ANNEX 6-A
APPLICATIONS AND AWARDS FOR THE NASA SBIR PROGRAM, FY2005-2014

Phase I SBIR Award Demographics

Woman-owned Small Businesses

Phase I Applications and Success Rates

The number of applications received from WOSBs declined steadily over the study period (see Figure 6-4), reflecting the overall decline in all applications to NASA.

The success rates for WOSB applications fluctuated substantially, reaching a peak at 22 percent in FY2008 and a low at 11 percent in FY2011 (see Figure 6-5). However in every 1 of the 9 years of data provided by NASA, WOSB success rates were lower than those for all applications. Overall, the average success rate for WOSB applications was 17 percent, while average success rate for non-WOSB applications was 26 percent.

Phase I Awards

The number of awards to WOSBs grew fairly steadily from FY2005 until FY2010, albeit from a low base. However, in FY2011 the number of awards to WOSBs declined sharply and did not fully recover (see Figure 6-6).

WOSBs received a declining share of all NASA Phase I SBIR awards during the study period. Although they averaged about 12 percent overall, this percentage is buoyed by larger shares in FY2009 and FY2012 (see Figure 6-7). The last year of the study period is also the year with the lowest WOSB share of awards, at less than 9 percent.

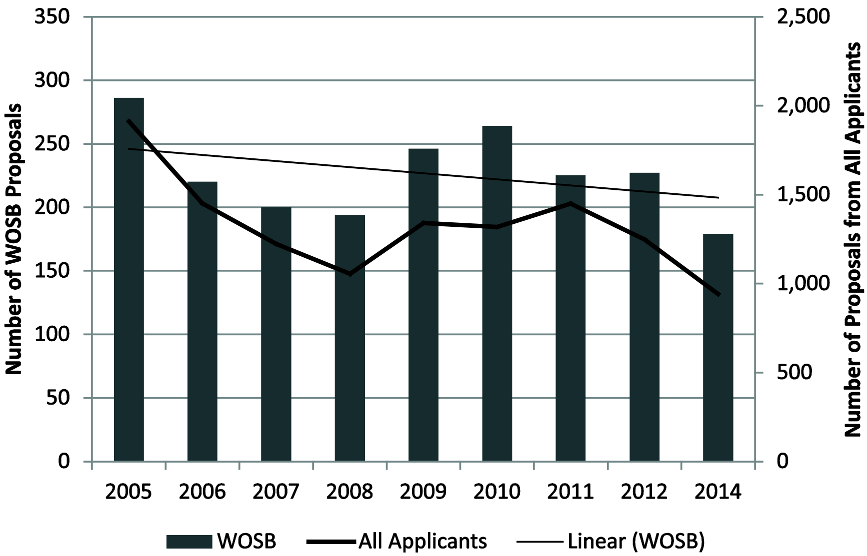

FIGURE 6-4 NASA SBIR Phase I proposals from all applicants and from WOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

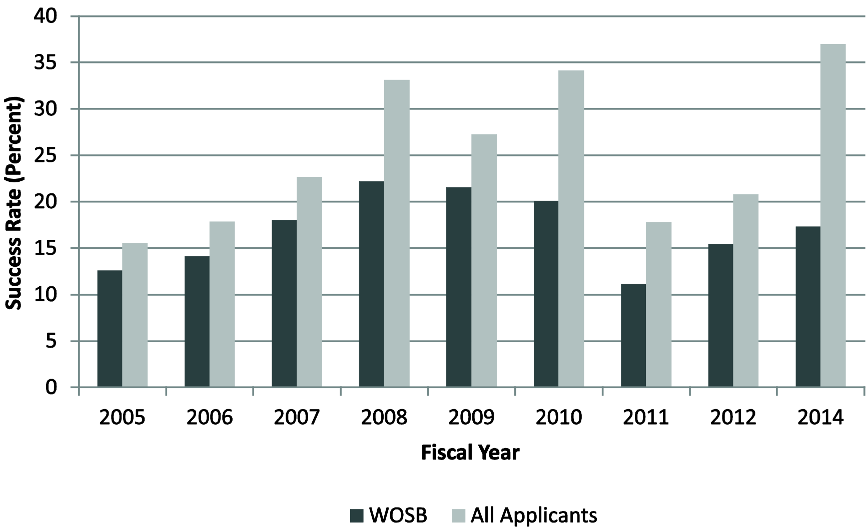

FIGURE 6-5 NASA SBIR Phase I success rates from WOSBs and from all applicants, FY2005-2014.
SOURCE: NASA awards and applications database.

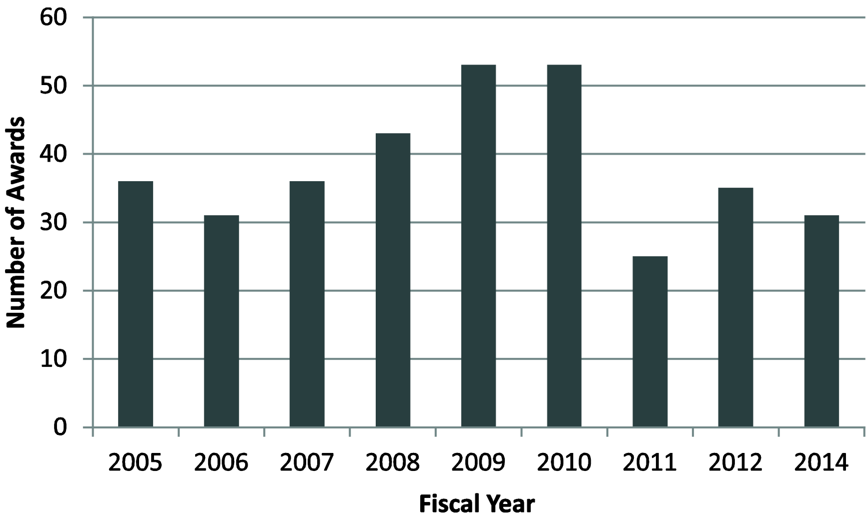

FIGURE 6-6 NASA Phase I SBIR awards to WOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

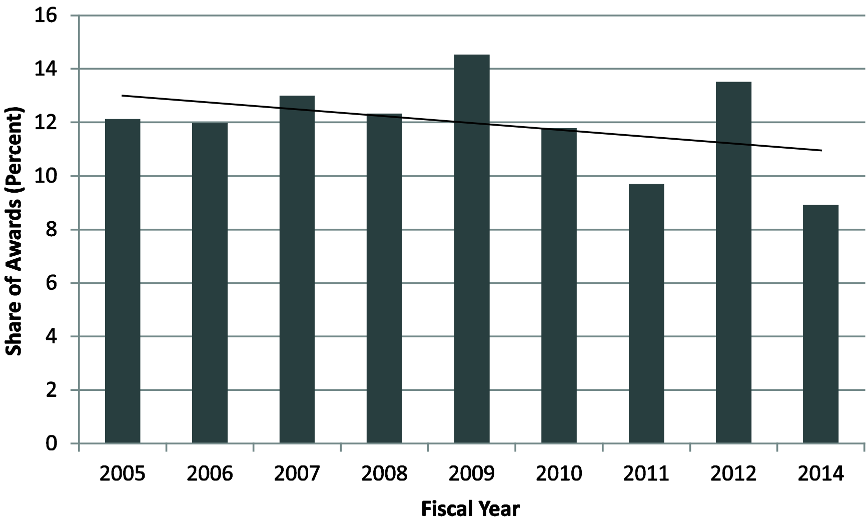

FIGURE 6-7 WOSB share of all NASA SBIR Phase I awards, FY2005-2014.
SOURCE: NASA awards and applications database.

Top Winners Among WOSBs

When reviewing these results, it is important to note that the very large roles played by three WOSBs (Physical Optics, Intelligent Automation, and CFD Research) in the program tend to skew the data. All three were wholly or in part founded by their female owners, who continue to play a major role at each, so they meet the SBA standard for WOSBs. Combined, they accounted for about 22 percent of all Phase I awards to WOSBs during the study period. Table 6-6 lists the top 20 WOSB NASA SBIR Phase I awardees from FY2005 to FY2014. Together the top 20 accounted for slightly more than half of all Phase I awards to WOSB during the study period. A closer look at contributing factors to the success of these WOSBs might be instructive.

Minority-owned Small Businesses

Phase I Applications

The number of Phase I applications from MOSBs declined steadily from a peak of more than 360 in FY2005 to 144 in FY2014 (see Figure 6-8). This decline mirrors, but is somewhat steeper than, the overall decline in applications to NASA during the study period. Overall, the number of MOSB applications declined by more than one-half during the study period.

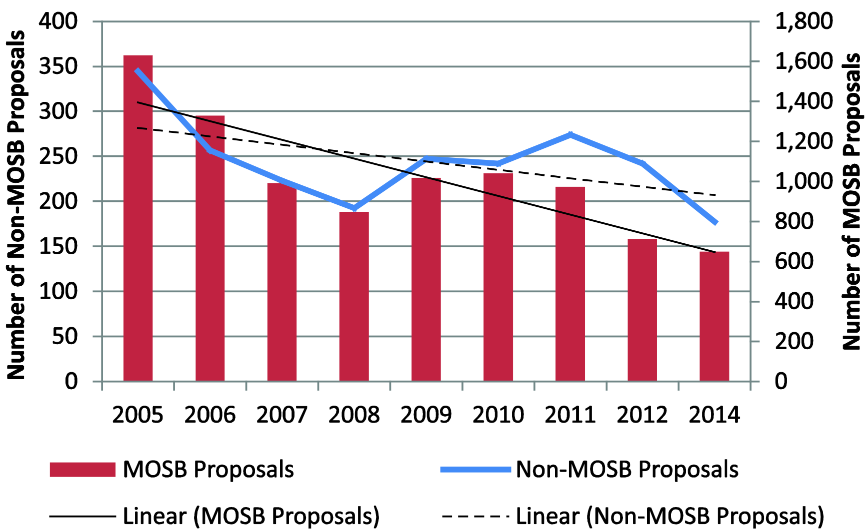

FIGURE 6-8 NASA SBIR Phase I proposals from MOSBs and all applicants, FY2005-2014.
SOURCE: NASA awards and applications database.

TABLE 6-6 Top Winners Among WOSBs, NASA SBIR Phase I awards, FY2005-2014

Company Name	Number of NASA SBIR Phase I Awards
Intelligent Automation, Inc.	32
CFD Research Corporation	23
Physical Optics Corporation	20
Ridgetop Group, Inc.	14
Paragon Space Development Corporation	11
Microcosm, Inc.	11
Cybernet Systems Corporation	10
InnoSense, LLC	8
Signal Processing, Inc.	7
Florida Turbine Technologies, Inc.	7
Composite Technology Development, Inc.	7
The Innovation Laboratory, Inc.	7
Spectral Energies, LLC	6
M4 Engineering, Inc.	6
Michigan Engineering Services, LLC	5
ElectroChem, Inc.	5
Sukra Helitek, Inc.	4
Jabiru Software and Services	4
Nano EnerTex	4
Touchstone Research Laboratory, Ltd.	4
Total	195
All WOSB awards	342
All Awards	2,862
Top 20 WOSB companies as percentage of WOSB awards	57.0
Top 20 WOSB companies as percentage of all awards	6.8

SOURCE: NASA awards and applications database.

Success rates for MOSBS were lower than those for non-MOSBs for every year of the study period. In 2 years (including FY2014), success rates for MOSBs were less than half of those for non-MOSB firms. Across the entire study period, the average success was 25.9 percent for non-MOSBs and 14.5 percent for MOSBs. NASA has provided no explanation for these results.

Phase I Awards

Declining applications and flat or declining success rates inevitably lead to declining numbers of awards (see Figure 6-10). Combined with the growth in overall awards, the lower numbers of awards to MOSBs resulted in a declining share of awards for MOSBs. There are year-to-year fluctuations, but the overall trend is clear.

Top Winners Among MOSBs

Awards to MOSBs were less concentrated in specific companies than were those to WOSBs. Table 6-7 shows that the top 20 MOSB awardees accounted for about 42 percent of all Phase I awards to MOSBs. The top three MOSBs received a total of 57 awards, or 12 percent of all MOSB awards—a much lower percentage than for the top three WOSBs.

Phase II SBIR Award Demographics

Woman-owned Small Businesses

Phase II Applications and Success Rates

As with Phase I, the number of Phase II applications from WOSBs largely tracked the pattern of all applications, rising in response to ARRA funding but otherwise largely flat throughout the period (see Figure 6-11).

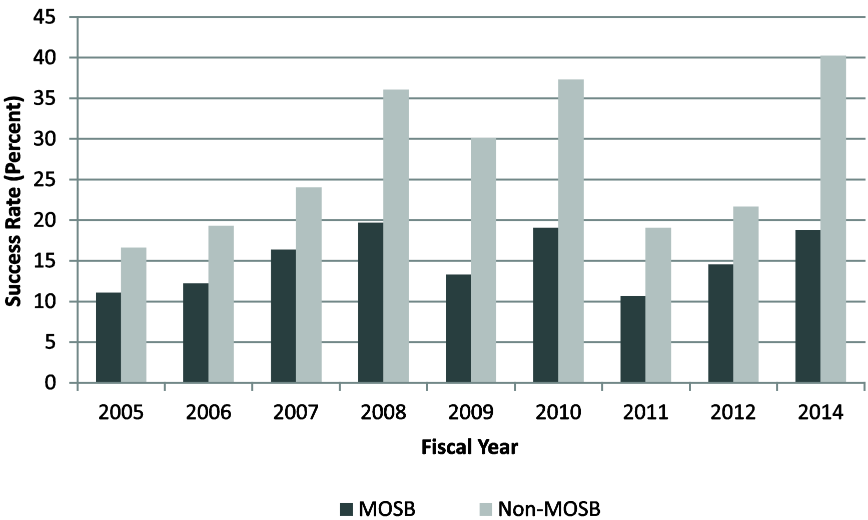

FIGURE 6-9 Success rates for NASA SBIR Phase I applications from MOSBs and from non-MOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

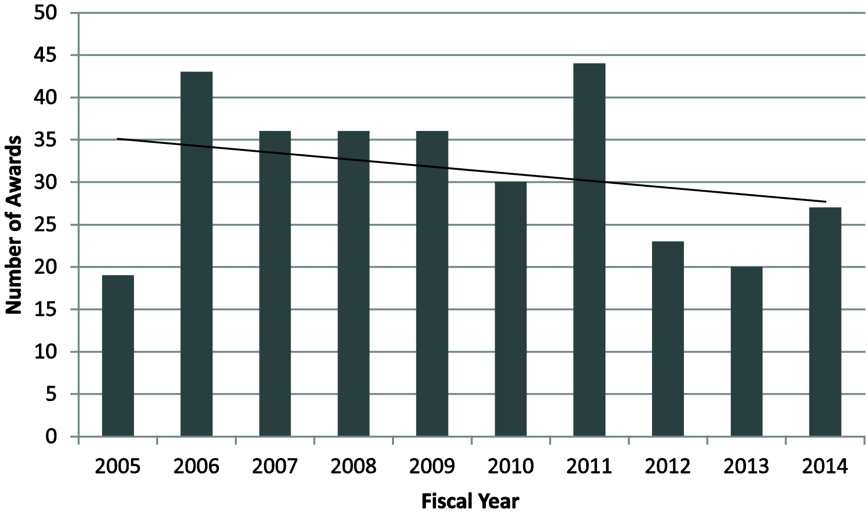

FIGURE 6-10 Number of NASA SBIR Phase I awards to MOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

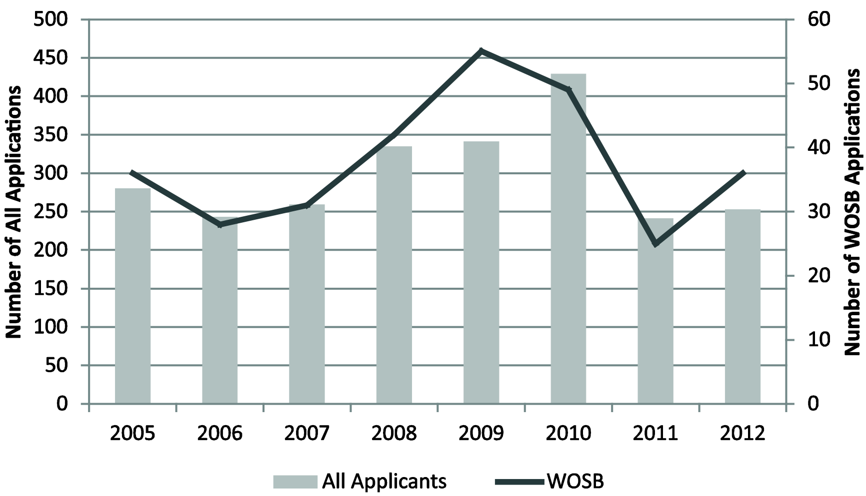

FIGURE 6-11 NASA SBIR Phase II applications from all applicants and from WOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

TABLE 6-7 Top Winners Among MOSB, NASA SBIR Phase I Awards, FY2005-2014

Company Name	Number of NASA Phase I SBIR Awards
Scientific Systems Company	24
ZONA Technology	17
SVT Associates	16
Materials Modification	15
American GNC	15
Aurora Flight Sciences	14
Optimal Synthesis	11
Tietronix Software	10
Cybernet Systems	10
Signal Processing	7
Mobitrum	7
Acellent Technologies	7
TTH Research	6
Materials Technologies	6
ElectroDynamic Proposals	6
Analytical Services (ASI)	6
Applied Material Systems Engineering (AMSENG)	6
AdValue Photonics	6
Advanced Dynamics	6
Agave BioSystems	6
Total	201
All MOSB awards	477
Top 20 percent of total	42.1

NOTE: Zona Technology reported itself as not minority owned for three additional awards. Aurora Flights Sciences reported itself as minority owned through 2008 only.
SOURCE: NASA awards and applications database.

As with Phase I and MOSB Phase II, success rates for WOSBs were lower than those for non-WOSBs in every year of the study period except for FY2005, as shown in Figure 6-12.

Phase II Awards

The number of awards made to WOSBs in any given year was small—the most being 32 in FY2009, when additional funding from the American Recovery and Reinvestment Act (ARRA) became available (see Figure 6-14). After 2009, the number of awards to WOSBs declined to 10 or fewer in each of the three most recent fiscal years for which data are available.

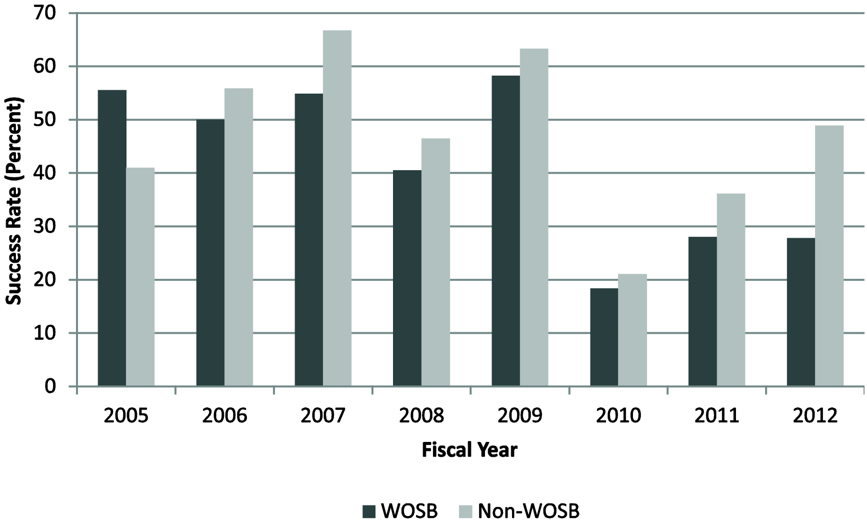

FIGURE 6-12 NASA SBIR Phase II success rates for WOSBs and non-WOSBs, FY2005-2012.
SOURCE: NASA awards and applications database.

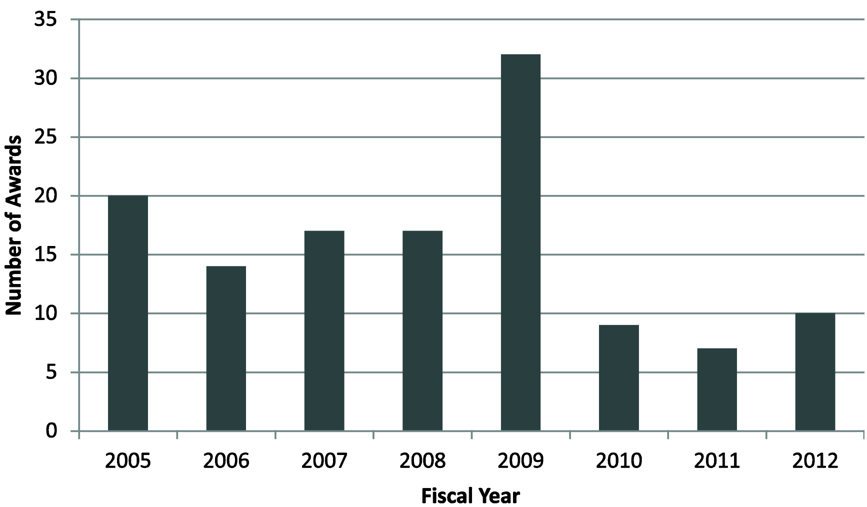

FIGURE 6-13 NASA SBIR Phase II awards to WOSBs, FY2005-2012.
SOURCE: NASA awards and applications database.

Figure 6-14 shows that overall the WOSB share of all awards declined steadily except for the year of ARRA funding. As the share of awards to WOSBs declined, so did the number of awards.

Top Winners Among WOSBs

As expected, many of the WOSBs who led Phase I also led Phase II. There were some changes in the order, largely because of differences in the Phase I to Phase II conversion rate[16] (the share of Phase I awards that are transitioned to Phase II), even among the top three firms. The differences in conversion rates were substantial enough that NASA SBIR program management should analyze them further, because low conversion rates suggest that Phase I resources may not be focused on the most likely projects. Overall, the top winners accounted for 91 out of 146 (62 percent) Phase II to WOSBs during the study period.

Minority-owned Small Businesses

Phase II Applications

NASA SBIR Phase II applications data are missing for FY2013 and FY2014, so only limited conclusions can be drawn, especially about more recent

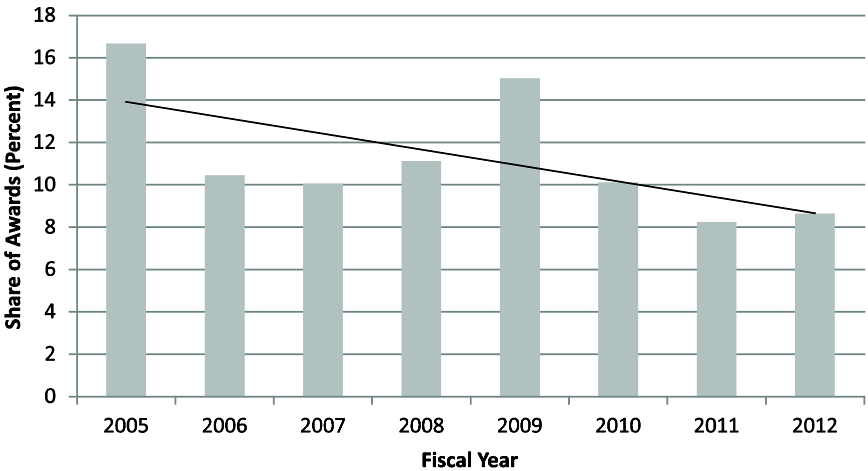

FIGURE 6-14 WOSB share of all NASA SBIR Phase II awards, FY2005-2012.
SOURCE: NASA awards and applications database.

[16]The conversion rate is the number of Phase II awards received by a company expressed as a percentage of the number of Phase I awards received by that company.

TABLE 6-8 Top Winners Among WOSBs, NASA SBIR Phase II awards, FY2005-2014

Company Name	Number of NASA Phase I Awards	Number of NASA Phase II Awards	Phase I-Phase II Conversion Rate (Percent)
Intelligent Automation, Inc.	32	17	53.1
Paragon Space Development Corporation	11	9	81.8
CFD Research Corporation	23	8	34.8
Physical Optics Corporation	20	7	35.0
Microcosm, Inc.	11	6	54.5
InnoSense, LLC	8	5	62.5
Cybernet Systems Corporation	10	5	50.0
Ridgetop Group, Inc.	14	5	35.7
Composite Technology Development, Inc.	7	4	57.1
M4 Engineering, Inc.	6	3	50.0
ElectroChem, Inc.	5	3	60.0
WEVOICE, Inc.	3	3	100.0
SIFT, LLC	2	2	100.0
Sukra Helitek, Inc.	4	2	50.0
Innovative Dynamics, Inc.	2	2	100.0
Ceramic Composites, Inc.	2	2	100.0
Florida Turbine Technologies, Inc.	7	2	28.6
Nuvotronics, LLC	3	2	66.7
Masstech, Inc.	2	2	100.0
Touchstone Research Laboratory, Ltd.	4	2	50.0

NOTE: The conversion rate is the number of Phase II awards received by a company expressed as a percentage of the number of Phase I awards received by that company.
SOURCE: NASA awards and applications database.

trends. Figure 6-15 shows that MOSB and non-MOSB applications tracked quite closely until FY2011 when non-MOSB applications responded to the ARRA funding by rising sharply while MOSB applications declined sharply and remained low in FY2012.

Overall, the MOSB share of Phase II applications declined over the time period, although data for the most recent fiscal years is not available (see Figure 6-16). Success rates for MOSBs and non-MOSBs fluctuated, but MOSB success rates in every year were lower than those for non-MOSB firms (see Figure 6-17). Overall, MOSB success rates were 13 percentage points lower than those for non-MOSBs.

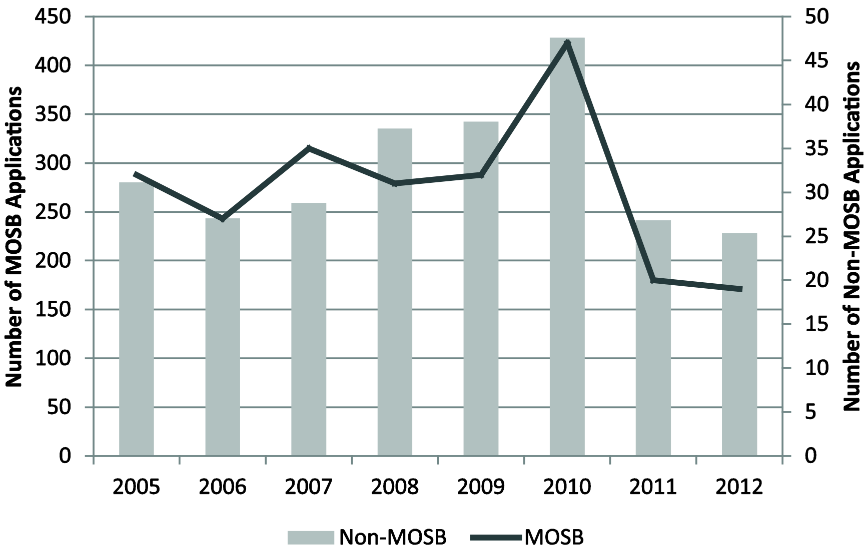

FIGURE 6-15 NASA SBIR Phase II SBIR Applications from MOSBs and non-MOSBs, FY2005-2012.
SOURCE: NASA awards and applications database.

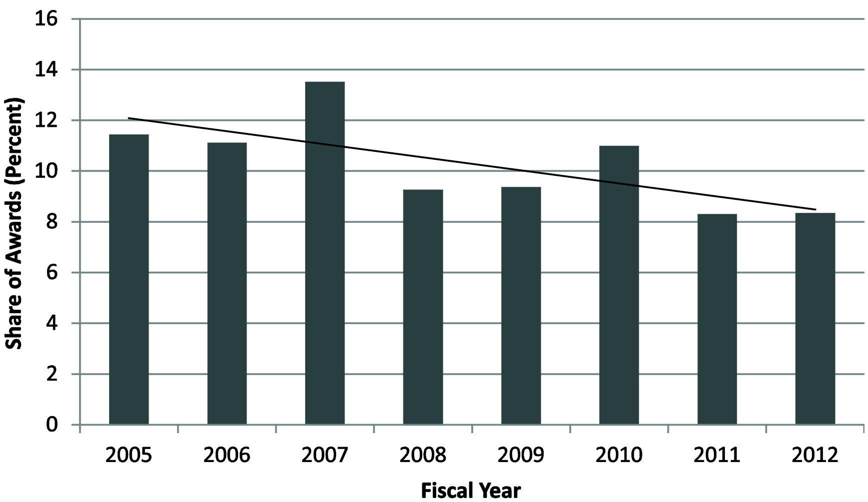

FIGURE 6-16 MOSB share of NASA SBIR Phase II Applications, FY2005-2012.
SOURCE: NASA awards and applications database.

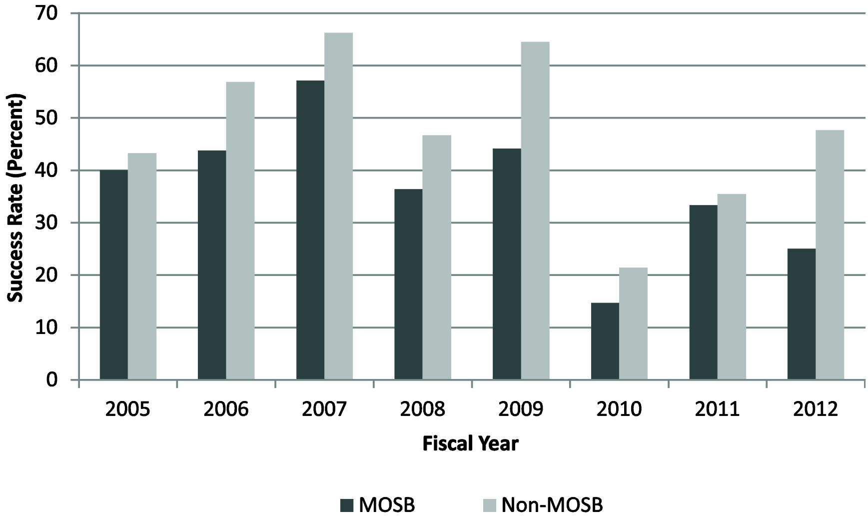

FIGURE 6-17 NASA SBIR Phase II success rates for MOSBs and non-MOSBs, FY2005-2012.
SOURCE: NASA awards and applications database.

Phase II Awards

The data reveal very low levels of awards to MOSBs throughout the study period, with a decline that has, if anything, accelerated in more recent years (see Figure 6-18). In FY2014 NASA reported five Phase II awards to MOSBs, down from 16 in FY2005 and a peak of 19 in FY2009. These data lead directly to the steady decline in the MOSB share of all Phase II SBIR awards, from 13 percent in FY2006 to 6.8 percent in FY2012 (see Figure 6-19).

Top Winners Among MOSBs

Unlike the case for WOSBs, where the top companies are among the biggest winners among all companies, no MOSB received as many as 10 Phase II awards during the period. The top winner, ZONA Technology, received 7 (see Table 6-9). Overall, the top 20 winners received 52 Phase II awards from FY2005 to FY2012, accounting for 59 percent of all MOSB Phase II awards, and 4.8 percent of all Phase II awards.

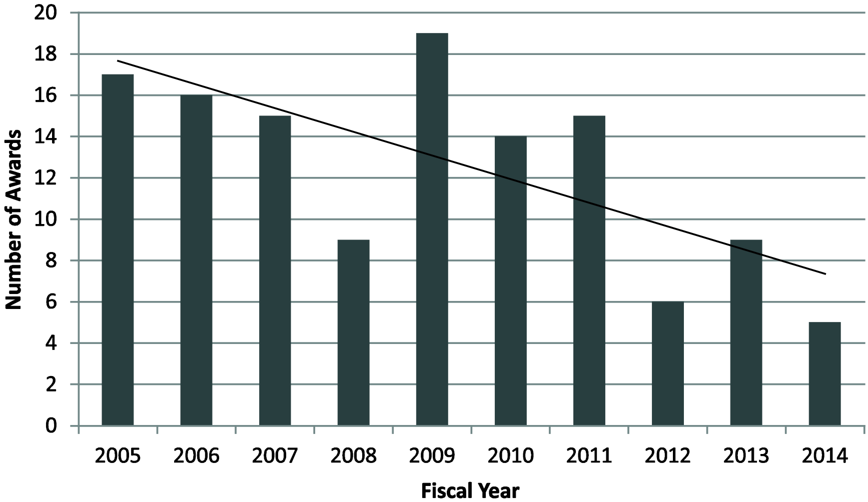

FIGURE 6-18 NASA SBIR Phase II awards to MOSBs, FY2005-2014.
SOURCE: NASA awards and applications database.

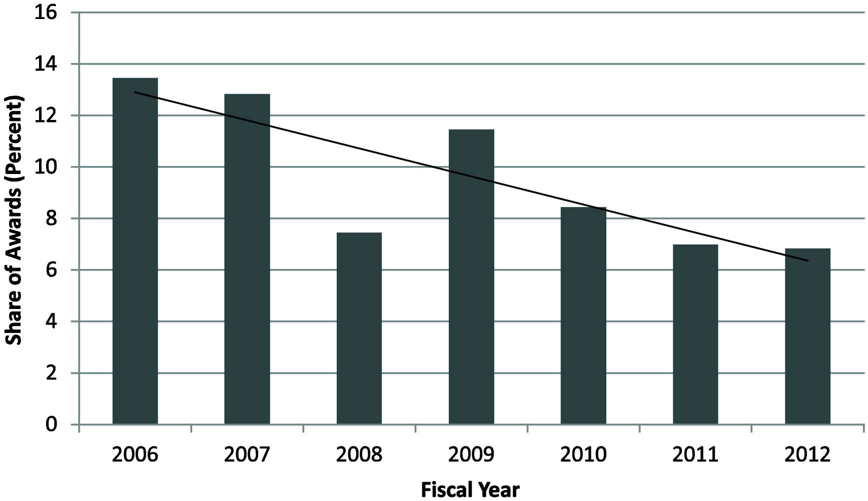

FIGURE 6-19 MOSB share of all NASA SBIR Phase II awards, FY2006-2012.
SOURCE: NASA awards and applications database.

TABLE 6-9 NASA Top MOSB Phase II Awardees, 2005-2014

Company Name	Number of NASA SBIR Phase I Awards	Number of NASA SBIR Phase II Awards	Phase I-Phase II Conversion Rate (Percent)
ZONA Technology, Inc.	13	7	53.8
Cybernet Systems Corporation	10	5	50.0
AdValue Photonics, Inc.	6	4	66.7
Scientific Systems Company, Inc.	17	4	23.5
Mobitrum Corporation	5	4	80.0
Transition45 Technologies, Inc.	4	3	75.0
S&K Aerospace	5	3	60.0
ElectroChem, Inc.	5	3	60.0
Advanced Dynamics, Inc.	6	2	33.3
SVT Associates	13	2	15.4
Discovery Semiconductors, Inc.	2	2	100.0
Ashwin-Ushas Corp, Inc.	2	2	100.0
Tao of Systems Integration, Inc.	3	2	66.7
Aurora Flight Sciences Corporation	8	2	25.0
Applied Material Systems Engineering, Inc. (AMSENG)	5	2	40.0
MetaHeuristics	1	1	100.0
Xigen, LLC		1	n/a
Andrews Space, Inc.	2	1	50.0
N&R Engineering	3	1	33.3
Materials and Systems Research, Inc.	3	1	33.3

NOTE: The conversion rate is the number of Phase II awards received by a company expressed as a percentage of the number of Phase I awards received by that company.
SOURCE: NASA awards and applications database.

7

Insights from Survey Responses[1] and Case Studies

This chapter reviews a range of impacts of the Small Business Innovation Research (SBIR) program based on written responses to open-ended questions solicited in the 2011 Survey and interviews with executives for the case studies. The survey process is described in Appendix A, and the survey instrument is provided in Appendix C. Data from the survey are used to support analysis throughout the report; this chapter draws from the written, open-ended responses to survey questions. Box 7-1 lists the case study firms, all of which were NASA SBIR award winners. Full case studies can be found in Appendix E. Companies selected for case studies are not intended to be statistically representative of NASA SBIR award winners or their award outcomes. Although the number of case studies completed as part of this study is limited, case studies of selected firms can offer qualitative evidence about experiences with the program of firms that have achieved some success and may have acquired some insights regarding how the SBIR program, particular aspects of the program, or the manner in which the company utilized the program may have contributed to that success. Interviewees were also asked to raise any problems and provide their own recommendations about how the program could be improved. Future research could benefit from a broader base of case study companies, including less successful companies, whose responses could provide a useful comparison.

This qualitative review provides needed context for the data discussed in Chapter 5 and aids understanding of the perspectives of award recipients as well as those who did not receive Phase II funding for what they considered to be a highly promising project.

[1]All direct quotations are, unless otherwise indicated, drawn from the case studies included as Appendix E. All survey responses are provided in boxes, and are drawn verbatim from responses to the 2011 Survey of NASA SBIR award recipients.

BOX 7-1
Companies Profiled in Case Studies

The following companies, all winners of NASA SBIR awards, are profiled in case studies in Appendix E:

Advanced Cooling Technologies (ACT)
Cybernet Systems
Continuum Dynamics (CDI)
Eltron Research
Honeybee Robotics
Intelligent Automation (IAI)
Paragon Space Development
Princeton Scientific Instruments
Stottler Henke
Techno-Sciences Inc. (TSI)
ZONA Technology

The impacts of the SBIR program can be clustered into the following broad headings, which are discussed in turn, below:

- Helping with company formation.
- Providing critical early funding for projects and companies that are for various reasons not able to access other sources of funding.
- Validating companies and projects that are subsequently able to raise outside money.
- Funding new technology and product development.
- Other impacts, including building partnerships with prime contractors and building human capital.
- Supporting the agency mission at the National Aeronautics and Space Administration (NASA), including social impacts.

The chapter first draws on case study and survey data regarding program impacts and then summarizes program management issues raised by case study interviewees. Views summarized do not necessarily reflect the views of the committee.

Together, these sections provide the first wide-ranging publicly available feedback by program recipients of the NASA SBIR program.

HELPING WITH COMPANY FORMATION

It is easy to forget that the SBIR program overall provides considerably more funding for very early-stage projects than the entire U.S. venture capital (VC) industry: in 2012, VCs provided $820 million for seed and startup projects compared with the overall spending of $2.13 billion by the SBIR program.[2]

Evidence from interviews and survey responses confirms that, for many companies, SBIR funding allows a company to get started. As one survey respondent noted, "The SBIR program is the sole reason for the existence of our company. Without the original Phase I wins in 2003, it would have been difficult for the founders to gather the resources to start a new company, which has grown from 4 to 26 full time employees in the interim." (See this and other comments on company formation in Box 7-2.) Advanced Cooling Technologies won its first SBIR award in 2003, the year it was founded, and its president Dr. John Zuo, interviewed for a case study, said that SBIR was "very important to the company's success during the early years, and continues to be important today."

BOX 7-2
Survey Responses on SBIR and Company Formation

"SBIR was essential to our company. Beginning with a small Phase I DARPA SBIR in 1993, our company developed the beginnings of a new motor technology."

"The SBIR program is the sole reason for the existence of our company. Without the original Phase I wins in 2003, it would have been difficult for the founders to gather the resources to start a new company, which has grown from 4 to 26 full time employees in the interim."

"Without this program our company would never have been founded, let alone grow to 98 employees and 3 spin off companies."

"The SBIR program is the only win - win program I am aware of for small businesses working with US Government Research entities such as NASA. Without the SBIR funding, this company would not have existed at all..."

SOURCE: 2011 Survey.

[2] PriceWaterHouseCoopers MoneyTree Survey, https://www.pwcmoneytree.com/MTPublic/ns/nav.jsp?page=historical, accessed Jan 28 2014. See also http://www.sbir.gov/awards/annual-reports, accessed April 24, 2015.

PROVIDING CRITICAL EARLY FUNDING OF PROJECTS

Commercial funding from investors or lenders is often very difficult to find for small or newer companies with limited records, working to develop products that do not yet exist and hence have no existing market. These funding problems center on a number of issues, including access to early or seed funding and funding problems for projects that have very long lead times.

Very early-stage funding is largely unavailable from commercial sources, especially in areas with limited markets and long timelines. As a result, the SBIR program provides crucial seed funding for projects that may otherwise have difficulty obtaining funding. As Mr. Anderson (Paragon) noted that SBIR provides seed funding to explore an idea. Paragon usually loses money on Phase I, and sometimes loses money on Phase II, so SBIR is a supplement to internal funding rather than being a profit center.[3] Box 7-3 provides survey responses on SBIR as a critical early funder.

Many survey respondents also noted that their research required the investment of considerable time and resources before it would become possible to reach the market. The ongoing support for longer-term projects was seen by many as a particularly important characteristic of NASA SBIR awards. (See Box 7-4 for related suvey comments.)

VALIDATING COMPANIES

SBIR funding can reduce the risk of projects to a level that investors are willing to accept. Risk is a key ingredient in private-sector funding algorithms: the higher the risk, the less likely funders are to invest (and the more equity they require). In addition, developing new high-tech products is an inherently risky business: the more innovative the product and the less developed the existing market, the greater the risk.

By funding the movement of projects along the technological development curve[4], SBIR helps companies overcome technological risks. In some cases, SBIR funding helps lower project risk. But in others, SBIR funding allows companies to develop projects that otherwise would be too risky to contemplate. (See Box 7-5 for related survey comments.)

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[3]Dr. MacCallum was a co-founder of Paragon Space Development Corporation and served as its chief executive officer for over 20 years. He is currently the chief technology officer for World View Enterprises.

[4]This is the idea that a technology's performance trajectory may be described as a curve, where performance is plotted against time, and where the curve may take an S-shape—evolving slowly in the beginning, at some point achieving more rapid advancement, such as when a breakthrough is achieved, and eventually slowing as the technology comes up against limits of what is at the time scientifically possible.

BOX 7-3
Survey Responses on the Critical Early Role of SBIR

"After 6 years of hard grind as a start-up, NASA SBIR was the only funding opportunity that recognized our skills to produce [our new technology]. No Angel Investors, no VC's, in [our home state], or US wide could be persuaded to invest."

"Because we are addressing a complex technology with a limited market, it is unlikely, if not impossible to obtain funding from private sources. Developing such a product often requires much more investment than even those knowledgeable in the field would anticipate. Hence, even if private funding were available, the risk would be too great for investors."

"SBIR funding was the only funding we could achieve. The VC investors that we engaged look on our technology as too early-stage and too risky. Angel investors were scared away by fears of the regulatory ambiguities."

"The successful completion of this program helped us improve our [XYZ fabrication technology], which greatly contributed to our [XXX] division success."

"The Phase II funding allowed for the development of a product that is essential to the survival of our company."

"The technologies we developed under SBIR funding are at the heart of the products that are our backbone for the future."

"This particular SBIR helped us develop [XXX technology] that is fundamental to many of our products and research systems that we manufacture and was a huge advance for us."

"While the experience was positive, we did not have much business savvy."

NOTE: Company identifying information is struck from the survey comment.
SOURCE: 2011 Survey.

FUNDING TECHNOLOGY AND PRODUCT DEVELOPMENT

Many small companies have limited internal resources for research and development. Often, the SBIR program provides the funding needed to take an idea for an innovative product to the point at which it may enter the market or attract additional funding needed to do so. (See Box 7-6 for related survey comments.)

BOX 7-4
Survey Responses on Long-Cycle Research

"SBIR funding helped develop unconventional concepts that were either initially not ready for immediate applications or readily acceptable to the user community for their on-going programs. It has taken many years to mature the technology."

"Aerospace engineering requires long-term maturation process to provide acceptable levels of reliability, safety, and operational life. The SBIR program has given small companies [opportunities] to go through this process without going out of business."

SOURCE: 2011 Survey.

BOX 7-5
Survey Responses on High-Risk High-Reward

"The technology development we perform is high risk, high payoff. Many of our other SBIR programs have had tremendous results. Without the SBIR program, we would not have a technology company at all due to the risk inherent with the technology we are developing."

"The SBIR program allows us and other companies to perform high risk, translational research on applied (i.e., of potentially significant commercial value) which would probably not take place under any other existing mechanism of federal or state government support. It has been a huge job creator in our region."

"Because we are addressing a complex technology with a limited market, it is unlikely, if not impossible to obtain funding from private sources. Developing such a product often requires much more investment than even those knowledgeable in the field would anticipate. Hence, even if private funding were available, the risk would be too great for investors.

SOURCE: 2011 Survey.

Funding Core Technology Development

For many SBIR companies, the program funded development of the company's core technology or at least its first commercially viable technology. In 2005, Advanced Cooling Technologies (ACT) won awards from NASA and the Department of Defense (DoD) to explore heat exchanger technologies.[5] As

[5]NASA Phase I "Heat Pipe Heat Exchangers with Double Isolation Layers for Prevention of Interpath Leakage;" DoD Phase I "VCHP Heat Exchanger for Passive Thermal Management of a Fuel Cell Reforming Process."

BOX 7-6
Survey Responses on SBIR and Commercialization

"We have grown to an almost $10M/year business, due to the fact that the SBIRs allowed us to get enough technology developed through feasibility that we could garner industry support."

"There were several spin offs from this development into other products at the company."

"This project allowed us to develop a world-class [XXX technology] that has resulted in over $4 million in follow on sales and development services."

"Our company has had SBIR awards in other technology areas that have resulted in 32 patents, 3 in-house products, and three active commercial licenses that are generating revenue for the company."

"Such products provide us with a significant competitive edge, and the IP protection afforded by SBIRs keeps that edge for several years."

"SBIR enabled core technology development which has spurred several offshoot technologies and significant licensing revenues from [XXX sector]."

"SBIR funding has provided the technology base that led to two significant (one was $6.5M, one was $26M) NASA awards to build hardware that supported earth science satellite missions."

[Company] "was unable to maintain a revenue stream and business viability."

NOTE: Company identifying information is struck from the survey comment.
SOURCE: 2011 Survey.

detailed in the case study, these technologies generated very promising results, and the company then undertook a market survey, which encouraged it to invest its own funding to accelerate development. The funding was used to develop and launch products aimed at addressing needs expressed by thermal control customers. At the same time, the company continued with its R&D through the end of the Phase II awards in 2006, and also invested in ISO 9001 certification, a key to successful market penetration.

The Constant and Variable Conductance Heat Pipe (CCHP and VCHP) products that emerged have generated millions of dollars in revenues for ACT.[6]

[6]According to ACT, "Variable conductance heat pipes (VCHPs) are used to achieve temperature control. This is accomplished by blocking a fraction of the condenser with a small amount of non-condensable gas. When the heat load or the condenser temperature increases, the heat pipe temperature tends to rise. The increased vapor pressure compresses the non-condensable gas, exposing more condenser area and as a result increases the heat pipe conductance. The opposite happens when the heat load or the condenser temperature decreases. The variation of the

At ZONA Technology, Mr. Chen observed that the SBIR program played a critical role in the development of the company, because SBIR funding from the Air Force and NASA supported development of the company's first product, ZONA51. And at TSI, Dr. Gil Blankenship noted that the company transitioned toward a product-driven model, SBIR funded the research that led to both of the company's core product lines—SARSAT search and rescue, and Trident ship-based monitoring. (See Box 7-7 for related survey responses.)

Non-Linear Development

Among the many responses received from the survey were a considerable number that illustrated the importance of what can be termed a "nonlinear" path for product development. Indeed, the path from idea to innovation to prototype to product to commercial success is rarely direct for small innovative firms. In many cases, firms must struggle to find the right fit between their technical ideas and market needs; often this requires re-engineering their products, adapting existing approaches, or even starting again after discovering that a core technical expectation was simply wrong.

For example, NASA SBIR awards have played a pivotal role in supporting both Continuum Dynamics and, indirectly, rotorcraft manufacturing in the United States. According to Dr. Bilanin, all U.S. manufacturers (and most

BOX 7-7
Survey Responses on Core Product Development

"The Phase II funding allowed for the development of a product that is essential to the survival of our company."

"The successful completion of this program helped us improve our overall [XXX technology], which greatly contributed to our [XXX division] success."

"The technologies we developed under SBIR funding are at the heart of the products that are our backbone for the future."

"This particular SBIR helped us develop a [XXX product] that is fundamental to many of our products and research systems that we manufacture and was a huge advance for us."

"This particular program and related work was discontinued at the end of the Phase I effort, therefore there was no long-term effect."

NOTE: Company identifying information is struck from the survey comment.
SOURCE: 2011 Survey.

conductance keeps the heat pipe operating temperature nearly constant over a wide range of heat inputs and condenser thermal environments."

of those overseas) now utilize CDI rotorcraft software in the design and analysis of helicopters.

Expansion into New Markets

There is a blurred line between core products and new applications, which often involve core technologies being applied in new ways. Nonetheless, a number of interviewees and many survey respondents indicated that SBIR funding was being used to expand a company's products and offerings beyond its first product and its core product.

One example of a firm working diligently to adapt its skills to new markets is Paragon Space Development Corporation. The company was formed to work on life support systems in space environments and continues to be a valued partner for many NASA projects. However, Paragon also developed the Paragon Dive System for the U.S. Navy, which protects divers working in contaminated waters. And more recently, Paragon was the technology (suit) provider for Alan Eustace's dive from near space in October 2014 in which he broke the altitude record for human free fall.[7]

Other companies also use SBIR funding to explore new markets. Although SBIR has funded the development of ZONA's core technologies, it has also, according to Mr. Chen, funded the innovation that drives growth for the company in the form of new technology that can be commercialized. In addition, at TSI, Dr. Blankenship said that SBIR funding supported the company's push into new technologies and new markets such as air-driven technology for aircraft flaps.

Selling into NASA

The small size, long timeline, and specialized nature of NASA acquisitions provide formidable challenges for NASA SBIR companies. Typically, procurement contracts for SBIR-funded technologies at NASA are not large enough or sustained enough to support a viable business although, of course, even tightly targeted mission-oriented projects can do on occasion produce technologies with sometimes significant non-NASA market potential.

The lengthy time lags in NASA development cycles offer another challenge. The timeline between the start of a Phase II award and its insertion into the production phase of a NASA project (usually requiring a Technology Readiness Level (TRL) of 8 or 9)[8]can be over a decade.

During this long period, there is often insufficient funding to support further development of the technology. Although large companies are more

[7]For an account of providing the suit for the Eustace dive, see http://www.paragonsdc.com/stratex/.
[8]Definitions of NASA Technology Readiness Levels are available at http://www.esto.nasa.gov/files/trl_definitions.pdf.

likely to have access to internal or external funding, SBIR companies are typically too small to do so.

Changes in NASA mission objectives during this long period of development can also be disastrous for SBIR projects. For example, Dr. Zuo of ACT said that an initial $1.2 million award from Glenn Research Center, although technically successful, was focused on a project that NASA subsequently cancelled.

Paragon has encountered certain problems in part because it has remained primarily a government contractor working for NASA. These funding sources provide low margins, which mean that when times become more difficult the company usually does not have a significant backlog of work or resource base to turn to. This makes it challenging to weather any kind of difficulties with government funding cycles.

Mr. Stottler of Stottler Henke identified what he sees as a systemic problem in the linkage between SBIR funding and the rest of the NASA budget process. Because SBIR-funded projects are not part of the standard budgeting process at the agency, there is typically minimal or zero follow-on funding even for maintenance. Good projects are therefore sometimes left to die.

OTHER COMPANY IMPACTS

Partnering with Primes

Some SBIR-recipient companies have made concerted efforts to work with NASA prime contractors. Dr. Haynes of IAI noted that SBIR awards were often the basis for technology capabilities that allowed the company to become involved in major projects as partners or major subcontractors to prime contractors. IAI has been included on major bid teams led by Raytheon, Honeywell, Northrop Grumman, and Lockheed Martin.

IAI has made a strategic shift toward commercialization through partnerships, beyond its existing business model as a contract research company largely focused on SBIR, by developing close relations with a number of prime contractors. In many cases, IAI has become a part of the bid team for major contracts. In others, primes have picked up what IAI calls "productized services," packages of technology and related service contracts, for integration into larger projects. Prime customers include BAE Systems, Honeywell, Northrop Grumman, Boeing, and Raytheon.[9]

Capacity Building—Human Capital

SBIR funding can be used in part to provide small companies with necessary equipment, but interviews and survey responses show that the human

[9]TecFusion™ is an attempt to systematically bring SBCs together with primes after Phase II is completed.

BOX 7-8
Survey Responses on Partnerships

"With the SBIR funds, I was able to form working relationships with other companies that I still rely on today."

"The award of SBIR funds legitimizes the work my company does. As a small business owner, it is hard to be taken seriously by the likes of NASA, the Air Force, the Navy, Lockheed Martin, and Boeing. All of these organizations have proposed the use of my company's technology at some time or the other since 2002, in a large part due to the SBIR Phase II work that was done."

"[SBIR funded] research enabled us to make materials that did not exist and get companies to test them. This made us value added partners instead of a Small Disadvantaged Business looking for a handout."

SOURCE: 2011 Survey.

capital effects can be more important. Most directly, SBIR funding allows companies to hire staff, typically approximately two to four full-time staff at the PhD level for a Phase II project. SBIR funding has other capacity building effects as well. According to one survey respondent, "During the actual work phases the principal investigator (PI) and co-workers communicated with other colleagues in the field which facilitated various aspects of the project while providing industrial training to PI. In fact this PI has gone on to start another company drawing on what was learned from the NASA SBIR program."

SUPPORTING THE AGENCY MISSION

Building Innovative Technologies Needed by NASA

Evidence from cases strongly supports the view that the SBIR program provides important technologies that are taken up by NASA and could perhaps not be acquired by other mechanisms.

Honeybee has, according to Irene Yachbes, its director of technology development, provided technologies used by NASA for on-Mars missions:

- The Rock Abrasion Tool (RAT) was the first machine to access rock interiors on another planet. Designed, developed, and operated by Honeybee Robotics as a part of NASA's 2003 Mars Exploration project, the RAT uses grinding wheels of diamond dust and resin to gently abrade the surface of Martian rocks (see Box 7-9).[10]

[10]For more on Honeybee's technologies used for on-Mars missions, see http://marsrover.nasa.gov/mission/spacecraft_instru_rat.html.

- The Icy Soil Acquisition Device (ISAD) flew on NASA's 2007 Phoenix Mission. The ISAD (sometimes called the Phoenix Scoop) is both a soil scoop and a precision ice-sampling tool integrated on the end of the robotic arm of the Phoenix lander.[11] The ISAD was used to dig into the surface surrounding the lander and to acquire icy soil samples. These samples were then delivered to science instruments for examination. According to Ms. Yachbes, Honeybee designed, built, and tested the ISAD in only 14 months in response to an urgent request from NASA for improved methods of gathering samples from very icy soil targets. This development was possible in part because Honeybee maintains the facilities and expertise for preparing and testing tools utilizing simulated Mars soil under simulated Mars temperatures.

These highly specialized capabilities have been developed by Honeybee in the course of more than 100 projects for NASA, serving the needs of nine NASA Centers.

BOX 7-9
Honeybee Rock Abrasion Tool (RAT) Project

The Rock Abrasion Tool (RAT) was the first machine to access rock interiors on another planet. According to Ms. Yachbes, Honeybee was originally brought into the Mars mission by the principal investigator, Steve Squires, to implement some preliminary ideas about a rock abrasion tool. Designed, developed, and operated by Honeybee Robotics as a part of NASA's 2003 Mars Exploration project, the RAT uses grinding wheels of diamond dust and resin to gently abrade the surface of Martian rocks.[a]

The RAT meets a number of critical mission needs. To begin with, it is compact and low power. Using three small motors, the RAT requires only 11 watts of electricity to cut into Martian rock. The RAT weighs 685 grams, and is 7 cm in diameter and 10 cm long—about the size of a coke can. The RAT also is used to develop data about the properties of Martian rocks. Remarkably, the RAT has continued to perform long beyond its design life in the dusty Mars environment. In fact, the RAT was originally designed to open 1-3 rocks. Ms. Yachbes noted that during its initial operations, it completed more than 100 grinding and brushing operations, and was instrumental in some of the key Mars discoveries—notably blueberries (hematite concretions), which are on Earth found only in the presence of large amounts of water.

[a]See http://marsrover.nasa.gov/mission/spacecraft_instru_rat.html.

SOURCE: Case Study of Honeybee Robotics in Appendix E of this report.

[11]For more on the ISAD, see http://phoenix.lpl.arizona.edu/index.php.

Many other companies had similar (although perhaps not such dramatic stories) about the technologies developed for NASA. According to Dr. Bilanin, all U.S. manufacturers (and most of those overseas) now utilize CDI rotorcraft software in the design and analysis of helicopters.

Other companies have developed a consistent relationship with NASA that allows them to become a go-to source of high-end technical expertise. Paragon, for example, has been involved in a number of ground-breaking scientific and technical efforts (see Box 7-10).

Working with NASA Centers and Commercial Partners

NASA Centers are important research enterprises in their own right. They often maintain unique technical facilities (such as the wind tunnel at Glenn Research Center) and have a highly qualified staff of engineers and scientists. Over time, some SBIR companies are able to develop important ongoing relationships with NASA Centers, which serve both parties well.

BOX 7-10
SBIR and Paragon Space "Firsts"

The first commercial experiment on the International Space Station (ISS). "Paragon designed, fabricated, tested, and prepared" this experiment for flight in only 10 weeks, utilizing a Russian Progress vehicle. Paragon claims "this work was the pathfinder for all future commercial projects involving the RSA/Energia and SPACEHAB."

"The first animals in space to perform complete life cycles." Paragon managed "completed life cycles from birth, to adulthood, to procreation" and subsequent generation of births. It "did so during a [4-]month experiment" on the Mir Space Station. This "first multigenerational animal experiment in space is also [still] the longest [duration] microgravity animal experiment"—more than 18 months.

Subsequent experiments on "four space flights (shuttle, ISS, Mir)" used Paragon's Autonomous Biological System (ABS) to deploy the "first aquatic angiosperms to be grown in space, the first completely bioregenerative life support system in space, and among the first gravitational ecology experiments." Also, the "first full-motion, long-duration video (4 months, 60 total minutes) of plant and animal growth on orbit was accomplished with a Paragon-designed digital camera system using a Paragon-specified Sony DCR-7 digital camera with custom EPROM."

SOURCE: Case Study of Paragon Space Development in Appendix E of this report. Quoted text originally from Paragon Space Development Corporation website, http://paragonsdc.com.

For example, Dr. Bilanin (CDI) noted CDI had built a long standing and durable relationship with some NASA centers, in some cases reaching back more than 30 years. The company's collaborative work with NASA/Ames had numerous benefits for the company—including a steady flow of work, access to NASA tools and testing—but also for NASA, where CDI had consistently delivered the tools needed to solve NASA-defined problems. In addition, the Center had helped to link CDI to the industry groups and companies that came to Ames to use NASA facilities. (See Box 7-11 for an example.) This linkage was especially helpful in the early years of CDI.

These soft linkages are important: they reflect the two-way flow of knowledge between the public and private sectors, facilitated to an important degree by publications afforded by SBIR contracts.

Companies that are successful in working with the NASA SBIR program tend to be able to serve more than one Center. For example, Intelligent Automation has developed relationships with NASA-Ames (related to Air Traffic Management (ATM) systems), NASA-Goddard (related to Airborne

BOX 7-11
Continuum Dynamics CHARM Technology

Continuum Dynamics (CDI) has leveraged SBIR projects funded by NASA, in particular projects sponsored by the Subsonic Rotary Wing and Supersonics elements of the Fundamental Aeronautics Program through NASA/Ames, NASA/Glenn, and NASA/Langley Research Centers, to build a new set of modeling capabilities that have had a substantial impact especially in the rotorcraft segment of the aerospace industry.

This work resulted in CDI's Comprehensive Hierarchical Aeromechanics Rotorcraft Model (CHARM)—software that models the complete aerodynamics and dynamics of rotorcraft in general flight conditions, resulting from more than 25 years of continuous development of rotorcraft modeling technologies at CDI. NASA awards in the 1980s and 1990s for helicopter wake modeling played a central role.

CHARM provides tools for advanced rotorcraft aerodynamic design and research on emerging rotorcraft technologies. CHARM supports many different modeling needs.

CHARM is the center-piece of CDI's aerospace modeling capabilities, but CDI has also developed a number of complementary capabilities. These tools, built with the help of NASA and other SBIR funding, have positioned CDI to develop close working relations with large aerospace and defense contractors such as Sikorsky Aircraft, Lockheed Martin, Boeing, CAE, and General Electric Aircraft Engines.

SOURCE: Case Study of Continuum Dynamics in Appendix E of this report.

SAR radar for biomass measurement), NASA Langley and NASA Glenn (related to ATM and UAS systems).

Specialized Capabilities

Although SBIR companies are small, they may have developed specialized capacities that are uniquely useful to meeting agency mission needs. For example, Honeybee's facilities include small-scale mechanical and electrical test equipment calibrated in conformance with MIL-STD-45662 and ISO 17025. Equipment includes a FARO GagePlus articulated-arm coordinate measuring machine for precise measurement of large or complex parts, optical comparators and microscopes, digital micrometers, gages, precision balances, etc. The Quality Control room also features ultrasonic cleaning equipment for parts processing and secure storage in preparation for flight.

Paragon became part of the team working on the replacement for the shuttle starting in the late 1990s and soon became involved in the Orion program and more generally in space capsule life support design. The company has worked successfully in these fields for more than 17 years. Even today, it is deeply involved in work on the next generation of space suits and on a capsule for moon operations, both for NASA.

Four software systems built by Stottler Henke have been listed in *Spinoff*, NASA's showcase of successful spin-off technologies. In 2006, NASA released a Hallmarks of Success video[12] that showcases innovative scheduling and training technologies that Stottler Henke developed for NASA. One of these systems, the Automated Manifest Planner (AMP), "automatically makes scheduling decisions based on knowledge input by expert schedulers."[13] It "automatically schedules long-term space shuttle processing operations and sets launch dates at Kennedy Space Center."[14] It was designed using Artificial Intelligence (AI) "techniques, allowing expert shuttle schedulers to input their knowledge to create a working automatic scheduling system."[15]

More generally, evidence from the survey indicates that in many cases the NASA SBIR program does support innovative technologies that could not otherwise be funded (see Box 7-12).

Social Impacts

Not all outcomes from SBIR have substantial commercial impacts, but they can still be important (see Box 7-13). For example, CDI used SBIR awards

[12]For more on NASA's Hallmarks of Success video, see http://www.stottlerhenke.com/company/nasa_hallmarks.htm.
[13]National Aeronautics and Space Administration SBIR website, <http://sbir.gsfc.nasa.gov>.
[14]Ibid.
[15]Ibid.

BOX 7-12
Survey Responses on Supporting Innovative Technologies

"This funding has been essential to allow us to bring the innovative [XXX technology] we are developing to the point of technological maturity where we can get investors interested in supporting product development, and get customers interested in using our technology."

"SBIR dramatically expanded the breadth and depth of R&D that the company could pursue, hence dramatically increasing the scope and complexity of innovations that the company could create and commercialize."

"The SBIR program has allowed our company to pursue a revolutionary technology that will benefit both NASA and the DOD."

"The SBIR program is critical for developing innovative technologies."

"Every technology that we sell was originally developed with SBIR funding, even when it was further developed with private funding."

SBIR funding permits technology exploration that otherwise would be unlikely to occur. Some of these technologies develop into mature products, others don't. The role SBIR plays is critical for spurring innovation.

NOTE: Company identifying information is struck from the survey comment.
SOURCE: 2011 Survey.

from NASA/Glenn in 1988 and 1993 to fund development of software that predicts turbomachinery flutter, subsequently adapted for use by New Jersey pharmaceutical companies and the Washington Public Power Supply System.

In addition, some companies appear to see the diffusion of knowledge as an aspect of marketing. Mr. Anderson (Paragon) said that publication in peer-reviewed journals is a part of maintaining his company's competitiveness: "We often publish, because it shows our quality and sometimes scares off the competition when they know how far ahead you are." Paragon's strategy is to create intellectual property (IP) cover using patents and then to publish. This strategy seems to have helped Paragon during the review process. Similarly, the Stottler Henke website lists more than 100 published academic papers.

Rapid Response

The SBIR program is in some circumstances able to develop needed technologies much faster than standard procurement for NASA and DoD (see Box 7-14). For example, Stottler Henke sees its role, in some respects, as performing closely specified research for NASA and DoD, plugging gaps and

BOX 7-13
Survey Responses on Social Impacts

"The SBIR program has allowed us to develop a highly specialized technology that is being used throughout the world to study and solve pressing environmental problems, such as global climate change. This technology has also become a multi-million dollar commercial success for our company and continues to grow each year."

"Our licenses are to American-owned companies, and thus the SBIR program has helped promote sales by America companies even though we ourselves are not instrument manufacturers."

"Because we are addressing a complex technology with a limited market, it is unlikely, if not impossible to obtain funding from private sources. Developing such a product often requires much more investment than even those knowledgeable in the field would anticipate. Hence, even if private funding were available, the risk would be too great for investors. However, the technology (in this case, XXX) is of vital importance."

NOTE: Company identifying information is struck from the survey comment.
SOURCE: 2011 Survey.

BOX 7-14
Survey Responses on Contributions to Agency Mission

"The SBIR program allowed us to develop software tools that are now in use throughout the government and industry servicing civilian and DoD needs related to the [XXX industry]."

"SBIR projects in general, provide an excellent opportunity for the Government to receive innovative applied research from companies that may not already be known in the field."

"The barriers to entry into the Government-funded R&D field are significant. The SBIR program provides an easy and relatively low-cost way for the Government to give aggressive small companies a chance to show their capabilities."

"We introduced [XXX technology] to the NASA Earth Sciences community, resulting in Phase III field demonstration."

NOTE: Company identifying information is struck from the survey comments.
SOURCE: 2011 Survey.

meeting rapid turn-around requirements, while the agencies use the SBIR program to fund this work. Mr. Stottler observed that Phase II awards to his company usually result in operational software, rather than the preliminary prototypes often delivered at the end of Phase II in other (non-software) sectors.

According to Ms. Yachbes, Honeybee designed, built, and tested the Icy Soil Acquisition Device (ISAD) in only 14 months in response to an urgent request from NASA for improved methods of gathering samples from very icy soil targets. This development was possible in part because Honeybee maintains the facilities and expertise for preparing and testing tools utilizing simulated Mars soil under simulated Mars temperatures.

ISSUES IN PROGRAM MANAGEMENT

Solicitation Topics

Mr. Stottler of Stottler Henke observed that the topics developed by NASA originated in two distinct sets of locations. SBIR topics supported by operational groups with clear needs and objectives were often successful and usually generated the necessary follow-up funding. SBIR topics sponsored by research-oriented components within NASA, often not connected to end users, were less likely to find useful take-up within the agency.

Mr. Stottler also observed that the NASA topics did not change very much year-to-year. Continuity, however, had costs as well as benefits for the companies.

In Mr. Stottler's view, annual solicitations are no longer sufficient. Technology and requirements move too rapidly, and given the topic-driven nature of the process at NASA promising approaches could wait 2 years or more before an appropriate topic became available. Mr. Anderson (Paragon) supported bi-annual solicitations as in many other agencies. In his view, the current approach imposed substantial application burdens on NASA-centric companies, especially those where senior staff time was limited.

More generally, Dr. Jacobus (Cybernet) said that he saw the SBIR program as serving two distinctly different mission needs. In part, the SBIR program is aimed at providing specific technologies needed for use within NASA (somewhat like the DoD SBIR program). At the same time, the SBIR program also supports the forward-thinking emphasis within NASA on highly innovative research. In his view, NASA should strongly consider formally separating these objectives into two distinct solicitations, much as NIH has different solicitations for contracts and grants. Such an approach would avoid confusion in the selection process and would allow NASA to identify its needs more effectively.

Application Procedures

In general, companies had few specific complaints about the application process for NASA SBIR awards. Mr. Stottler (Stottler Henke) strongly approved of the DoD pre-solicitation period, during which agency representatives are available for discussion. He would like to see similar "communications windows" opened during the solicitation process at other agencies, particularly NASA. Similarly, Mr. Chen (ZONA) said that he wanted to see NASA adopt the DoD "talk time" approach, in which program managers would be made available for discussion and feedback for a set period after initial publication of the solicitation. Several other company representatives made similar comments.

Some company representatives noted that applications were much more likely to be successful if the company showed preliminary work of its own in the Phase I application. ZONA makes a practice of doing so in a conscious effort to improve success rates. Mr. Chen (ZONA) suggested that this was especially important when the proposed project was highly innovative. For example, ZONA did significant proof-of-concept work on the Dry Wind Tunnel before even applying for a Phase I SBIR award.

Application Review and Award Selection

The SBIR review process is an operational challenge at any agency. It is always difficult to assemble the hundreds of competent reviewers required for an effective review process. Overall, interviewed executives believed that the quality of technical review at NASA is very good. However, others thought the review process was flawed in several ways:

- Commercial reviews are often handled by scientists who have no expertise in commercial assessment. (Mr. Grimmer, Eltron).
- Reviewer can misunderstand the technology. Mr. Grimmer (Eltron) noted a lack of technical expertise among reviewers as a concern. Other companies (e.g., Stottler Henke) observed that there was a considerable random element in proposal review. Mr. Stottler said that the quality of reviews could be considerably improved if applicants were encouraged to provide the agencies with feedback about reviewers.
- Real-time feedback and review. Mr. Grimmer (Eltron) strongly believes that using new technologies to permit real-time rebuttal of reviews is needed.

More generally, several company representatives indicated that there is an appetite among the recipient base for mechanisms that would help to address inappropriate or inexplicable rejections. Two such mechanisms are resubmission and rebuttal. Companies such as Paragon see substantial value in allowing applicants to improve their applications in response to review.

Some agencies already address the issue of reviewers who misunderstand key elements of the proposal. The U.S. Department for Agriculture, for example, already uses a system whereby the program officer emails the company a list of up to 10 questions arising from review. This gives the company an opportunity to make its case in more detail and to clear away misunderstandings.

Interviewees had other comments and suggestions: Dr. Lowrance (Princeton Scientific Instruments) was concerned about reviewer comments that addressed commercialization plans in the context of Phase I proposals. He believed that reviewers focus on this in part to avoid addressing technical issues elsewhere that they may not feel qualified to judge. He recommended that the importance of the Phase I commercialization plan in selection decisions be sharply reduced or that the need for such a plan be eliminated altogether at this stage.

Funding Gaps and Issues

The 2011 Survey indicated that funding gaps between Phase I and Phase II remain an issue for many companies. Stottler Henke's representative said that the company experienced significant Phase I-Phase II gaps with NASA awards, which would have been damaging absent other work. Mr. Stottler observed that the key is for the company to find ways to retain existing project staff, paying for them from other sources during the gap period.

Paragon has also encountered problems in part because it has remained primarily a government contractor working for NASA. The SBIR program (and other government contracts) provides low profit margins, so when times become more difficult the company usually does not have a significant financial base to turn to. This makes it difficult to weather difficulties with government funding cycles.

Paragon noted that, overall, DoD's funding structure works much better for Paragon than NASA's. NASA funds Phase II awards steadily in small amounts over 2 years, so that all Phase II projects must take 2 years even if they could be completed more rapidly. Some of Paragon's DoD awards ran much faster—one recent Phase II award was in fact completed in 9 months. It could therefore be argued that the NASA approach represents a flawed contracting model. It provides a fixed fee (until recently $350,000 per year for 2 years), payable month by month, based on invoices indicating work completed. Effectively, it is a time and materials contract, but one with a fixed fee and an annual funding cap. Recipient companies must account for every hour of work—so any acceleration would increase risk. Paragon would much prefer payment for milestones accomplished. This is the approach adopted by NASA under Space Act agreements, under which a $1.4 million contract received by Paragon in 2010 is milestone-based.

This more effective approach has also been adopted more recently by Navy in particular, and Paragon sees it as a very positive development. Phase II could be a much more flexible mechanism, with some funding held back to make additional investments in successful projects. In general, one size does not fit all, and flexibility is critical. In addition, Paragon suggested that NASA could adopt the Navy model for providing Phase I-II bridging funds.

Ms. Yachbes of Honeybee supports the DoD concept of bridge funding and would recommend it to NASA. The company also supported the notion of a 9-month Phase I, because some necessary work simply takes longer than 6 months, especially because in reality the timeline is even shorter, because Phase II preparation must begin well before the proposal is due and usually depends on Phase I results.

Funding Levels

Several interviewees commented on the funding levels for awards.

Dr. Zuo of ACT said that he was strongly opposed to increases in the size of awards if there was not additional funding available to pay for the increase. He argued that in funding early-stage research, it would be important for NASA to hedge its bets and to ensure that research funding is not overly concentrated, because it was not possible to determine in advance which projects would in the end be successful. He was convinced that a reduction in the number of awards—even if each received increased funding—would result in reduced outcomes. He also believed that this concentration of resources would favor certain companies. Mr. Stottler of Stottler Henke was opposed to increasing the size of Phase I and Phase II awards. He believed that high-quality work can be accomplished at existing award levels and did not believe that a tradeoff of fewer but larger awards would be positive, while Mr. Chen of ZONA agreed that current funding levels were appropriate and that fewer awards would be counterproductive.

Mr. Anderson of Paragon observed that more variability in funding size would be an improvement; there were projects that need more than the standard award, and others that could be done with less. Overall, he thought that funding levels should be increased even if that means fewer awards. He noted that this would encourage NASA to focus more clearly on its top priorities, which would in turn lead to better connections between SBIR and Phase III opportunities.

On the other hand, a number of company representatives said that current funding levels were too low. Mr. Grimmer of Eltron said that materials technology requires far greater investment than a SBIR grant can provide.

Referencing the increase in Phase I award size allowed under 2011 reauthorization, Mr. Davis of Honeybee explained that "The increase in Phase 1 award amounts is particularly important because it allows a more thorough evaluation of a technology's value and feasibility. As a result our Phase 2 proposal quality is higher and Phase 2 programs are better positioned for success."

Overall, this wide range of views suggests that the award size should be tailored to the technologies and sectors at hand; what is sufficient for projects with low capital need and short cycles is not appropriate for sectors with heavy capital needs and very long cycles: software is not materials science, and providing the same amount of funding for both seems inappropriate.

Reduced Desirability of SBIR Awards

The desirability of SBIR funding appears to be declining, especially among companies that have access to other sources of funding. The number of Phase I applications has been declining at all agencies in recent years.

Mr. Grimmer, CEO of Eltron Research, which before pivoting from SBIR was a highly successful winner of SBIR awards from multiple agencies) provided several reasons why his company moved away from reliance on SBIR funding:

- **Noncommercial focus.** Mr. Grimmer noted that SBIR projects were not aligned with commercial strategy, and research to address SBIR topics could not easily be adapted to the commercial opportunities available to the company.
- **Long timeline.** SBIR takes a considerable amount of time—at a minimum, 3 years between topic release and the end of Phase II—according to Mr. Grimmer. That is a long time for a company trying to become more commercial.
- **Rigidity.** Eltron didn't find it possible to expand beyond its existing primary technical base using SBIR funding.

Other Issues

Interviewees raised a number of additional issues and concerns in relation to the NASA SBIR program. Some of these are described below:

- **Multiple annual application deadlines.** Although some company representatives endorsed the need for multiple deadlines, others did not. Ms. Yachbes of Honeybee, for example, said that the single annual application worked well for her company.
- **Speed to market.** Mr. Grimmer of Eltron noted that SBIR funds projects on a fixed schedule. In the private sector, promising projects attract more money faster to speed development. Therefore, the SBIR timeline slows development even after funding.
- **Partnership and business development funding.** Ms. Yachbes of Honeybee would like to see the program help her company to develop better relations with NASA's prime contractors. This occurred with Lockheed Martin in the context of the Orion mission (now cancelled), but in general there could be more support in this area, she said.

- **Contracting.** NASA SBIR contracting is handled at the office level. Mr. Chen of ZONA noted that this makes it impossible to develop ongoing relationships with individual contracting officers
- **ITAR.** Mr. Chen of ZONA said that NASA solicitations (unlike those at DoD) do not clearly indicate which topics are subject to International Traffic in Arms (ITAR) regulations. Consequently, companies spend time and resources to gain permissions they may not require.
- **Focused funding on smaller firms.** Although some agency staff said that it was important to ensure that funding goes to firms that have a good chance of commercializing their technology, Dr. Blankenship of TSI recommended that NASA focus its funding on smaller companies that have few other resources. He said that larger small companies (those with more than 100 employees, for example) are in less need of SBIR awards, which should be focused primarily on micro-businesses (those with less than 10 employees) and then on smaller and mid-size small companies. He believed that these larger small companies do not require SBIR funding to the same degree.

8

Findings and Recommendations

The findings and recommendations in this chapter address the Congressional objectives for the Small Business Innovation Research (SBIR) program, as reiterated in the recent program reauthorization and in the subsequent Small Business Administration (SBA) Policy Directive that guides program implementation at all agencies. Section 1c of the Directive lists the program goals as follows:

> *The statutory purpose of the SBIR Program is to strengthen the role of innovative small business concerns (SBCs) in Federally-funded research or research and development (R/R&D). Specific goals are to:*
>
> *(1) Stimulate technological innovation;*
> *(2) use small business to meet Federal R/R&D needs;*
> *(3) foster and encourage participation by socially and economically disadvantaged small businesses (SDBs; also called minority-owned small businesses [MOSBs] elsewhere in the report), and by women-owned small businesses (WOSBs), in technological innovation; and*
> *(4) increase private sector commercialization of innovations derived from Federal R/R&D, thereby increasing competition, productivity and economic growth.*[1]

This chapter reviews the extent to which each of these program goals is being addressed by the National Aeronautics and Space Administration (NASA). We also address some aspects of program management. However,

[1] Small Business Administration, Small Business Innovation Research (SBIR) Program Policy Directive, February 24, 2014.

prior to this analysis, we describe how the limited outcomes data available at NASA limited the scope of the assessment.

REVIEWING THE EVIDENCE

In assessing the NASA SBIR program, we found that quantitative data on the program outcomes was limited. Outcomes data for agency SBIR programs come from the funded companies and the funding agency. While there are major challenges in gathering and evaluating this data—described in Chapter 5 (Quantitative Outcomes)—most SBIR agencies have made significant efforts to acquire the quantitative data that permits evaluation and subsequently, in the ideal, more effective management of the program. The other four agencies studied by the Academies[2] in recent years—Department of Defense (DoD), National Institutes of Health (NIH), National Science Foundation (NSF), and Department of Energy (DoE)—have made efforts, with varying degree and success, to acquire relevant outcomes data and to use those data to develop internal assessments of the program. Until recently, this was not the case at NASA.

There are three paths for collection of company data: (1) utilization of a reporting system such as the Company Commercialization Record (CCR) database at DoD, where companies are required to report on outcomes from previous projects; (2) surveys of past awardees for the same purpose; and (3) contracts analysis which for agencies that acquire the end product of SBIR awards can indicate which technologies were further utilized within the agency.

The DoD's CCR database requires all companies to update outcomes for all previous SBIR awards (at DoD and elsewhere) every time they seek new funding. NSF and DoE track outcomes; NIH has done so sporadically. For both types of data acquisition, the goal is to determine, on a systematic basis, what happened after SBIR funding was provided. DoD (including in particular some departments such as Navy) has also made a substantial effort to identify SBIR Phase III contracts within DoD by analyzing data from the Federal Data Procurement System (FPDS) database.

Since 2012, NASA has started to collect data via an agency database where companies are encouraged but not required to update their information; NASA staff tell us that there are no program-related sanctions imposed on those failing to provide this information.

The new NASA tracking system appears to be well-designed to capture important elements of the use of SBIR technologies within NASA.[3] This is potentially valuable as these elements are not as effectively captured by the DoD

[2]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.
[3]See discussion of the NASA SBIR Electronic Handbook in Chapter 3 (Initiatives).

CCR. It is, however, still too early to determine whether the data collected will be sufficiently comprehensive to permit effective evaluation and analysis.

Qualitative information, including "success stories," supplements quantitative data. NASA does collect case studies of success stories, but most are company-provided with limited agency corroboration. It is therefore difficult to determine which cases reflect important accomplishments from the agency point of view.

Sources of Findings

The committee's findings are based on a complement of quantitative and qualitative tools including a survey, case studies of award recipients, agency data, public workshops, and agency meetings. The methodology is described in Chapter 1 and Appendix A of this report. In reviewing the findings below, it is important to note that the Academies' 2011 Survey—hereafter referred to as the 2011 Survey—was sent to every principal investigator (PI) who won a Phase II award from NASA, FY1998-2007 (not the registered company points of contact [POC] for each company.[4] Each PI was asked to complete a maximum of two questionnaires, which as a result excludes some awards from the survey. The preliminary population was developed by taking the original set of SBIR Phase II awards made by NASA during the study period and eliminating on a random basis awards to PIs who received more than two awards (to limit the burden on respondents). The resulting preliminary population was 1,131 awards. PIs for 641 of these awards were determined to be not contactable at the SBIR company listed in the NASA awards database. The remaining 490 awards constitute the effective population for this study. From the effective population, we received 179 responses. As a result, the response rate in relation to the preliminary population was 15.8 percent and in relation to the effective population response was 36.5 percent.

The absence of usable quantitative outcomes data from NASA limits the conclusions that can be drawn from this assessment. Although the 2011 Survey provides quantitative data on NASA outcomes agency-wide, the number of responses is too limited to permit definitive conclusions.[5] Similarly, although the limited data provided by NASA and that provided by DoD on NASA projects recorded in the DoD Company Commercialization Record database are helpful, neither is comprehensive.

Given the size of the survey population and response rates and overall potential sources of survey bias, the following findings and recommendations rely more heavily on company case studies, discussions with agency staff, and other documentation than we would have preferred. The committee's findings are accordingly qualified.

[4]Because there is a time lag in commercialization for new technologies, the survey did not include more recent awards than 2007. See Box A-1 for a discussion of this commercialization lag.
[5]See Appendix A for details on survey methodology.

STUDY FINDINGS

Although more and better data would improve the grounding for these findings, it is our judgment that the NASA SBIR program is encouraging the expansion of technical knowledge. And although the limited data available from the 2011 Survey indicates limited infusion of SBIR technologies into NASA Mission Directorates for awards made in FY1998-2007, the program has since then become increasingly aligned with NASA Mission Directorate needs. NASA SBIR projects commercialize at a level similar to that of comparable SBIR programs at DoD, although the small size of the NASA market limits the scale of commercialization. However, with regard to the third program objective, we conclude that the NASA SBIR program is not adequately fostering and encouraging participation by women and minorities and socially and economically disadvantaged small businesses.

It is our view that SBIR works best when the agency's leadership recognizes the strategic potential of the SBIR program and leverages it to help realize NASA's mission needs. Although in large measure the results of the NASA SBIR program appear to be positive, NASA has not developed a coherent place for SBIR as a valued part of its strategic plans for addressing its mission. It is telling that there is no section on SBIR in the 2014 NASA Strategic Plan, and only a handful of mentions in passing.[6] While other agencies have in recent years come to see that SBIR can, if utilized well, provide substantial value to the agency, it is hard to escape the conclusion that NASA has not fully embraced the possibility of treating SBIR as an opportunity (rather than a tax on its extramural research budget).

Moreover, we believe that the NASA SBIR program could be reconfigured to address a series of further opportunities: These include pilot initiatives to harness fast moving innovative small companies, to support the commercialization of space (e.g., the commercial use of space satellite navigation systems), and to integrate better with the Department of Defense, the closest analogous agency that also has mission needs in Space. Seizing these opportunities requires that NASA generate data and metrics that can guide and enhance the SBIR program's performance.

The findings are organized in terms of the four legislative objectives of the SBIR program plus findings on the management of the program. The summary below provides a guide to the more detailed description to follow.

Summary of Findings

I. Commercialization

A. NASA SBIR projects commercialize at a substantial rate.

[6]NASA, Strategic Plan 2014. Accessed on August 14, 2015, at https://www.nasa.gov/sites/default/files/files/FY2014_NASA_SP_508c.pdf.

B. A plurality of NASA SBIR projects has achieved some private sector commercial success.
C. Subsequent investment provides further evidence that NASA SBIR projects generate potential commercial value even if they have not yet reached the market.
D. NASA SBIR projects are associated with modest job growth.
E. NASA SBIR funding makes a substantial difference in determining project initiation, scope, and timing.
F. Some NASA SBIR companies report significant commercial outcomes.

II. Meeting the Mission Needs of the Agency

A. The lack of comprehensive quantitative data concerning the agency uptake of SBIR-funded technologies prevented effective determination of the program's impact within NASA.
B. Responses to the 2011 Survey shows limited uptake of SBIR projects within NASA.
C. There is qualitative evidence on uptake of SBIR-funded technologies within NASA.
D. Recent changes in program management, which has increased the alignment between SBIR and the Mission Directorates, may increase the uptake of SBIR technologies within NASA for awards made after FY2007.

III. Fostering the Participation of Women and Other Under-represented Groups in the NASA SBIR Program

A. The levels of participation by minority-owned and woman-owned firms in the NASA SBIR program are low and in some areas falling.
B. NASA has not made sustained efforts to "foster and encourage" the participation of WOSBs and MOSBs.
C. NASA does not report on or sufficiently track participation by WOSBs and MOSBs.
D. NASA has not engaged sufficiently with the challenge of encouraging women and minority participation in SBIR.

IV. Enhancing Science and Technology

A. The SBIR program at NASA supports the development and adoption of technological innovations. However there is growing misalignment between the enhancement of science and technology and the demands of meeting specific agency mission needs.
B. The NASA SBIR program continues to connect companies and universities.

C. NASA SBIR projects generate substantial knowledge-based outputs such as patents and peer reviewed publications.

V. Fostering Innovative Companies

A. The NASA SBIR program fosters the formation of innovative small companies.
B. NASA SBIR awards lower the risks of innovation and helps small businesses enter new markets.
C. The NASA SBIR program has supported the development of small innovative companies in the United States.
D. The NASA SBIR program limits small company dependence on government grants.

VI. Program Management

A. NASA's SBIR program is not sufficiently driven by metrics.
B. Many of NASA's commercialization initiatives are potentially promising but are too recent to provide an outcome assessment.
C. NASA's monitoring and evaluation of the SBIR program is insufficient.
D. Some NASA program management practices do not reflect best practices.

I. Commercialization

Each agency has its own priorities for the SBIR program. At NASA, the overwhelming emphasis has been on the adoption of SBIR-funded technologies for use within the agency in support of its mission. This mission support overlaps to a substantial degree with the commercialization objective of the SBIR program: projects adopted for use within NASA are also provided with downstream NASA or other federal contracts and are therefore, in our view, successfully commercialized.

However, the focus on agency mission has important implications for the extent of commercialization. At NIH and NSF, commercial success is achieved in most cases outside the agency and hence is measured in terms of standard economic outputs such as sales, revenues, and company growth. At DoD, the acquisitions market is large enough that companies can become successful by serving that market alone: defense contractors can grow to become very large, and contracts in the tens or hundreds of millions of dollars are possible.

At NASA, however, contracts within the agency for SBIR-funded technologies tend to be relatively small. There is rarely a need for thousands of a particular item; it is more common for a technology requirement to be for a particular instrument or a component for a larger system of which, at best, a small number will be built. For example, the market for the SBIR-funded batteries that are designed to power the Mars Rover is limited. Indeed, NASA's own newsletter notes the need to find outside markets: "NASA technology needs are more likely to be met if they can be engineered to overlap significantly with commercial or Department of Defense (DoD) needs."[7] Of course, even tightly targeted mission-oriented projects can and do produce technologies with sometimes significant non-NASA market potential. Most notably, a NASA SBIR contract to develop technology for autonomous rendezvous and docking of space vehicles to service satellites was later adapted to track and compensate for eye movements in now commonplace laser surgery for vision correction.[8]

In the main, however, it appears that many NASA SBIR companies are affected by the small size of the NASA marketplace and sometimes very long lags as technology matures and large scale programs evolve toward completion. In some ways, they also suffer from the NASA SBIR program's focus on NASA's specialized needs.

Such companies would seldom be able to grow rapidly and become substantial commercial entities with hundreds of employees—as has happened to a number of SBIR companies working primarily within DoD. The market within NASA is not large enough to support this kind of development. Discussions with companies and agency staff as well as survey responses indicate that small companies, whose mission is to work on space technologies for NASA, typically remain small in size and hence are unlikely to generate huge commercial outcomes from their projects. (NASA SBIR companies averaged 10 employees at the time of the surveyed award, and 15 at the time of the 2011 Survey). More research is required to determine the scale and impact of this phenomenon.

That said, there remains a distinction between projects that generated sales or further investment and resources, especially from within NASA, and those that did not. In some cases, spinoffs from the technologies led to contracts and successes outside NASA. Some company case studies reveal that the NASA contracts base was not sufficient to support the company's vision and that they had successfully gone outside NASA into the commercial marketplace or DoD (a number of companies working within NASA also acquire contracts from DoD).

Within this broad context, we make the following findings:

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[7]NASA, *The Concept*, vol. 3, no. 2, Spring 2012, p.3.
[8] This technology has been cited in the White House Tibbitts Awards. See https://www.sbir.gov/sites/default/files/tibbetts_2013_book_print_version.pdf.

A. NASA SBIR projects commercialize at a substantial rate.[9]

1. Forty-six percent of respondents to the 2011 Survey reported some sales.[10]
2. An additional 26 percent reported that they anticipate future sales.[11]
3. However, the scale of commercialization was limited: no projects reported aggregate sales of $20 million or more, and 1 percent of projects reported project-related sales of $10 million to <$20 million.[12]

B. A plurality of NASA SBIR projects has achieved some private-sector commercial success. Among surveyed projects reporting sales—

1. An average of 35 percent of project sales were to domestic private-sector customers.[13]
2. An average of 9 percent of project sales were to export customers.[14]

C. Subsequent investment provides further evidence that NASA SBIR projects generate potential commercial value even if they have not yet reached the market.

1. Sixty-five percent of survey respondents reported receiving additional investment funding in the surveyed project.[15]
2. For those projects receiving funding, non-SBIR-STTR federal funding was overwhelmingly the most likely source of additional funding (71 percent of reported funding). No other source provided more than 10 percent of funding. Two percent of reported funding came from U.S. venture capital (VC).[16]

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[9]NASA does not maintain data on commercialization rates across the study period (the 2011 Survey covered awards made in FY 1998-2007 inclusive). The data in this section are drawn from the 2011 Survey, which generated 179 responses from Phase II SBIR awardees. Unless otherwise noted, all percentage responses are therefore percentages of those 179 responses, which is 36.5 percent of the effective population of awards and 15.8 percent of the preliminary population of awards. See Appendix A for a description of the survey methodology.
[10]See Table 5-2.
[11]See Table 5-2.
[12]See Table 5-3.
[13]See Table 5-4.
[14]See Table 5-4.
[15]2011 Survey, Question 33.
[16]See Table 5-7.

D. NASA SBIR projects are associated with modest job growth.

1. Respondents reported that the median size of firms with NASA Phase II awards grew from 10 employees at the time of award to 15 employees at the time of survey.[17]
2. SBIR firms with NASA awards are small, substantially smaller than at DoD. Despite large percentage increases over time, the average SBIR firm at NASA starts from a small base.[18]

E. NASA SBIR funding makes a substantial difference in determining project initiation, scope, and timing:

1. Seventy-five percent of respondents reported that their NASA project probably or definitely would not have proceeded without SBIR funding.[19]
2. Among those anticipating that the project would have been initiated in the absence of SBIR funding, about two-thirds reported that the project would have been delayed by at least 1 year, and 67 percent reported that the project would have been narrower in scope.[20]

F. Some NASA SBIR companies report significant commercial outcomes.

1. Although company case studies do not provide a basis for quantitative assessment, they do provide examples of companies that have become commercially successful and sustainable based on their work for NASA via the SBIR program.
2. There is an important strategic difference between companies that are started to address a commercial need (and use SBIR as a way to fund their R&D and product development) versus those that start specifically to pursue an announced SBIR topic. The latter sort of company is typically much less successful in achieving meaningful commercialization while the former is more likely to pursue truly dual-use investigations and, eventually, achieve their commercialization goals.

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[17]See Table 5-5. Although these survey data cover Phase II awards made from FY1998 to FY 2007 and firm growth can vary according to length of time since award was made, data from firms with older awards may also be biased toward surviving firms.
[18]See Table 5-5. N=170 respondents. See also Tables 3-4 and 3-5 in National Research Council, *SBIR at the Department of Defense*, Washington, DC: The National Academies Press, 2014.
[19]See Table 5-1.
[20]As this question was asked only of the small number of companies who would have proceeded even absent funding, these numbers should be treated with caution; they are indicative only. N=12. See 2011 Survey, Questions 25 and 26.

II. Meeting the Mission Needs of the Agency

NASA's current mission is to "Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth."[21]

In general, the NASA SBIR program has focused on developing technologies that can meet the agency's own mission needs. Discussions with agency staff indicate that the agency's primary metric for program success is the deployment of SBIR-funded technologies on NASA missions.

Case studies and NASA success stories show that SBIR has provided important support for some missions. The question is whether this is happening at a sufficient rate. NASA has not provided comprehensive quantitative data against which to measure success on this core metric. NASA has not effectively tracked Phase III contracts stemming from SBIR awards or systematically tracked the utilization of SBIR-funded technologies at NASA Field Centers or on NASA missions. However, the new tracking database does lay the groundwork for such tracking in the future, and this is a positive step that has the potential to aid future assessments of the program.

A. The lack of comprehensive quantitative data concerning the agency uptake of SBIR-funded technologies prevented effective determination of the program's impact within NASA.

1. NASA was unable to provide comprehensive data on follow-on contracts after Phase II. The new data collection mechanism may provide better data in the future.
2. The absence of comprehensive data on NASA Phase III contracts limits any conclusions on NASA uptake of SBIR technologies.
3. NASA has not developed any alternative mechanisms for measuring impact (e.g., surveys either of companies or of NASA acquisitions staff).

B. Responses to the 2011 Survey shows limited uptake of SBIR projects within NASA.[22]

1. Among surveyed projects with some sales, an average of 17 percent of reported sales were to NASA. An average of 14 percent of reported project sales were to DoD. An average of 2 percent were to NASA prime contractors, although as there is considerable overlap between NASA primes and DOD primes, not all of these projects are likely to

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[21]NASA Strategic Plan FY2014, p. 2.
[22]See Table 5-4.

have been for NASA. This means that an average of about 20 percent of reported project sales were to NASA or NASA primes.[23]

2. More positively, of the two thirds of respondents that reported further investment in the project beyond Phase II, 71 percent of reported funding was non-SBIR federal funding.[24]
3. Firms working for both NASA and DoD can create sustainable markets for their products.[25] However, NASA does not have in place systematic efforts to connect with DoD projects or programs, for example by taking advantage of opportunities to publicize NASA projects to DoD services or for NASA to acquire DoD SBIR-funded technologies.

C. There is qualitative evidence on uptake of SBIR-funded technologies within NASA.

1. Company case studies provide examples of technologies that were used on NASA missions or that made important contributions to NASA operations.[26] NASA has also published a regular newsletter covering success stories for its SBIR program. A review of "success stories" collected by NASA also shows that in a number of cases SBIR-funded technologies did provide important technologies to NASA and were integral to NASA missions.
2. Evidence from SBIR-funded companies indicates that some important technologies were developed with the help of SBIR funding and that many of these technologies would not have been developed without NASA SBIR funding because funding sources were not available.[27]
3. Discussions with NASA staff indicate that in some cases SBIR filled significant gaps in NASA technology plans, often using less money and taking less time than traditional contracts through the NASA prime contractors.

D. Recent changes in program management, which has increased the alignment between SBIR and the Mission Directorates, have the potential to increase the uptake of SBIR technologies within NASA for awards made after FY2007 (the last year covered by the 2011 Survey).

1. Mission Directorate staff are now deeply involved in the development of SBIR topics

[23]See Table 5-4.
[24]See Table 5-7. N=116 respondents.
[25]See Table 5-4.
[26]See also the discussion in Chapter 7 (Insights).
[27]For example, see the Honeybee case study in Appendix E (Case Studies).

2. Mission Directorate staff also now have a much greater role in award selection.

As noted under Finding IV, this may have a negative effect on NASA support of technologies that do not have potential for infusion into NASA programs in the short term.

III. Fostering the Participation of Women and Other Under-represented Groups in the NASA SBIR Program

NASA has not effectively addressed the mandate to foster the participation of women and other under-served populations. Current outcomes and activities by NASA are not sufficient to meet the SBIR program objective of fostering and encouraging the participation by minority and disadvantaged persons in technological innovation.

A. The levels of participation by minority-owned and woman-owned firms in the NASA SBIR program are low and in some areas falling.

1. Data from NASA indicate that approximately 8 percent of Phase I awards in FY2014 went to Woman-owned Small Businesses (WOSBs).[28] Approximately an equal share went to Minority-owned Small Businesses (MOSBs).
2. The percentage share of Phase I awards to MOSB declined steadily during the study period, while the percentage share of Phase I awards to WOSBs were largely flat, excluding FY2014.[29]
3. Phase I success rates (awards/applications) for MOSBs were lower than those for non-MOSBs every year since FY2005. In FY2014 the gap was more than 20 percentage points.[30]
4. Phase I success rates for WOSB were lower than those for non-WOSBs in all the years studied. The gap was largest in FY2014, about 20 percentage points.[31]
5. MOSB shares of Phase II awards fell substantially: MOSB firms received 19 Phase II awards in FY2009 and 5 in FY2014.[32] Their share declined by over half after FY2006.[33]
6. The WOSB share of Phase II awards declined to below 8 percent in FY2011 and FY2012.
7. MOSB Phase II success rates in every year FY2005-2012 were lower than those for non-MOSB firms Overall, MOSB success rates were 13 percentage points lower than those for non-MOSBs.[34]

[28]See Figure 6-7.
[29]See Figure 6-7.
[30]See Figure 6-9.
[31]See Figure 6-5.
[32]See Figure 6-18.
[33]See Figure 6-18.

8. Phase II success rates for WOSBs were lower than those for non-WOSBs in every year of the study period (FY2005-2012) except for FY2005.[35]
9. WOSB shares are in part supported by the presence of three especially successful WOSB companies which accounted for nearly one-quarter of all WOSB Phase I awards during this period. There were no comparable MOSBs.[36]

B. NASA has not made sustained efforts to "foster and encourage" the participation of WOSBs and MOSBs.

1. NASA did not provide evidence of implementing any substantial program for outreach to these communities, and there is little evidence of any sustained activity focused on this objective. The NASA SBIR program participates in one workshop annually, organized by another component within NASA. No efforts have been made by the NASA SBIR Program to reach out to WOSBs.
2. There appears to be some evidence of outreach activity at NASA Field Centers (notably Johnson Space Center), but the NASA SBIR Office provided no data on these activities or their outcomes.

C. NASA does not report on or sufficiently track participation by WOSBs and MOSBs.

1. NASA does not sufficiently track participation by MOSBs. NASA's annual report to SBA provides some data on participation but provides very limited information on efforts to foster and encourage participation, especially at the different Field Centers.
2. NASA provided no separate data on Black-owned and Hispanic-owned small businesses or on minority or female principal investigators (PIs). Responses to the 2011 Survey indicate that Black-owned and Hispanic-owned small businesses are themselves a very small share of MOSBs overall.[37]
3. NASA did not share any data it may have on woman and minority PIs in their program. The 2011 Survey reveals that about 11 percent of Phase II respondents reported a minority PI and 5 percent a female PI.[38]

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[34]Figure 6-17.
[35]See Figure 6-12.
[36]Tables 6-6, 6-7, 6-8, and 6-9.
[37]See 2011 Survey, Question 19, and section on "Minority Company Ownership" in Chapter 6 (Participation of Women and Minorities).
[38]Tables 6-1 and 6-4 (N=177 respondents).

Further analysis of the Survey data indicates that there were two Black PIs in the overall responding population, and four Hispanic PIs.[39]

D. NASA has not engaged sufficiently with the challenge of encouraging women and minority participation in SBIR.

1. NASA did not provide evidence that it has reviewed the role of women and minorities within the SBIR program.
2. There has been no concerted effort to determine what could be done—within budget constraints—to improve participation and therefore both meet Congressional objectives for the program and expand the pool of qualified applicants and capabilities.

IV. Enhancing Science and Technology

NASA undertakes many scientific missions, its outreach to the public focuses on scientific accomplishments, and it retains a strong educational mission (indeed, for a time the SBIR program was located within NASA's education directorate.) Evidence suggests that the NASA SBIR program is providing support for the development of new technologies related to NASA's missions and enhancing science and technology more broadly, as is summarized in the following items A-C.

A. The SBIR program at NASA supports the development and adoption of technological innovations.[40] However there is growing misalignment between the enhancement of science and technology and the demands of meeting specific agency mission needs.[41]

1. Selection of topics and individual projects for funding maintains a strong focus on technological innovation.
2. Topic selection is closely aligned with the technical needs of NASA Mission Directorates, which have effective veto power over topic and sub-topic statements.
3. Some SBIR companies indicated that the NASA SBIR program has shifted away from scientific inquiry toward more tightly defined contract research for the agency. In their view, this potentially reduces opportunities for breakthrough innovation.[42]
4. Review scoring for individual proposals is now increasingly weighted toward meeting agency mission needs. Peer review is essentially

[39]See Table 6-3 and section on "Minority Principal Investigators" in Chapter 6 (Participation of Women and Minorities).
[40]See Chapter 2 (Program Management).
[41]See Appendix E (Case Studies).
[42]See Chapter 5 (Quantitative Outcomes).

advisory, while final decisions are made by Mission Directorates based on their needs and priorities.[43]

B. The NASA SBIR program continues to connect companies and universities.

The NASA SBIR program continues to connect companies and academic institutions in a variety of ways. 2011 Survey data indicate that NASA SBIR projects continue to utilize universities (in addition to the even closer connection through the Small Business Technology Transfer (STTR) program, which was not included in the survey data).

1. Just over 30 percent of respondents reported a link to a university. About 21 percent of respondents reported that a research institution was a subcontractor; about 15 percent, reported that university faculty worked on the project (not as PI); and 14 percent reported employing graduate students.[44]
2. Survey respondents identified 75 different universities as project partners; 21 were mentioned by two or more respondents. Universities with the most mentions were cited by four respondents.[45]
3. More than 60 percent of responding companies reported at least one academic founder, and about 30 percent reported that the most recent prior employment of a founder was at a university.[46]

C. NASA SBIR projects generate substantial knowledge-based outputs such as patents and peer reviewed publications. These are widely recognized metrics for the creation of technical knowledge. Based primarily on data from the 2011 Survey:

1. Patenting remains an important component of knowledge diffusion (and protection).

    - Forty-five percent of respondents reported receiving at least one patent related to the surveyed project.[47]

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[43]Discussions with NASA SBIR managers. See section on “Selection” in Chapter 2 (Program Management).
[44]See Table 5-13; N=177. These figures are similar to those reported for DoD. See National Research Council, *SBIR at the Department of Defense*, Washington DC: The National Academies Press, 2014, Chapter 3, University connections.
[45]See Table 5-14 and Appendix D (List of Universities). These numbers are close to those reported for the DoD SBIR program. See National Research Council, *SBIR at the Department of Defense*, 2014 op. cit.
[46]See Tables 5-15 and 5-16.
[47]See Table 5-11.

- Fourteen percent of responding companies reported receiving 10 or more patents for all SBIR funded technologies.[48]

2. Publication of peer-reviewed articles remains the primary currency of scientific discourse, and despite the need to protect ideas in the commercial environment of small businesses, NASA SBIR firms continue to participate deeply in scientific publication.

- More than 80 percent of respondents reported at least one resulting peer-reviewed publication related to the surveyed project.[49] This is much higher than the 40 percent figure found in the 2005 Survey.
- Thirty-one percent of respondents reported more than three publications resulting from the surveyed project.[50]
- Some of the case studies indicate that companies take pride in the number of peer-reviewed publications developed by their scientists and engineers, both within and outside of the NASA SBIR program. Papers are often prominently posted on company websites.[51]

V. Fostering Innovative Companies

The case studies and 2011 Survey show that the NASA SBIR program supports for the foundation and growth of innovative companies.

A. The NASA SBIR program fosters the formation of innovative small companies.

1. Forty percent of respondents said that the company was founded entirely or in part because of the SBIR program.[52]

B. NASA SBIR awards lower the risks of innovation and helps small businesses enter new markets.

1. The NASA SBIR program provides important seed funding.[53]

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[48]See Table 5-10 (N=64 responding companies).
[49]See Table 5-12, (N=129 respondents).
[50]See Table 5-12.
[51]See Appendix E (Case Studies).
[52]See section on "Quantitative Survey Evidence that NASA Stimulated Technological Innovation" in Chapter 5 (Quantitative Outcomes) and 2011 Survey Question 6 (N=73 companies). Survey question refers to SBIR program overall, not necessarily just NASA.
[53] See section on "Quantitative Survey Evidence that NASA Stimulated Technological Innovation" in Chapter 5 (Quantitative Outcomes), sections on "Company Formation and Very Early-Stage Funding" and "Funding Otherwise Unfundable Projects" in Chapter 7 (Insights), and Appendix E (Case Studies).

- Open-ended responses to the 2011 Survey, as well as a number of case studies show that the program provided funding at a stage when the project was too risky for other investors.
- NASA SBIR funding supports technology development, which can be supported through additional commercial and government funding further downstream.

2. NASA funding can support company efforts to enter new markets.[54]

- In some cases, companies use SBIR funding to build on existing platform technologies specifically to enter new markets. This platform-driven approach is used by a number of the companies profiled in the case studies.[55]
- Innovative companies must often make mid-course corrections. According to respondents, NASA funding has helped a number of surveyed companies successfully make what are often difficult changes that are hard to fund.

C. The NASA SBIR program has supported the development of small innovative companies in the United States.

1. The 2011 Survey provided a sample of SBIR companies with the opportunity to report the overall impact on the company of the awards about which they were surveyed and to identify specific kinds of impacts.

- Twenty-five percent of responding companies indicated that the funding had a "transformative" effect on their company. Another 56 percent said that it had a "substantial positive long term effect."[56]
- Textual responses revealed a wide range of impacts, summarized in Box 8-1.

D. The NASA SBIR program limits small company dependence on government grants.[57]

1. The NASA program does not provide large numbers of awards to individual companies.

[54]See Chapter 7 (Insights).
[55]See Appendix E (Case Studies).
[56]See Table 5-20.
[57]The evidence here echoes previous studies by the Academies, which discussed the question of multiple SBIR awards to companies. The 2009 report concluded that multiple awards to companies was not a significant problem. See National Research Council, *An Assessment of the Small Business Innovation Research Program*, The National Academies Press: Washington DC, 2008.

BOX 8-1
Different Ways in Which NASA SBIR Awards Helped to Transform Companies

- Funding, especially very early stage funding
- Credibility based on success in a peer reviewed process
- Access to other NASA programs (and to other Federal agencies)
- Connections to key stakeholders in core technical areas (including agencies, prime contractors, investors, suppliers, subcontractors, and universities)
- Support for developing new markets, and particularly niche markets
- Staff development, including the hiring and training of young researchers in particular
- Encouragement to develop a more commercial company culture

SOURCE: Analysis of company responses to 2011 Survey. For each bulleted item multiple responses indicated its existence and importance for surveyed projects and firms.

- Firms may apply for only 10 awards per year.
- The most successful firm received 27 SBIR Phase II awards during the period FY2005-2012.[58]
- Many NASA program participants are not dependent on SBIR awards.
- More than one-quarter of responding companies received no SBIR funding in the most recent fiscal year (at the time of the survey).[59]
- Less than one-quarter of respondents reported that SBIR accounted for more than 50 percent of company revenues for the most recent fiscal year (at the time of the survey).[60]

2. Small innovative companies rarely develop linearly, directly from idea to R&D to commercialization/development to sales with a single SBIR award. Notably—

- More than three quarters of Phase II survey respondents reported at least one prior SBIR or STTR Phase I award related to the surveyed project.[61]

[58]See Table 4-6.
[59]See Table 5-18 (N=72 responding companies). Question 9 of the 2011 Survey asked "What percentage of the company's revenues during its most recent completed fiscal year was Federal SBIR funding (Phase I and/or Phase II)?"
[60]See Table 5-18 (N=72 responding companies).
[61]See Table 5-19 (N=154 respondents).

- Thirty-nine percent reported at least two additional related awards.

VI. Program Management

A. NASA's SBIR program is not sufficiently driven by metrics.

1. NASA lacks sufficient evidence on the operations of its SBIR program: In general, there is insufficient evidence to support definitive conclusions about operation of the NASA SBIR program; this insufficiency of evidence is in itself troubling.

    - NASA has not provided data that could show the extent to which the program is systematically meeting its objectives, and how this has changed over time.[62]
    - NASA does not have interim milestones to suggest that this is the case.

2. NASA's Technology Infusion Strategy is potentially promising, but needs effective metrics.

    - NASA's use of Technology Infusion Managers (TIMs) at every Field Center is a promising effort to link technologies developed through the SBIR program with the needs of NASA program managers.[63]
    - TIMs operate quite independently and as a result use different tools and approaches. TIMs are also focused primarily on the NASA programs that run at their Field Center. This can limit their effectiveness as agents of commercialization and technology transfer.[64]
    - However, NASA does not have metrics and reviews in place to determine best practices among TIMs. Hence we have no evidence on which to determine whether the program is fully effective.[65]

3. The limits placed by NASA on the number of SBIR submissions per company are effective: Limits on submissions per company are an appropriate mechanism for ensuring that the number of submissions is limited while at the same time not excluding any specific project. The

[62]See Chapter 5 (Quantitative Outcomes).
[63]See Chapter 2: (Program Management).
[64]See Chapter 2: (Program Management).
[65]See Chapter 2: (Program Management).

limit of 10 submissions per solicitation does provide some practical limitation on a small number of companies.[66]

4. SBIR-funded research is aligning with the specific needs of the Mission Directorates: The Mission Directorates are playing a growing role within the NASA SBIR program because they are directing the technical aspects of the program more closely. This reflects pressure to align funded research with the specific needs of the Mission Directorates.[67]
5. NASA's once a year SBIR solicitation is not adequate:

    - The NASA SBIR program continues to offer one solicitation annually. As technology moves more rapidly, this is increasingly problematic, and other major agencies have recently increased the number of solicitations per year.
    - However the long cycles of NASA programs and space technology more generally means that an annual solicitation cycle will be justified after further NASA review.

6. The Phase I to Phase II transition hurts firms and does not serve NASA:

    - According to NASA's FY 2012 annual report to the SBA, the time lag per project between the end of Phase I funding and the beginning of Phase II funding averaged 233 days.[68]
    - This lag is potentially disastrous for small firms that do not have other suitable projects to fund staff during the gap period.[69]
    - This lag also raises the risk of loss of effort and the inability of the firm to help meet NASA's mission requirements in a timely and cost effective manner.

7. NASA currently makes it difficult for SBIR companies to connect directly to technical contacts at NASA. Like DoD, NASA enforces communications restrictions based on Federal Acquisition Regulations during the solicitation period. Unlike DoD, it does not offer a pre-solicitation window through which such connections can be made.[70] This absence is counterproductive, especially as the NASA charter allows the agency to share to the maximum extent practicable the results of its R&D.

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[66]See Chapter 4 (SBIR Awards).
[67]See Chapter 2 (Program Management).
[68]See section on "Funding Gaps" in Chapter 2 (Program Management).
[69]See section on "Funding Gaps" in Chapter 2 (Program Management).
[70]See section on "Access to Program Staff During Solicitation Period" in Chapter 2 (Program Management).

B. Many of NASA's commercialization initiatives are potentially promising but are too recent to provide an outcome assessment.

1. NASA has initiated a number of programs to support commercialization of NASA Phase II projects.[71]

   - The Phase II-E program provides additional bridge funding for selected Phase II projects. However, it is not clear—and NASA has not determined—whether this modest additional funding is sufficient to affect outcomes.
   - The Phase II-X program is more ambitious and can help in de-risking investments for NASA programs, thus encouraging more uptakes within NASA.
   - Select Topics: The even more recent introduction of Select Topics and the proposed effort to introduce a Commercialization Readiness Program are likewise too recent to permit substantive analysis, although the Select Topics initiative seems to be an appropriate effort to add funding to high-priority areas.

2. NASBO: The NASA Alliance for Small Business Opportunity (NASBO) incubator initiative, discussed in the 2009 National Research Council report on the NASA SBIR program, has ended with little to show in terms of outputs.[72]
3. TecFusion™: NASA supported development of a TecFusion™ program to link large and small businesses, although this program was not focused exclusively on SBIR. The program has changed in recent years and now focuses primarily on providing NASA technology managers with improved links to small companies. It is a small program—five managers have received services according to NASA's contractor.[73]
4. Agency Support: NASA does not provide any agency-level support for companies that are focused on commercialization of SBIR projects. It has not in the past funded efforts that involve third-party commercialization support companies. The NASA SBIR program office relies primarily on the agency's Technology Transfer Program to help NASA SBIR companies find opportunities outside NASA, although this program is not limited to SBIR. NASA does not have data

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[71]See Chapter 3 (Initiatives).
[72]National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Washington, DC: The National Academies Press, 2009, Chapter 5.
[73]See section on "Technology Infusion Managers" in Chapter 2 (Program Management).

available about its effectiveness either in general or in particular with reference to SBIR.[74]

C. NASA's monitoring and evaluation of the SBIR program is insufficient.

We have noted in Chapter 1 and in Appendix A that there are broad challenges in tracking commercialization, at both the company and project levels. Companies move in and out of the program, and tracking is harder once they have left. More generally, commercialization can come many years after an award and involve multiple awards plus considerable additional funding. All this makes it difficult to assert that any specific outcome "results from" an SBIR award. But there are also specific challenges with existing tracking tools.

1. While NASA has initiated a tracking system focused on commercialization starting in 2012, participation is key.[75]

    - The basic data template for NASA's tracking system is good and includes, in particular, detailed information on technology uptake within NASA.
    - The primary challenge in tracking commercialization and agency uptake of SBIR technologies through the new tool will be to ensure that company participation reaches sufficient levels to generate the comprehensive analysis needed for effective use as a management tool.

2. NASA does not track other important program outcomes. NASA does not currently have in place data collection and tracking systems that address all congressional objectives. Tracking for knowledge effects is essentially absent, and there are significant weaknesses in tracking of participation by women and minorities and uptake of SBIR technologies within the agency.[76]
3. NASA has not provided metrics against which program improvement could be measured.[77] Outcomes potentially provide important signals for program management about the effectiveness of different kinds of topics, different staff, different outreach strategies, etc. These signals are not extensively used for SBIR program management.
4. NASA has not provided any documentation that suggests that the Program Office uses data collected via the electronic handbook to

[74]See section on "Technology Infusion Managers" in Chapter 2 (Program Management).
[75]See section on "Electronic Handbook (EHB)" in Chapter 3 (Initiatives).
[76]See Chapter 2: (Program Management) and Chapter 3 (Initatives).
[77]See Chapter 2: (Program Management).

provide strategic management for the program, beyond operational matters related to the processing of applications and awards.

5. NASA has not sufficiently exploited the opportunities presented by the existence of multiple NASA Field Centers to operate and assess pilot projects. For example, NASA has not provided any data about utilization or outcomes from the Mentor Protégé Program.

D. Some NASA program management practices do not reflect best practices.[78]

1. NASA's SBIR contracts management is unnecessarily rigid.

    - Discussions with agency staff confirm information from company case studies that NASA contracts management is quite rigid. For example, NASA does not provide no-cost extensions for Phase I, which may prevent the best possible use of NASA research resources and compresses the actual research conducted under Phase I into a tight timeline.
    - Agency staff also confirmed that NASA SBIR contracts pay out at a set dollar value per month for the life of the contract. This means that not only do companies have no incentive to accelerate promising research, but also the payment schedule actively prevents them from doing so.

2. Funding gaps between Phase I and Phase II have not been effectively addressed.

    - NASA's FY2012 annual report to SBA found that the average gap between the last day of Phase I funding and the first day of Phase II funding was 233 days. This is well beyond the SBA benchmark of 180 days.
    - Despite the large gap between Phases, no gap funding is available to provide a bridge between Phase I and Phase II, unlike some other SBIR programs.

        - NASA itself has no gap funding program, such as the Phase I options available for many DoD contracts.
        - Firms cannot begin work at their own risk. There is no mechanism for paying companies for work completed during the gap, if and when, a Phase II contract is eventually issued. This is again unlike the practice at some other SBIR agencies.

[78]See Chapter 2: (Program Management).

3. NASA's reporting on the SBIR program remains weak.

  - As noted above, there is no quantitative reporting on program outcomes, and qualitative reporting is limited in quality.
  - The report provided to SBA meets SBA requirements, but essentially provides only a basic justification for the program. NASA's annual SBIR-STTR reports do not cover new initiatives effectively and do not address all congressional objectives (indeed they do not address outcomes at all).

4. The number of applications for SBIR support has been declining.

  - While all agencies have seen declines in applications in recent years, NASA's decline has been substantial: about 50 percent decline in Phase I applications across the FY2005-2014 time frame.[79]
  - This is potentially of significance to the program especially if high-quality companies are concluding that the effort to apply is simply not worth the reward.[80]
  - NASA has not provided a hypothesis to explain the declining numbers (e.g. explanations related to application difficulties, narrower topics, declines in the number of space or aeronautics oriented small companies) and does not have in place any strategy for increasing the number of applicants aside from participation in outreach efforts developed by SBA.

RECOMMENDATIONS

SBIR presents NASA with an important opportunity to advance its mission, work with fast moving innovative small companies, support the commercialization of space, and integrate better with related missions of other agencies. The following recommendations, which are organized in terms of four sets of leading actions needed to improve the SBIR program at NASA, can help improve outcomes. A detailed description follows the summary of key points below.

Summary of Recommendations

I. Furthering a Culture of Monitoring, Evaluation, and Assessment Predicated on Enhanced Information Flows

[79] See section on "SBIR Phase I: Applications and Awards" in Chapter 4 (Awards).
[80] See section on "SBIR Phase I: Applications and Awards" in Chapter 4 (Awards).

A. The NASA SBIR program should improve current data collection approaches and methodologies.
B. NASA should use new commercially available tools to gather more current data on its SBIR program.
C. NASA should better use the data it collects on the SBIR program. These data should be utilized to systematically guide program management.
D. NASA should improve its reporting on the SBIR program.

II. Addressing Under-represented Populations

A. Quotas are not necessary.
B. NASA should develop new and improved metrics.
C. NASA should develop outreach and education programs focused on expanding participation of under-represented populations.
D. NASA should share best practices.

III. Commercialization

A. NASA should improve support for the commercialization of SBIR technologies.

IV. Improving Program Management

A. NASA should improve the application process.
B. NASA should adopt more flexible contracting practices to encourage firm participation in the program.

I. Furthering a Culture of Monitoring, Evaluation, and Assessment Predicated on Enhanced Information Flows

The lack of comprehensive and granular outcomes data prevents development of quantitative analysis which would allow the agency to determine the extent to which is it meeting Congressional mandates and could also allow NASA to identify strengths and weaknesses of its SBIR program and to adjust it accordingly.

A. The NASA SBIR program should improve current data collection approaches and methodologies.[81] NASA should make it a top priority to develop and implement appropriate metrics for assessing program outcomes.

[81]See Finding VI-C.

1. *NASA should expand data collection*. NASA's data collection efforts should expand substantially to address the entire range of congressionally mandated outcomes, not only commercialization. In particular, NASA should ensure that data related to Congressional goals for the participation of women and minorities are fully captured and that uptake of SBIR technologies within NASA is fully captured.[82]
2. *NASA should track the adoption of technologies within NASA*. NASA should use the new tools embedded within NASA's electronic program management tool, the Electronic HandBook (EHB), to ensure that the uptake of SBIR technologies within NASA is comprehensively and consistently tracked, and reported in a timely manner. Such tracking must be comprehensive, but care must be given to ensure that it is not burdensome on small businesses.[83]
3. *NASA should adopt available data collection methodologies*. This includes tracking of Phase III contracts; a company commercialization/outcomes record similar to the DoD CCR database (tuned to NASA's needs); and regular surveys of companies.[84]
4. *NASA should adopt best practices in program metrics*. NASA should review reports by the Academies on other SBIR programs as well as other assessments (e.g. from Government Accountability Office) to develop a set of metrics for program assessment and evaluation. This process should be completed rapidly.
5. *NASA should adopt multiple metrics for commercialization*. NASA should address commercialization in ways similar to the now widely accepted methodology developed for the Academies' SBIR studies—that is, utilizing multiple metrics.[85] These additional metrics will provide a deeper and more nuanced basis for further analysis.
6. *NASA should improve its collection of demographic data*. Demographics of company ownership should be extended to show the specific SBA-defined socially and economically disadvantaged category for each minority applicant. Applicants should be asked, on a voluntary basis, to complete the same demographic questions about the PI as well as the company's owners in the course of their application.[86]
7. *NASA should more systematically develop qualitative outcomes data*. Qualitative data provide important insights, and NASA should develop and adopt a more systematic approach for the use of success stories. Success stories can provide inspiration, lessons learned, and important information not available elsewhere about program impacts.[87]

[82]See Finding III-C.
[83]See Finding II-A.
[84]See Finding IV-C.
[85]See methodology discussions in Chapter 1 (introduction) and Appendix A (Methodology).
[86]See Finding III-C.
[87]See Finding IV-D.

B. NASA should use new commercially available tools to gather more current data on its SBIR program.[88]

1. *NASA should develop pathways to provide ongoing feedback from companies about program activities and operations.* These could include various electronic communication tools. SBIR companies and agency staff who act as technical points of contact—like "customers" in other markets—could be important sources of information about program strengths and weaknesses.[89]
2. *Similarly, NASA should develop mechanisms to share information about NASA SBIR projects*. Electronic tools should be used through which recipients can share information about NASA SBIR projects, helping them to find technical or marketing partners and to navigate the often-complex environment of NASA programs.[90]
3. *NASA should draw on and adopt best practices from its Field Offices*. The NASA SBIR Program Office should identify, evaluate and possibly adopt and adapt program management tools that have already at least in part been developed at Field Centers, such as Langley Research Center.[91]

C. NASA should better use the data it collects on the SBIR program.[92] **These data should be utilized to systematically guide program management.**

1. *NASA should analyze the data to identify potential factors associated with successful transition first to Phase III and then to adoption by NASA Mission Directorates.*[93] By collecting more and better outcomes and participation data, as well as participant feedback, NASA will be better positioned to undertake regular analysis of key program management issues, such as the following:

    - What partnership programs and other commercialization supports encourage transition beyond Phase II?
    - How successfully do NASA selection processes predict eventual successful projects? How could these be improved?
    - What Field Center activities and initiatives are associated with better outcomes? Can these be developed into best practices and transferred across the agency?

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[88]See Finding VI-C.
[89]See Finding VI-C.
[90]See Finding II-B.
[91]See Finding VI-D and the discussion in Chapter 2 (Program Management).
[92]See Finding VI-C.
[93]See Finding II-A.

- To what extent is NASA connecting with relevant programs within DoD?

D. NASA should improve its reporting on the SBIR program.[94]

Although caution should be employed when imposing new reporting burdens on the NASA SBIR program, implementation of an improved data collection and information management system would provide a cost- and time-effective basis on which to provide better reporting on the program. The annual report recommended below would provide much improved transparency and a coherent point of discussion for other stakeholders. This annual report would effectively replace the existing report to SBA, which is of limited utility for NASA or other stakeholders.

1. *The NASA SBIR program should provide a comprehensive annual report to Congress and the public on its operations.*[95]
2. *Although the precise details should be left to the agency, NASA should consider including five areas of program operations:*[96]

   - Inputs, including aggregate current and longitudinal data on numbers of applications and awards, broken out by relevant subgroups (such as demographics, region).
   - Program management and initiatives, which would provide an opportunity to describe any initiative undertaken by the program as well as how the agency is addressing known issues such as the Phase I-Phase II gap.
   - Aggregated outcomes drawn from any data collected on outcomes and subsequent analysis.
   - Improved qualitative outcomes information drawing on case studies, better quality success stories, and social media.
   - Summary conclusions about the extent to which NASA is meeting Congressional objectives for the program and plans for the coming year to do so more effectively.

3. *The proposed annual report to Congress should replace all other reporting requirements imposed on the program by Congress and the SBA.*

[94]See Finding VI-D.
[95]See Finding VI-C.
[96]See Finding VI-C.

II. Addressing Under-represented Populations

NASA should immediately enhance efforts to address the Congressional mandate to foster the participation of under-represented populations in the SBIR program.[97]

A. Quotas are not necessary.[98]

1. While NASA should strive to increase participation of under-represented populations in the SBIR program, it should not develop quotas for that purpose.

B. NASA should develop new and improved metrics.[99]

1. *The NASA SBIR-STTR Program Office should develop metrics for the participation of under-served populations in the program*. Simply counting awards and applications will not be sufficient: it will be important to develop appropriate metrics in the context of the pool of potential applicants, and we recommend that NASA work closely with experts from the science and engineering indicators group at NSF to develop the more sophisticated metrics required.[100]
2. *NASA should ensure that analysis of minority participation fully disaggregates the participation of socially disadvantaged groups by ethnicity, and that attention is focused on the clear Congressional intent to support "minority" participation*. The current SBA definition of "socially and economically disadvantaged" is not in any way sufficient to meet this objective.[101]
3. *NASA's analysis should address key questions, which would include levels and trends for the following metrics:* [102]

    - Shares of applications from companies owned by women and minorities
    - Shares of applications with woman and minority PIs
    - Shares of Phase I awards
    - Shares of Phase II awards

4. *Metrics should also track related program operations, including outreach efforts and initiatives at the program and Field Center levels*

[97]See Finding III-B.
[98]See Box 6-3.
[99]See Finding III-C.
[100]See Finding III-D.
[101]See Finding III-B.
[102]See Finding III-C.

to enhance commercialization and NASA uptake of SBIR technologies (see below).[103]

C. NASA should develop outreach and education programs focused on expanding participation of under-represented populations.[104] This will require the provision of agency resources and senior staff time and should be a high priority for the program. NASA will need to make concerted efforts in this area.

1. *NASA should develop a coherent and systematic outreach strategy that provides for cost-effective approaches to enhanced recruitment, developed in conjunction with other stakeholders and with experts in the field*. This can in part build on existing efforts at some Field Centers, notably those at the Johnson Space Center as well as other efforts to enhance diversity at NASA.[105]
2. *NASA should ensure that outreach to selected populations is an integral part of its overall program outreach activities*. These should be defined as women and minorities who are also qualified participants in the SBIR program. Piggybacking on other NASA activities for general outreach is not sufficient.[106]
3. *NASA should review internal award and selection data and processes to identify and then understand and potentially address disparities between success rates and award levels for disadvantaged and not disadvantaged populations*.[107]
4. *NASA should provide significant management resources to address the participation of under-represented populations because expanding their participation is likely to be a difficult and long-term effort*. Specifically, NASA should designate a senior staffer to work exclusively on participation issues, providing for both improved reporting and the deployment of new initiatives laid out in the new strategy identified in 1) above.[108]

D. NASA should share best practices.

1. NASA SBIR and STTR program representatives should meet regularly with other SBIR/STTR agencies to share best practices and strategies to increase participation of under-represented populations.

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[103] See Finding III-B and III-D.
[104] See Finding III-B.
[105] See Finding III-D.
[106] See Finding III-D
[107] See Finding III-C.
[108] See Finding III-B.

III. Commercialization

The NASA SBIR program has focused primarily on uptake within NASA, and has appropriately placed priority on agency utilization of SBIR-funded technologies. However, the agency has recognized that there are limits to the size and scale of commercialization within NASA; commercialization outside NASA remains an important objective for the program.

A. NASA should improve support for the commercialization of SBIR technologies.[109]

1. *Reviewing technology infusion activities*. The activities of TIMs should be reviewed in light of new data to be collected. Currently, it is difficult to determine whether they are effective providers of support services, particularly for the critical role of connecting companies to markets outside NASA.[110]
2. *Identifying and applying best practices*. Potentially, different approaches adopted by various NASA Field Centers could provide valuable data on more and less effective commercialization support strategies. Such analysis would of course require better data and a commitment to this kind of analysis and subsequent follow-up.[111]
3. *Leveraging existing programs and opportunities*. For example NASA should explore more systematic ways to connect with DoD SBIR commercialization efforts, particularly given the significant overlap between NASA and DoD revealed by the 2011 Survey and the DoD CCR database. The innovative program to utilize existing suppliers (Boeing) and a new entrant (Space-X) to replace the original NASA-run shuttle program to resupply the space station is an example of this kind of initiative.[112]

    - NASA should seek ways to connect directly to the Air Force SBIR program, and to relevant activities of others at DoD (e.g. MDA, DARPA, and Navy). For example, NASA could seek to participate in the annual Navy Opportunity Forum, in which some Centers have participated on a pilot basis in the past, or Air Force efforts in this area.
    - NASA should seek ways to capitalize on the overlap between DoD primes and NASA primes, with a view to helping companies bring NASA funded technologies to the wider DoD market.

[109]See Finding VI-A and Finding VI-B.
[110]See Finding VI-A.
[111]See Finding VI-D.
[112]See the discussion under "Reviewing the Evidence" in this chapter.

4. *NASA should explore ways to connect the SBIR program to the emerging commercial space sector.* [113]

- Given the clear overlap of technological interests, NASA should on a pilot basis develop topics that are of special interest not only to NASA Mission Directorates but the commercial space sector as well.
- NASA should also better connect with state and local entrepreneurship programs and venture capital and angel groups to help drive commercially minded companies into the program.

IV. Improving Program Management

Recommendations in this section are designed to improve program operations in ways that should enhance the program's ability to address some or all legislative objectives.

A. NASA should improve the application process.[114]

1. *NASA should improve connections with applicants prior to application.* The current rigid exclusion of contacts between NASA technical staff and company scientists once a solicitation is published is counterproductive. It generates proposals that do not adequately address NASA needs and potentially excludes others that could be submitted if more information was available. NASA should review and potentially adopt DoD's pre-release period, which is used to provide precisely the connection between agency technical staff and company researchers that NASA currently prohibits.[115]
2. *NASA should also review and consider for adoption a "white paper" process such as those in use at DoE and NSF.* White papers provide a structured opportunity for companies to present possible approaches to NASA prior to full submission. Using this approach can reduce the application burden on companies and NASA reviewers, while improving the average quality of applications.[116]
3. *NASA should not use low success rates to validate program quality.* These variables are not in principle related (if more weak proposals were screened out before application, then overall success rates would go up but so would the quality of funded projects). However, very high success rates especially for Phase I are a warning sign that the program

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[113]See the discussion under "Study Findings."
[114]See Finding VI-A and Finding VI-D.
[115]See Finding VI-D-4.
[116]See Finding VI-D-4.

is not attracting sufficient applications and in particular sufficient high-quality applications.

4. *The declining numbers of applications noted in the Awards chapter are a potential concern*. Applications are down more than 50 percent between 2005 and 2013. NASA should contact companies that have dropped out of the program to determine why they have done so.[117]

B. NASA should adopt more flexible contracting practices to encourage firm participating in the program.[118]

1. *NASA should reduce unnecessary rigidities in its contracting procedures*:[119]

- NASA should provide more flexibility in terms of payment schedules. It is not in the agency's interest to insist that work be spread out over the full two years of a Phase II project it if could be accomplished faster with more flexible application of the same resources. The NASA SBIR-STTR Program Office should explore adoption of contracting procedures that are already available within NASA under the Space Act to accelerate payments appropriately.
- NASA should consider permitting no-cost extensions to Phase I and Phase II awards. High-quality research cannot always be completed exactly on schedule, and the short timeframe for Phase I awards as well as the need to conclude the project to prepare for immediate filing of Phase II applications (see below) force companies to focus only on work that they know can easily be accomplished within a few months. NASA already takes a long time to initiate funding for Phase II awards; some of the gap could be utilized to permit companies to better complete funding Phase I research.
- NASA should consider loosening the very tight timeline between the end of Phase I and the deadline for Phase II submission (currently 2 weeks). This timeline seems unnecessarily tight and likely reduces the quality of Phase II applications to no purpose (given the long gap between Phase I and Phase II; see B.2).

[117]See Finding VI-D-4.
[118]See Finding VI-D.
[119]See Finding VI-D-1.

2. *NASA should review and address the overly long gap between Phase I and Phase II.*[120]

- NASA should substantially reduce the size of the Phase I-Phase II gap. 233 days is not an acceptable gap for small companies to face without funding, especially for worthy projects that are in the end funded.
- NASA should also consider ways to provide bridge funding during this period, in line with practice at some other agencies. It might also explore options such as Fast Track at NIH that combines Phase I and Phase II applications.
- NASA should permit companies to work at their own risk after Phase II submission, being prepared to pay for this work if a Phase II award is eventually made. This accelerates work at no risk or additional cost to NASA.

[120]See Finding VI-D-2.

APPENDIXES

Appendix A

Overview of Methodological Approaches, Data Sources, and Survey Tools

This report on the Small Business Innovation Research (SBIR) program at the National Aeronautics and Space Administration (NASA) is a part of a series of reports on SBIR at the National Institutes of Health (NIH), Department of Defense (DoD), Department of Energy (DoE), and National Science Foundation (NSF). Collectively, they represent a second-round assessment of the program by the National Academies of Sciences, Engineering, and Medicine.[1]

The first-round assessment, conducted under a separate ad hoc committee, resulted in a series of reports released from 2004 to 2009, including a framework methodology for that study and on which the current methodology builds.[2] Thus, as in the first-round study, the objective of this second-round study is "*not* to consider if SBIR should exist or not"—Congress has already decided affirmatively on this question, most recently in the 2011 reauthorization of the program.[3] Rather, we are charged with "providing assessment-based findings of the benefits and costs of SBIR . . . to improve public understanding of the program, as well as recommendations to improve the program's effectiveness." As with the first-round, this study "will *not* seek to compare the value of one area with other areas; this task is the prerogative of the Congress and the Administration acting through the agencies. Instead, the study is concerned with the effective review of each area."

[1]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1.
[2]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.
[3]National Defense Authorization Act of 2012 (NDAA) HR.1540, Title LI.

These areas refer to the four legislative objectives of the SBIR program:[4]

- Expand the U.S. technical knowledge base
- Support agency missions
- Improve the participation of women and minorities
- Commercialize government-funded research

The SBIR program, on the basis of highly competitive solicitations, provides modest initial funding for selected Phase I projects (up to $150,000) for feasibility testing, and further Phase II funding (up to $1 million) for about one-half of Phase I projects.

From a methodology perspective, assessing this program presents formidable challenges. Among the more difficult are the following:

- **Lack of data.** Tracking of outcomes varies widely across agencies, and in no agency has it been successfully implemented into a fully effective tracking system. There are no successful systematic efforts by agencies to collect feedback from awardees.
- **Intervening variables.** Analysis of small businesses suggests that they are often very path dependent and, hence, can be deflected from a given development path by a wide range of positive and negative variables. A single breakthrough contract—or technical delay—can make or break a company.
- **Lags.** Not only do outcomes lag awards by a number of years, but also the lag itself is highly variable. Some companies commercialize within 6 months of award conclusion; others take decades. In addition, often the biggest impacts take many years to peak even after products have reached markets.

ESTABLISHING A METHODOLOGY

The methodology utilized in this second-round study of the SBIR program builds on the methodology established by the committee that completed the first-round study.

Publication of the 2004 Methodology

The committee that undertook the first-round study and the agencies under study formally acknowledged the difficulties involved in assessing SBIR programs. Accordingly, that study began with development of the formal

[4]The most current description of these legislative objectives is in the Policy Guidance provided by the Small Business Administration (SBA) to the agencies. SBA Section 1.(c) SBIR Policy Directive, October 18, 2012, p. 3.

volume on methodology, which was published in 2004 after completing the standard Academies peer-review process.[5]

The established methodology stressed the importance of adopting a varied range of tools, which meshes with the methodology originally defined by the study committee to include a broad range of tools, based on prior work in this area. The committee concluded that appropriate methodological approaches

> "…build from the precedents established in several key studies already undertaken to evaluate various aspects of the SBIR. These studies have been successful because they identified the need for utilizing not just a single methodological approach, but rather a broad spectrum of approaches, in order to evaluate the SBIR from a number of different perspectives and criteria.
>
> This diversity and flexibility in methodological approach are particularly appropriate given the heterogeneity of goals and procedures across the five agencies involved in the evaluation. Consequently, this document suggests a broad framework for methodological approaches that can serve to guide the research team when evaluating each particular agency in terms of the four criteria stated above. [Table APP A-1] illustrates some key assessment parameters and related measures to be considered in this study."[6]

TOOLS UTILIZED IN THE CURRENT SBIR STUDY

Quantitative and qualitative tools being utilized in the current study of the SBIR program include the following:

- **Case studies.** The committee commissioned in-depth case studies of 11 SBIR recipients at NASA. These companies are geographically diverse, demographically diverse, funded by several different NASA Research Centers and Mission Directorates, and are at different stages of the company life cycle.
- **Workshops.** The committee convened a number of workshops to allow stakeholders, agency staff, and academic experts to provide unique insights into the program's operations, as well as to identify questions that need to be addressed.
- **Analysis of agency data.** A range of datasets covering various aspects of agency SBIR activities were sought from NASA and other sources. The committee has analyzed and included the data that was received as appropriate.

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[5]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, 2.
[6]Ibid.

TABLE APP A-1 Overview of Approach to SBIR Program Assessment

SBIR Assessment Parameters →	Quality of Research	Commercialization of SBIR-Funded Research/Economic and Non-economic Benefits	Small Business Innovation/Growth	Use of Small Businesses to Advance Agency Missions
Questions	How does the quality of SBIR-funded research compare with that of other gov't-funded R&D?	What is the overall economic impact of SBIR-funded research? What fraction of that impact is attributable to SBIR funding?	How to broaden participation and replenish contractors? What is the link between SBIR and state/regional programs?	How to increase agency uptake while continuing to support high-risk research
Measures	Peer-review scores, publication counts, citation analysis	Sales; follow-up funding; progress; initial public offering	Patent counts and other intellectual property/employment growth, number of new technology firms	Agency procurement of products resulting from SBIR work
Tools	Case studies, agency program studies, study of repeat winners, bibliometric analysis	Phase II surveys, program manager surveys, case studies, study of repeat winners	Phase I and Phase II surveys, case studies, study of repeat winners, bibliometric analysis	Program manager surveys, case studies, agency program studies, study of repeat winners
Key Research Challenges	Difficulty of measuring quality and of identifying proper reference group	Skew of returns; significant interagency and inter-industry differences	Measures of actual success and failure at the project and firm levels; relationship of federal and state programs in this context	Major interagency differences in use of SBIR to meet agency missions

NOTE: Supplementary tools may be developed and used as needed.
SOURCE: National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004, Table 1, p. 3.

- **Open-ended responses from SBIR recipients.** For the first time, the committee solicited textual responses in the context of the 2011 Survey, drawing more than 150 observations from respondents on the NASA SBIR program (respondents were asked to describe in their own words significant long-term impacts of the SBIR program on their company).
- **Agency interviews.** Agency staff was consulted on the operation of the SBIR program, and most were helpful in providing information both about the program and about the challenges that they faced.
- **Literature review.** In the time period since the start of our research in this area, a number of papers have been published addressing various aspects of the SBIR program. In addition, other organizations, such as the Government Accountability Office (GAO), have reviewed particular parts of the SBIR program. These works are referenced in the course of this analysis.

Taken together with our committee deliberations and the expertise brought to bear by individual committee members, these tools provide the primary inputs into the analysis.

We would stress that, for the first-round study and for our current study, multiple research methodologies feed into every finding and recommendation. No findings or recommendations rest solely on data and analysis from the survey; conversely, data from the survey are used to support analysis throughout the report.

COMMERCIALIZATION METRICS AND DATA COLLECTION

Congressional discussions of the SBIR program in the context of the 2011 reauthorization reflected strong interest in the commercialization of technologies funded through SBIR. This enhanced focus is understandable: the investment made should be reflected in outcomes approved by Congress.

However, no simple definition of "commercialization" exists.[7] Broadly speaking, in the context of the program it means funding for technology development beyond that provided under Phase II SBIR funding. Given the diversity of Mission Directorates and Centers at NASA, it is not surprising that there is considerable variation in the definition of commercialization and in the collection of data that can be used for assessment and measurement. Possible meanings and elements include the following:

- issuance of a certified Phase III contract by NASA directly to the small firm;

[7]See Chapter 5 (Quantitative Outcomes) for related analysis of commercialization in the SBIR program.

- adoption of a technology by a NASA program;
- utilization of a technology in space activities;
- licensing of technologies to prime contractors (primes) and other parties serving NASA;
- sale of products and services to primes for use on NASA systems (this may or may not include sale of data rights); and
- any sale of goods or services derived from SBIR-funded technologies, to NASA or to other purchases, including the U.S. private sector, other U.S.-based government agencies, and foreign buyers.

Challenges in Tracking Commercialization

The challenges involved in accurately tracking commercialization are of formidable scale and complexity. So it is useful to break the tracking issue into three broad components:

- within NASA;
- in the NASA primes and other companies serving NASA;
- and all remaining commercialization.

Tracking Phase III Commercialization within NASA: FPDS

The primary mechanism for tracking commercialization within NASA should be through the Federal Procurement Data System (FPDS), which records all agency procurement and which should therefore include information on all Phase III contracts. However, like DoD, and perhaps to an even greater extent, FPDS does not capture Phase III contracts effectively. A recent GAO study concluded that

> "…comprehensive and reliable technology transition data for SBIR projects are not collected. Transition data systems used by DOD provide some transition information but have significant gaps in coverage and data reliability concerns. The military departments have additional measures through which they have identified a number of successful technology transitions, but these efforts capture a limited amount of transition results."[8]

[8]U.S. General Accountability Office, *Small Business Innovation Research: DOD's Program Supports Weapon Systems, but Lacks Comprehensive Data on Technology Transition Outcomes*, GAO-14-96, December 20, 2013.

For FPDS to become a successful tracking tool, contracts which are designed as Phase III contracts should be marked as such. But this requires training for contracting officers across the agency, many of whom will not have had any experience with SBIR. In addition, because designation as a Phase III contract carries with it significant data rights for the small business, there may also be incentives for contracting officers, who do not want to share these rights, to avoid this designation, according to company interviewees.

Although the Navy SBIR program has made a concerted effort by devoting dedicated staff time to improving the quantity and quality of Phase III contracts captured by FPDS, this effort is an outlier, and at NASA no such effort has been undertaken. As a result, we have no data showing the extent to which NASA Phase III contracts are so designated in FPDS. It does not appear that NASA utilizes FPDS data for any program management functions.

Tracking Commercialization Through NASA Primes

Activities resulting in commercialization on behalf of NASA present a further layer of complexity. Because these activities take the form of private contracts between a prime and the subcontractor (the SBIR awardee), NASA does not collect detailed data as part of the contracting process. Typically, data about the SBIR heritage of a subcontract are not collected by the prime and are not further delivered to NASA for review.

Tracking Commercialization Outcomes Outside NASA and the NASA Primes

The contracting process sheds no light no activities outside NASA. Instead, all of the SBIR agencies must reply on reports from companies provided either through reports provided by the agency or through surveys conducted on the agency's behalf. DoD (and in the future NIH) utilizes the former, NSF and DoE utilize the latter. NASA has recently settled on the former, with the addition of tracking modules to the Electronic Handbook (EHB) discussed in Chapter 3 (Initiatives).

Why New Data Sources Are Needed

Congress often seeks evidence about the effectiveness of programs or indeed about whether they work at all. This interest has in the past helped to drive the development of tools such as the Company Commercialization Record database at DoD. However, in the long term the importance of tracking lies in its use to support program management. By carefully analyzing outcomes and associated program variables, program managers should be able to manage more successfully.

We have seen significant limitations to all of the available data sources. FPDS captures a limited dataset, and even that is not accurate especially with regard to Phase III. Data from the primes are often not directly reported. Although self-reporting through the EHB is growing, it is far from comprehensive at NASA.

BEYOND COMMERCIALIZATION METRICS

Although Congressional interest has focused primarily on commercialization in recent years, it remains the case that there are four congressionally mandated objectives for the SBIR program, and that commercialization is only one of them. The data collection tools described above focus almost exclusively on that objective; they have in general no capabilities for collecting data about the other three program objectives described in the introduction to this appendix. Some data from NASA's Electronic Handbook was ultimately made available for this study, but the data was too incomplete to be utilized; however, the EHB does hold substantial promise in eventually helping NASA to address concerns about data collection.

OVERVIEW OF THE SURVEY

Our analysis of the SBIR program at NASA makes extensive use of case studies, interviews, and other qualitative methods of assessment. These sources remain important components of our overall methodology, and Chapter 7 (Insights) is devoted to lessons drawn from case studies and other qualitative sources. But qualitative assessment alone is insufficient.

The Role of the Survey

The survey offers several significant advantages over other data sources, as follows:

- covers all kinds of commercialization inside and outside of NASA;
- provides a rich source of textual information in response to open-ended questions;
- probes more deeply into company demographics and agency processes;
- addresses principal investigators (PIs), not just company business officials;
- allows comparisons with previous data-collection exercises; and
- addresses other Congressional objectives for the program beyond commercialization.

At the same time, however, we are fully cognizant of the limitations of this type of observational survey research in this case. To address these issues while retaining the utility and indeed explanatory power of survey-based methodology, this report contextualizes the data by comparing results to those from the survey conducted as part of the first-round assessment of the SBIR program (referred to below as the "2005 Survey"[9]). This report also adds transparency by publishing the number of responses for each question and indeed each subgroup, thus allowing readers to draw their own conclusions about utility of the data.

We contracted with Grunwald Associates LLC to administer a survey to NASA award recipients. This survey is based closely on the 2005 Survey but is also adapted to lessons learned and includes some important changes discussed in detail below. A methodology subgroup of the committee was charged with reviewing the survey and the reported results for best practice and accuracy. The survey was carried out simultaneously with surveys focused on the SBIR programs at NSF and DoD.[10]

The primary objectives of the 2011 survey were as follows:

- Provide an update of data collected in the Academies survey completed in 2005, maximizing the opportunity to identify trends within the program;
- Probe more deeply into program processes, with the help of expanded feedback from participants and better understanding of program demographics;
- Improve the utility of the survey by including a comparison group; and
- Reduce costs and shrink the time required by combining three 2005 survey questionnaires—for the company, Phase I, and Phase II awards—into a single questionnaire.

Box A-1 identifies multiple sources of bias in survey response.

Survey Characteristics

In order to ensure maximum comparability for a time series analysis, the survey for the current assessment was based as closely as possible on previous surveys, including the 2005 Survey and the 1992 GAO survey.

Given the limited population of Phase II awards, the starting point for consideration was to deploy one questionnaire per Phase II award. However, we

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[9]The survey conducted as part of the current, second-round assessment of the SBIR program is referred to below as the "2011 Survey" or simply the "survey." In general, throughout the report, any survey references are understood to be to the 2011 Survey unless specifically noted otherwise.

[10]Delays at NIH and DoE in contracting with the Academies combined with the need to complete work contracted with DoD NSF and NASA led the Committee to proceed with the survey at three agencies only.

BOX A-1
Multiple Sources of Bias in Survey Response[a]

Large innovation surveys involve multiple sources of potential bias that can skew the results in different directions. Some potential survey biases are noted below.

- **Successful and more recently funded firms more likely to respond.** Research by Link and Scott (2005) demonstrates that the probability of obtaining research project information by survey decreases for less recently funded projects, and it increases the greater the award amount.[b] Nearly 75 percent of Phase II responses to the 2011 Survey (the population for which was awards made FY1998-2007) were for awards received after 2003, largely because winners from more distant years are more difficult to reach: small businesses regularly cease operations, are acquired, merge, or lose staff with knowledge of SBIR awards. This may skew commercialization results downward, because more recent awards will be less likely to have completed the commercialization phase.
- **Non-respondent bias.** The committee acknowledges that because it was not possible to collect information from non-respondent PIs and because the agencies have minimal information about PIs which could be used to track potential non-respondent biases, we do not have data on which to develop an analysis of non-respondent bias. The committee has concluded that the data are likely to be biased toward PIs who are still working at companies that are still in business as corporate entities (i.e. have not failed or been acquired).
- **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 retrospective 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 PIs are in many cases simply the best source of information available.
- **Survey sampled projects from PIs with multiple awards.** Projects from PIs with large numbers of awards were underrepresented in the sample, because PIs could not be expected to complete a questionnaire for each of numerous awards over a 10-year time frame, and they were, therefore, asked to complete no more than two.
- **Failed firms difficult to contact.** Survey experts point to an “asymmetry” in the survey’s 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 captured.** For similar reasons, the 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.
- **Some firms unwilling to fully acknowledge SBIR contribution to project 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 lags.** Although the 2005 Survey broke new ground in data collection, the amount of sales made—and indeed the number of projects that generated sales—are inevitably undercounted in a snapshot survey taken at a single point in time. On the basis of successive datasets collected from NIH SBIR award recipients, it is estimated that total sales from all responding projects will be considerably greater than can be captured in a single survey, because technologies continue to generate revenue after the date of the survey. These positive outcomes are therefore not included in any single survey result.[e] This underscores the importance of follow-on research based on the now-established survey methodology. Figure Box A-1 illustrates this impact in practice: projects from 2006 onward had not yet completed commercialization as of August 2013.

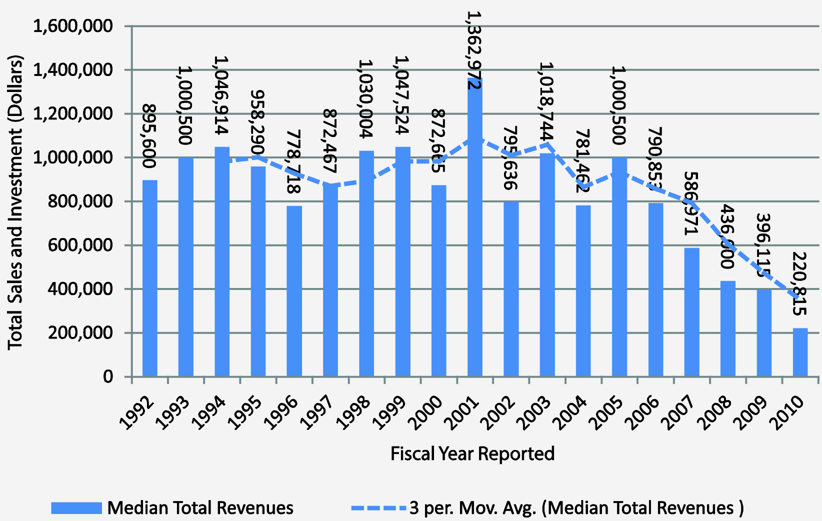

FIGURE Box A-1 The impact of commercialization lag.
SOURCE: DoD Company Commercialization Record database.

Box A-1 (continued)

Finally, the committee suggests that, where feasible, future assessments of the SBIR program include comparisons of non-awardees, such as in matched samples (Azouley et al., 2014) or regression discontinuity analysis (Howell, 2015).[f] In addition, future assessments should document the root cause of non-responsiveness. For example, determining whether the company is still in business even if the PI is no longer with the firm could provide useful evidence about the effectiveness of the SBIR award.

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[a] The limitations described here are drawn from the methodology outlined for the previous survey in National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Washington, DC: The National Academies Press, 2009.

[b] A.N. Link and J.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 that individuals and companies 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 (1) G. G. Dess and D. W. Beard, "Dimensions of Organizational Task Environments," *Administrative Science Quarterly*, 29: 52-73, 1984; (2) A.N. Link and J.T. Scott, *Public Accountability: Evaluating Technology-Based Institutions*, Norwell, MA: Kluwer Academic Publishers, 1998.

[d] Link and Scott, *Evaluating Public Research Institutions*.

[e] Data from the assessment of the SBIR program at NIH indicate that a subsequent survey taken 2 years later would reveal 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*, Washington, DC: The National Academies Press, 2009.

[f] Pierre Azoulay, Toby Stuart and Yanbo Wang, Matthew: Effect or Fable?. *Management Science,* 60(1), pp. 92-109, 2014. Sabrina Howell, "DOE SBIR Evaluation: Impact of Small Grants on Subsequent Venture Capital Investment, Patenting, and Achieving Revenue." Paper presented at the National Academy of Sciences, Engineering, and Medicine Workshop on the Economics of Entrepreneurship, June 29, 2015.

were also aware that the survey imposes burdens on respondents. Given the detailed and hence time-consuming nature of the survey, it would not be appropriate to over-burden potential recipients, some of whom were responsible for many awards over the years.

An additional point of consideration was that this survey was intended to add detail on program operations, rather than the original primary focus on program outcomes. Agency clients were especially interested in probing operations more deeply. We decided that it would be more useful and effective to administer the survey to PIs—the lead researcher on each project—rather than to the registered company point of contact (POC), who in many cases would be an administrator rather than a researcher.

The survey was therefore designed to collect the maximum amount of relevant data, consistent with our commitment to minimize the burden on individual respondents and to maintain maximum continuity between surveys. Survey questionnaires were to be sent to PIs of all projects that met selection characteristics, with a maximum of two questionnaires per PI. (The selection procedure is described below in "Initial Filters for Potential Recipients".)

Based on reviewer feedback about the previous round of assessments, we also attempted to develop comparison groups that would provide the basis for further statistical analysis. This effort was eventually abandoned (see comparison group analysis section below).

Key similarities and differences between the 2005 and 2011 Surveys are captured in Table A-2.

The 2011 Survey included awards made from FY1998 to FY2007 inclusive. This end date allowed for completion of Phase II awards (which nominally fund 2 years of research) and provided a further 2 years for commercialization. This time frame was consistent with the 2005 Survey, which surveyed awards from FY1992 to FY2001 inclusive. It was also consistent with a previous GAO study, published in 1992, which surveyed awards made through 1987.

The aim of setting the overall time frame at 10 years was to reduce the impact of difficulties generating information about older awards, because some companies and PIs may no longer be in place and because memories fade over time. Reaching back to awards made in 1998, while ensuring comparability, generated few results from older awards.

Determining the Survey Population

Following the precedent set by both the original GAO study and the first-round study of the SBIR program, we differentiated between the total population of awards, the preliminary survey target population of awards, and the effective population of awards for this study.

Two survey response rates were calculated. The first uses the effective survey population of awards as the denominator, and the second uses the preliminary population of awards as the denominator.

From Total Population of Awards to Effective Population

Upon acquisition of data from the sponsoring agencies (DoD, NSF, and NASA) covering record-level lists of awards and recipients, initial and secondary filters were applied to reach the preliminary survey population and ultimately the effective survey population. These steps are described below.

Initial Filters for Potential Recipients: Identifying the Preliminary Survey Population

From this initial list, determining the preliminary survey population required the following steps:

TABLE A-2 Similarities and Differences: 2005 and 2011 Surveys

Item	2005 Survey	2011 Survey
Respondent selection		
Focus on Phase II winners	✓	✓
Inclusion of Phase I winners	✓	✓
All qualifying awards		✓
Respondent = PI		✓
Respondent = POC	✓	
Max number of questionnaires	<20	2
Distribution		
Mail	✓	No
Email	✓	✓
Telephone follow-up	✓	✓
Questionnaire		
Company demographics	Identical	Identical
Commercialization outcomes	Identical	Identical
IP outcomes	Identical	Identical
Women and minority participation	✓	✓
Additional detail on minorities		✓
Additional detail on PIs		✓
New section on agency staff		✓
New section on company recommendations for SBIR		✓
New section capturing open-ended responses		✓

- elimination of records that did not fit the protocol agreed upon by the committee—namely, a maximum of two questionnaires per PI (in cases where PIs received more than two awards, the awards were selected by agency [NASA, NSF, DoD, in that order], then by year [oldest], and finally by random number); and
- elimination of records for which there were significant missing data—in particular, where emails and/or contact telephone numbers were absent.

This process of excluding awards either because they did not fit the protocol agreed upon by the committee or because the agencies did not provide sufficient or current contact information, reduced the total award list provided by the three agencies to a preliminary survey population for all three agencies of approximately 15,000 awards. From this, the preliminary survey population of Phase II SBIR and STTR awards for NASA was 1,131 awards.

Secondary Filters to Identify Recipients with Active Contact Information: Identifying the Effective Population

This preliminary population still included many awards for which the PI contact information appeared complete, but for which the PIs were no longer associated with the contact information provided and hence effectively unreachable. This is not surprising given that there is considerable turnover in both the existence of and the personnel working at small businesses and that the survey reaches back 13 years to awards made in FY1998. PIs for awards may have left the company, the company may have ceased to exist or been acquired, or telephone and email contacts may have changed, for example. Consequently, two further filters were utilized to help identify the effective survey population.

- First, PI contacts were eliminated—and hence the awards assigned to those PI contacts were eliminated—for which the email address bounced twice. Because the survey was delivered via email, the absence of a working email address disqualified the recipient PI and associated awards. This eliminated approximately 30 percent of the preliminary population (340 awards).
- Second, efforts were made to determine whether non-bouncing emails were in fact still operative. Email addresses that did not officially "bounce" (i.e., return to sender) may still in fact not be active. Some email systems are configured to delete unrecognized email without sending a reply; in other cases, email addresses are inactive but not deleted. So a non-bouncing email address did not equal a contactable PI. In order to identify not contactable PIs, we undertook an extensive telephone survey. Telephone calls were made to every PI with an award among the preliminary survey population of awards at NASA and who did not respond to the first round of questionnaire deployment. On the basis of responses to the telephone survey, we were able to ascertain that PI's for a further 27 percent of the preliminary population awards were in fact not contactable even though their email addresses did not bounce.

There was little variation between agencies or between programs in the quality of the lists provided by the agencies, based on these criteria.[11]

[11]The share of preliminary contacts that turned out to be not contactable was higher for this survey than for the 2005 Survey. We believe this is primarily because company points of contact (POCs) to which the 2005 Survey was sent have less churn than do principal investigators (PIs) (often being senior company executives).

Following the application of these secondary filters, the effective population of NASA Phase II awardees was 490.

Deployment

The survey opened on October 4, 2011, and was deployed by email, with voice follow-up support. Up to four emails were sent to the PIs for the effective population of awards (emails were discontinued once responses were received or it was determined that the PI was non-contactable). In addition, two voice mails were delivered to non-responding PIs of awards in the effective population, between the second and third and between the third and fourth rounds of email. In total, up to six efforts were made to reach each PI who was sent an award questionnaire.

After members of the data subgroup of the committee determined that additional efforts to acquire new responses were not likely to be cost effective, the survey was closed on December 19, 2011. The survey was therefore open for a total of 11 weeks.

Response Rates

Standard procedures were followed to conduct the survey. These data collection procedures were designed to increase response to the extent possible within the constraints of a voluntary survey and the survey budget. The population surveyed is a difficult one to contact and obtain responses from as evidence from the literature shows.[12] Under these circumstances, the inability to contact and obtain responses always raises questions about potential bias of the estimates that cannot be quantified without substantial extra efforts requiring resources beyond those available. (See Box A-1 for a discussion of potential sources of bias.)

The lack of detailed applications data from the agency makes it impossible to estimate the possible impact of non-response bias. We, therefore, have no evidence either that non-response bias exists or that it does not. For the areas where the survey overlaps with other data sources (notably DoD's mandatory CCR database) results from the survey and the DoD data are similar. Table A-3 shows the response rates at NASA, based on both the preliminary study population and the effective study population after all adjustments

Table A-3 shows the response rates at NASA, based on both the preliminary study population and the effective study population.

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[12]Many surveys of entrepreneurial firms have low response rates. For example, Aldrich and Baker (1997) found that nearly one-third of surveys of entrepreneurial firms (whose results were reported in the academic literature) had response rates below 25 percent. See H. E. Aldrich and T. Baker, "Blinded by the Cites? Has There Been Progress in Entrepreneurship Research?" pp. 377-400 in D. L. Sexton and R. W. Smilor (eds.), *Entrepreneurship 2000,* Chicago: Upstart Publishing Company, 1997.

TABLE A-3 2011 Survey Response Rates at NASA

Preliminary Population of Awards	1,131
Awards for which the PIs were Not Contactable	-641
Effective Population of Awards	490
Number of Awards for which Responses were Received	179
Percentage of Effective Population of Awards Contacted	36.5
Percentage of Preliminary Population of Awards	15.8

SOURCE: 2011 Survey.

The survey primarily reached companies that were still in business: overall, 97 percent of PIs responding for an award in the effective population indicated that the companies were still in business.[13]

Effort at Comparison Group Analysis

Several readers of the first-round reports on the SBIR program suggested inclusion of comparison groups in the analysis. There is no simple and easy way to acquire a comparison group for Phase II SBIR awardees. These are technology-based companies at an early stage of company development, which have the demonstrated capacity to undertake challenging technical research *and* to provide evidence that they are potentially successful commercializers. Given that the operations of the SBIR program are defined in legislation and limited by the Policy Guidance provided by SBA, randomly assigned control groups were not a possible alternative.

Efforts to identify a pool of SBIR-like companies were made by contacting the most likely sources (Dun & Bradstreet and Hoovers), but these efforts were not successful, as insufficiently detailed and structured information about companies was available.

In response, we sought to develop a comparison group from among Phase I awardees that had not received a Phase II award from the three surveyed agencies (DoD, NSF, and NASA) during the award period covered by the survey (1999-2008). After considerable review, however, we concluded that the Phase I-only group was also not appropriate for use as a statistical comparison group.

[13] 2011 Survey, Question 4A.

Appendix B

Major Changes to the SBIR Program Resulting from the 2011 SBIR Reauthorization Act, P.L. 112-81, December 2011

1) **The SBIR program received an increased share of federal agencies' extramural budget:**[1]
   a. Congress increased the SBIR/STTR share from 2.5 percent to 2.6 percent in FY2012 and by 0.1 percent per year thereafter through FY2017, when the share would be 3.2 percent.
2) **STTR's share of the overall combined program was increased:**[2]
   a. It is to grow from 0.25 percent to 0.3 percent in FY2011, 0.35 percent in FY2012, 0.4 percent in 2013, and 0.45 percent thereafter.
3) **Award levels were increased:**[3]
   a. The existing limit of $100,000 for Phase I SBIR and STTR awards was increased to $150,000.
   b. The existing limit of $750,000 for Phase II SBIR and STTR awards was increased to $1,000,000.
   c. These limits were also for the first time indexed to inflation.
4) **Agency flexibility to issue larger awards was curtailed:**[4]
   a. Awards may no longer exceed 150 percent of guidelines (i.e., $1.5 million for Phase II) without a specific waiver from the Small Business Administration (SBA) Administrator.
   b. The waiver can apply only to a specific topic, not to the agency as a whole. The agency must meet specific criteria and must show in its application that these criteria have been met before a waiver can be issued.

[1] U.S. Congress, P.L. 112-81, Sec. 5102 (a)(1)(a).
[2] Sec. 5102(b).
[3] Sec. 5103.
[4] Sec. 5103.

   c. For every award under a waiver, agencies must maintain additional information about the recipient, including the extent to which they are owned or funded by venture capital or hedge fund investors.

5) **Agencies are permitted to utilize awards from other agencies:**[5]
   a. Agencies gained the ability to adopt Phase I awards from other agencies for Phase II funding; however, senior agency staff must certify that this is appropriate.
   b. Similarly, the legislation now permits between-phase crossovers between SBIR and STTR.
6) **Phase II invitations were eliminated:**[6]
   a. Previously some agencies—especially the Department of Defense (DoD)—required that a company be invited by the agency before it could propose work for Phase II. This requirement is now prohibited.
7) **Pilot programs to skip Phase I were established:**[7]
   a. The legislation allows the National Institutes of Health (NIH), DoD, and the Department of Energy (DoE) to undertake pilot programs in this area. Discussions with agency staff indicate that for now DoD does not expect to utilize this new flexibility.
8) **Limited participation by previously excluded firms with majority venture capital or hedge fund ownership is now permitted (although subsidiaries of large operational companies are still excluded):**[8]
   a. NIH, NSF, and DoE are permitted to award up to 25 percent of their program funding to such companies.
   b. Other agencies are limited to 15 percent.
   c. For each award to such an entity, the Agency or component head must certify that this award is in the public interest based on criteria laid out in Sec. 5107(A)(dd)(2).
   d. Access to venture capital or hedge fund support may not be used as an award selection criterion by agencies.
   e. Special "affiliation" rules are provided for venture capital– and hedge fund–owned companies:
      i. Portfolio companies partially owned by venture firms or hedge funds are not deemed to be "affiliated" for purposes of determining whether an applicant meets size limitations, unless they are wholly owned or the owning company has a majority of board seats on the portfolio company.

[5] Sec. 5104.
[6] Sec. 5105.
[7] Sec. 5106.
[8] Sec. 5107.

9) **Explicit procurement preference were given for SBIR and STTR projects:**[9]
   a. The legislation states that agencies *and prime contractors* (emphasis added) must give preference to SBIR and STTR projects where practicable. However, there are no explicit targets included in the legislation.

10) **Sequential Phase II awards were permitted:**[10]
   a. The legislation now explicitly permits agencies to award one additional Phase II award after the first Phase II has been completed.
   b. The language implies that the provision of more than one sequential Phase II is prohibited.

11) **Commercialization support was expanded:**[11]
   a. Agencies are permitted to spend up to $5,000 per year per award on support for commercialization activities.
   b. Individual firms can now request up to $5,000 per year *in addition to their SBIR or STTR award* (emphasis added) to pay for commercialization activities from agency-approved vendors.

12) **The commercialization readiness pilot at DoD was converted to a permanent program—the Commercialization Readiness Program (CRP).** Details include in particular the following:[12]
   a. An SBIR Phase III insertion plan is now required for all DoD acquisition programs with a value of $100 million or more.
   b. SBIR/STTR Phase III reporting is now required from the prime contractor for all such contracts.
   c. The Secretary of Defense (SecDef) is now required to set goals for the inclusion of SBIR/STTR Phase II projects in programs of record and fielded systems and must report on related plans and outcomes to the SBA Administrator.
   d. The legislation explicitly requires the SecDef to develop incentives toward this purpose and to report on the incentives and their implementation.

13) **CRP may be expanded to other agencies:**[13]
   a. Other agencies may spend up to 10 percent of their SBIR/STTR program funds on commercialization programs.
   b. CRP awards may be up to three times the maximum size of Phase II awards.
   c. CRP authority expires after FY2017.

[9] Sec. 5108.
[10] Sec. 5111.
[11] Sec. 5121.
[12] Sec. 5122.
[13] Sec. 5123.

14) **Phase 0 pilot partnership program at NIH was enabled:**[14]
    a. NIH is permitted to use $5 million to establish a Phase 0 pilot program.
    b. The funding must go to universities or other research institutions that participate in the NIH STTR program.
    c. These institutions must then use the funding for Phase 0 projects for individual researchers.
15) **Data collection and reporting were enhanced:**[15]
    a. Overall, the legislation calls for substantially increased data collection for individual recipients and for much more detailed reporting from agencies to SBA and to Congress.
    b. Specific areas for improved reporting include the following:
        i. Participation of (and outreach toward) woman- and minority-owned firms and the participation of woman and minority principal investigators;
        ii. Phase III take-up (from both agencies and prime contractors);
        iii. Participation of venture capital– and hedge fund–owned firms;
        iv. Appeals and noncompliance actions taken by SBA;
        v. Sharing of data between agencies electronically;
        vi. Extra-large awards;
        vii. SBIR and STTR project outcomes (from participants);
        viii. University connections (especially for STTR projects);
        ix. Relations with the FAST state-level programs;
        x. Use of administrative funding;
        xi. Development of program effectiveness metrics at each agency; and
        xii. SBIR activities related to Executive Order 1339 in support of manufacturing.
    c. SBA is charged with developing a unified database to cover all SBIR and STTR awards at all agencies, as well as company information and certifications.[16]
16) **Funding was provided for a pilot program to cover administrative, oversight, and contract processing costs:**[17]
    a. Agencies are limited to spending 3 percent of their SBIR/STTR funding on this pilot.
    b. The pilot is initially designated to last for 3 fiscal years following enactment.
    c. Part of the funding must be spent on outreach in low-award states.

[14] Sec. 5127.
[15] Especially Sec. 5132, Sec. 5133, Sec. 5138, and Sec. 5161, but specific requirements are found throughout the legislation.
[16] Sec. 5135.
[17] Sec. 5141.

17) **Minimum commercialization rates for participating companies are required:**[18]
    a. Agencies must establish appropriate commercialization metrics and benchmarks for participating companies, for both Phase I and Phase II (subject to SBA Administrator approval).
    b. Failure to meet those benchmarks must result in 1-year exclusion for that company from the agency's SBIR and STTR programs.

[18] Sec. 5165.

Appendix C

2011 Survey Instrument

INTRODUCTION

Welcome to the National Academy SBIR Survey. Thank you for participating. This survey seeks responses related to the [Phase 1 or Phase II] project entitled [insert project title], funded by [insert agency name], at the following company [insert company name]. Funding was awarded in [insert FY].

Note: If you need to revisit the survey before finally completing it, you can return at the point you left off by clicking on the survey link in your email.

[Project title will be piped into the survey header throughout the survey]

PART 1. INFORMATION ABOUT YOU

This information is required only to determine your current status, and to ensure that we have accurate contact information. This information will be strictly private and will not be shared with any private entity or government agency.

1. For the project referenced above, were you (during the time period covered by this award) (select all that apply)
    a. Principal Investigator (PI) on this project
    b. Senior researcher (other than PI)
    c. the CEO
    d. not CEO but a senior executive with the company identified above
    e. None of the above (exit questionnaire)

PART 2. COMPANY INFORMATION SECTION

2. Have you already completed a questionnaire about another SBIR project for <u>this</u> National Academy survey related to [insert company name].
   [Yes/No. If yes, skip to Part 3]

3. Is [insert company name] still in business?
   [Yes/No]

4. Thinking about the number of founders of the company, what was…?
   a. The total number of founders [number box]
   b. The number of other companies started by one or more of the founders (before starting this one) [0,1,2,3,4,5 or more]
   c. The number of founders who have a business background [number box]
   d. The number of founders who have an academic background [number box]
   e. The number of founders with previous experience as company founders

5. What was the most recent employment of the company founders prior to founding the company? Select all that apply.
   a. Other private company
   b. Government
   c. College or University
   d. Other

6. Was the company founded because of the SBIR program?
   Yes
   No
   In part

7. What percentage of the company's total R&D effort (man-hours of scientists and engineers) was for SBIR activities during the most recent fiscal year
   ___%
   0%
   1-10%
   11-25%
   26-50%
   51-75%
   76-100%

8. What was the company's total revenue for the most recent fiscal year
   <100,000
   100,000-499,999
   500,000-999,999
   1,000,000-4,999,999
   5,000,000-19,999,999
   20,000,000-99,999,999
   100,000,000+

9. What percentage of the company's revenues during its most recent completed fiscal year was Federal SBIR funding (Phase I and/or Phase II)
   0%
   1-10%
   11-25%
   26-50%

51-75%
76-99%
100%

10. Which if any of the following has the firm experienced as a result of the SBIR program? Select all that apply.

    Made an initial public offering
    Planning to make an initial public offering in 2011-2012
    Established one or more spin off companies
    Been acquired by/merged with another firm
    None of the above

11. How many patents have resulted, at least in part, from the company's SBIR awards [number box]

12. Does the company have one or more full time staff for marketing? [Yes/No]

PART 3. PI/SENIOR EXECUTIVE INFORMATION

13. Please verify or correct the following information about yourself. Please indicate any corrections in the boxes provided. If all this information is accurate, click "Next" to continue. [Information will be piped in from respondent database to pre-populate editable text fields]
    a. Last name
    b. First name
    c. Current email address
    d. Current work telephone number (for follow up questions if necessary)

14. The Principal Investigator for this [SBIR] Award was a (check all that apply) (3 part question—14a, 14b, 14c)
    a. Woman
    b. Minority
    c. For those checking minority PI, add drop down list from SBA
       Asian-Indian
       Asian-Pacific
       Black
       Hispanic
       Native American
       Other

15. At the time of the award, the age of the leading PI was [20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65+]

16. What was the immigration status of the PI at the time of the award?
    American-born US citizen
    Naturalized US citizen
    US Green card
    H1 visa
    Other (please specify—box)

PART 4. POST-AWARD INFORMATION

17. Many agencies offer commercialization training in connection with SBIR awards. Did you (or another company staff member) participate in training related to this award?
    [Yes/No]

18. Number of company employees (including all affiliates)
    a. at the time of the award [pipe in award year] [Number box]
    b. Currently [Number box]

19. What was the ownership status of the company at the time of the award? (3 part question—19a, 19b, 19c)
    a. Woman-owned
    b. Minority-owned
    c. For those checking minority-owned, add drop down list from SBA
       Asian-Indian
       Asian-Pacific
       Black
       Hispanic
       Native American
       Other

PART 5. PROJECT STATUS INFORMATION

20. Please select the technology sector or sectors that most closely fit(s) the work of the SBIR project. Select all that apply.

    Aerospace
    Defense-specific products and services
    Energy and the environment
       Sustainable energy production (solar, wind, geothermal, bio-energy, wave)
       Energy storage and distribution
       Energy saving
       Other energy or environmental products and services
    Engineering
       Engineering services
       Scientific instruments and measuring equipment

Robotics
Sensors
Other engineering
Information technology
Computers and peripheral equipment
Telecommunications equipment and services
Business and productivity software
Data processing and database software and services
Media products (including web-, print- and wireless-delivered content)
Other IT
Materials (including nanotechnology for materials)
Medical technologies
Pharmaceuticals
Medical devices
Other biotechnology products
Other medical products and services
Other (please specify—box)

21. Prior to this SBIR [Phase I/Phase II] award, did the company receive funds for research or development of the technology in this project from any of the following sources?
    a. Prior SBIR (Excluding the Phase I which preceded this Phase II.) [this parenthetical not shown to Phase Is]
    b. Prior non-SBIR federal R&D
    c. Venture capital
    d. Other private company
    e. Private investor (including angel funding)
    f. Internal company investment (including borrowed money)
    g. State or local government
    h. College or university
    i. Other Specify __________

[Phase 1s continue/skip to question 30]

22. Did you experience a gap between the end of Phase I and the start of Phase II for this award? [P2 only]
    a. Yes Continue.
    b. No Skip to question 24

23. During the funding gap between Phase I and Phase II for this award, which of the following occurred? Select all answers that apply [P2 only]
    a. Stopped work on this project during funding gap.
    b. Continued work at reduced pace during funding gap.
    c. Continued work at pace equal to or greater than Phase I pace during funding gap.

d. Received bridge funding between Phase I and II.
e. Company ceased all operations during funding gap
f. Other [specify]

24. In your opinion, in the absence of this SBIR award, would the company have undertaken this project? [P2 only] Select one.
    a. Definitely yes
    b. Probably yes [If selected a or b, go to question 25]
    c. Uncertain
    d. Probably not
    e. Definitely not [If c, d or e, skip to question 27]

25. If you had undertaken this project in the absence of SBIR, this project would have been [P2 only]
    a. Broader in scope
    b. Similar in scope
    c. Narrower in scope

26. In the absence of SBIR funding… (please provide your best estimate of the impact) [P2 only]
    a. how long would the start of this project have been delayed? [text box - months]
    b. the expected duration/time to completion would have been…
        1) longer
        2) the same
        3) shorter
    c. in achieving <u>similar</u> goals and milestones, the project would be…
        1) ahead
        2) the same place
        3) behind

27. Did this award identify matching funds or other types of cost sharing in the Phase II Proposal? [P2 only]
    a. Yes.
    b. b. No. [If b, skip to question 30]

28. Matching or co-investment funding proposed for Phase II was received from (check all that apply). [P2 only]
    a. Our own company (includes borrowed funds).
    b. Federal non-SBIR funding.
    c. Another company.
    d. An angel or other private investment source.
    e. Venture capital.
    f. Other [specify]

29. How difficult was it for the company to acquire the funding needed to meet the matching funds requirements? [P2 only]
    a. No additional effort needed except paperwork
    b. Less than 2 weeks Full Time Equivalent (FTE) for senior company staff
    c. 2-8 weeks effort FTE for senior company staff
    d. 2-6 months of effort FTE for senior company staff
    e. More than 6 months of effort FTE for senior company staff

30. What is the current status of the project funded by the referenced award? Select the one best answer.
    a. Project has not yet completed SBIR funded research. Go to question 33.
    b. Efforts at this company have been discontinued. No sales or additional funding resulted from this project. Go to question 31.
    c. Efforts at this company have been discontinued. The project did result in sales, licensing of technology, or additional funding. Go to question 31.
    d. Project is continuing post-award technology development. Go to question 33.
    e. Commercialization is underway. Go to question 33.
    f. Products/Processes/ Services are in use by target population/customer/consumers. Go to question 33.
    g. Products/Processes/ Services are in use by population/customer/consumers not anticipated at the time of the award (for example, in a different industry). Go to question 33.

31. Did the reasons for discontinuing this project include any of the following?

	Yes
a. Technical failure or difficulties	
b. Market demand too small	
c. Level of technical risk too high	
d. Not enough funding	
e. Company shifted priorities	
f. Principal investigator left	
g. Project goal was achieved (e.g. prototype delivered)	
h. Licensed to another company	
i. Product, process, or service not competitive	
j. Inadequate sales capability	
k. Another firm got to the market before us	
l. Failed to receive Phase II award funding	
m. Other (please specify):	

32. Which of these was the primary reason for discontinuing the project? (pipe in reasons marked “yes” in question 31 for respondents to choose from)

PART 6. PROJECT OUTCOMES

33. Have you received or invested any additional developmental funding in this project since the SBIR award?
    a. Yes
    b. No [if no, skip to Q35]

34. To date, what has been the total additional developmental funding for the technology developed during this project? Enter dollars provided in drop down list provided for each of the listed sources below. [If none for a particular source, enter 0 (zero)]
    <100,000
    100,000-499,999
    500,000-999,999
    1,000,000-4,999,999
    5,000,000-9,999,999
    10,000,000-19,999,999
    20,000,000-49,999,999
    50,000,000+

    Source of Developmental Funding Since Receiving SBIR Award
    a. Non-SBIR federal funds
    b. Private Investment
        (1) U.S. venture capital
        (2) Foreign investment
        (3) Other Private equity (including angel funding)
        (4) Other domestic private company
    c. Other sources
        (1) State or local governments
        (2) College or Universities
    d. Not previously reported
        (1) Your own company (including money you have borrowed)
        (2) Personal funds

35. Has the 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.
    a. No sales to date nor are sales expected. Skip to question 38.
    b. No sales to date, but sales are expected. Skip to question 38.
    c. Sales of product(s)
    d. Sales of process(es)
    e. Sales of services(s)
    f. Other sales (e.g. rights to technology, licensing, etc.)

36a. For the company and/or the licensee(s), when did the first sale occur resulting from the technology developed during [name of project]?
If multiple SBIR Awards contributed to the ultimate commercial outcome, report only the share of total sales appropriate to this SBIR project.
For the company [Pulldown with choices from 1990-2011]
For any licensees [Pulldown with choices from 1990-2011]

36b. For the company and/or the licensee(s), what is the approximate amount of total sales dollars of product(s), process(es) or services to date resulting from the technology developed during the [name of project]?
For the company [Pulldown with choices: 0, <$100,000, $100,000-$499,999, $500,000-$999,999, $1,000,000-$4,999,999, $5,000,000-$9,999,999, $10,000,000-$19,999,999, $20,000,000-$49,999,999, $50,000,000+]
For any licensees [Pulldown with same choices]

36c. For the company and/or the licensee(s), what is the approximate amount of other total sales dollars (e.g. rights to technology, sale of spin-off company, etc.) to date resulting from the technology developed during the [name of project]?
For the company [Pulldown with choices: 0, <$100,000, $100,000-$499,999, $500,000-$999,999, $1,000,000-$4,999,999, $5,000,000-$9,999,999, $10,000,000-$19,999,999, $20,000,000-$49,999,999, $50,000,000+]
For any licensees [Pulldown with same choices]

37. 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 required to add to 100%.

a. Domestic private sector
b. Department of Defense (DoD)
c. NASA
d. Prime contractors for DoD
e. Prime contractor for NASA
f. Agency that awarded the Phase II (if not NASA or DoD)
g. Other federal agencies
h. State or local governments
i. Export Markets
j. Other (Specify)_____________

38. As a result of the technology developed during this project, which of the following describes the company's activities with other companies and investors? Select all that apply.

	U.S.		Foreign	
Activities	Finalized	Ongoing	Finalized	Ongoing
a. Licensing Agreement(s)				
b. Sale of Company				
c. Partial sale of Company				
d. Sale of technology rights				
e. Company merger				
f. Joint Venture agreement				
g. Marketing/distribution agreement(s)				
h. Manufacturing agreement(s)				
i. R&D agreement(s)				
j. Customer alliance(s)				
k. Other (specify)				

39. Please give the number of patents, copyrights, trademarks and/or scientific publications for the technology developed as a result of [name of project]. Enter numbers. If none, enter 0 (zero).

Number Applied For/Submitted		Number Received/ Published
	Patents	
	Copyrights	
	Trademarks	
	Scientific Publications	

40. How many SBIR awards has the company received that are related to the project/technology supported by this award?
    a. Number of related Phase I awards
    b. Number of related Phase II awards

Phase I recipients skip to Q44

PART 7. SBIR PROCESS AND RECOMMENDATIONS

41. In comparison to other Federal awards or Federal funding, how would you rate the process of applying for Phase II funding? Applying for Phase II funding was..." [Phase 2 only]
    a. Much easier than applying for other Federal awards

b. Easier
c. About the same
d. More difficult
e. Much more difficult
f. Not sure, not applicable, or not familiar with other Federal awards or funding

42. How adequate was the amount of money you received through Phase II funding for the purposes you applied for? Was it.. [P2 only]
    a. More than enough
    b. About the right amount
    c. Not enough

43. Should the size of Phase II awards be increased even if that means a proportionately lower number of Phase II awards are made? [P2 only]
    a. Yes
    b. No
    c. Not sure

44. Overall, would you recommend that the SBIR program be...?
    a. Expanded (with equivalent funding taken from other federal research programs that you benefit from and value)
    b. Kept at about the current level
    c. Reduced (with equivalent funding applied to other federal research programs you benefit from and value)
    d. Eliminated (with equivalent funding applied to other federal research programs you benefit from and value)

45. To what extent did the SBIR funding significantly affect long term outcomes for the company?
    a. Had a negative long term effect
    b. Had no long term effect
    c. Had a small positive effect
    d. Had a substantial positive long term effect
    e. Had a transformative effect

46. Can you explain these impacts in your own words? [memo field]

PART 8. WORKING WITH PROJECT MANAGERS

Project Managers take on different names at different agencies. At DoD they are called Technical Points of Contact (TPOCs); at NASA they are the Contracting Officer's Technical Representative (COTR); at NSF they are the Program Officer. We use Project Manager in the questions below to refer to all of these.

47. How often did you engage with your Project Manager in the course of your award?
    a. weekly
    b. monthly
    c. quarterly
    d. annually

48. How valuable was your Project Manager on a scale of 1-5, with 1 being no help and 5 being invaluable.

49. How knowledgeable was your Project Manager about the SBIR program. Were they able to guide you effectively through the SBIR process?
    a. Not at all knowledgeable
    b. Somewhat knowledgeable
    c. Quite knowledgeable
    d. Extremely knowledgeable

Phase I recipients skip to Q53

50. On a scale of 1-5, with one being least and 5 being most, how much did your project manager help during the Phase II award in the following areas: [1-5 scale for each row] [P2 only]
    a. The Phase II application process
    b. Providing direct technical help
    c. Introducing us to university personnel that could contribute to the project
    d. Introducing us to other firms that could provide technical expertise
    e. Finding markets for our technology or products/services

51. How closely did you work with your Project Manager as you pursued Phase III funding? [P2 only]
    a. Not at all
    b. Not much
    c. We discussed the application in detail
    d. The officer provided a lot of guidance during the application process
    e. We did not apply for Phase III funding

52. How effective was the Project Manager in connecting the company to sources of Phase III funding (such as acquisition programs or venture/angel funding)? [1-4 scale] [P2 only]
    Very helpful
    Somewhat helpful
    Not very helpful
    Not at all helpful

53. How easy was it to reach your Project Manager when you had questions or concerns? (New) [1-4 scale]
    Very hard
    Hard
    Easy
    Very easy

54. Was your Project Manager replaced during the course of your award? [Yes/No]

55. How do you see the time allocated for your Project Manager to work on your project? [1-3 scale]
    Insufficient
    Sufficient
    More than sufficient

56. Deleted during final instrument review

57. Additional comments on working with your TPOC or Program Officer [memo field]

58. Is a Federal System or Acquisition Program using the technology from this award?
    Yes (go to question 59)
    No (skip to question 60)

59. If yes, please provide the name of the Federal system or acquisition program that is using the technology. ____________________

60. This question addresses any relationships between your firm's efforts on this project and any University or College. Select all that apply.
    a. The PI for this project was at the time of the project a faculty member
    b. The PI for this project was at the time of the project an adjunct faculty member
    c. Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI
    d. Graduate students worked on this project
    e. The technology for this project was licensed from a University or College
    f. The technology for this project was originally developed at a University of College by one of the participants in this project
    g. A University or College was a subcontractor on this project
    h. None of the above

If any of these are checked (other than "none of the above"), continue to 60a; else skip to Q61 [if you do not check a-g, you should skip 60a as well]

60a. Which university (or universities) worked with your firm on this project?

61. Other comments on your experience with SBIR [memo field]

Appendix D

List of Universities Involved in Surveyed NASA SBIR Awards[1]

College or University Name	Number of Mentions
Arizona State University	1
Auburn University	1
Brown University	1
Carnegie Mellon University	1
Catholic University of America	1
The City University of New York	1
Colorado School of Mines	1
Colorado State University	1
Dartmouth College	2
Duke University	1
Embrey-Riddle University	1
Florida Atlantic University	1
Georgetown University	1
Georgia Institute of Technology	3
Harvard University	1
Loma Linda University	1
Louisiana State University	1
Mississippi State University	1
Missouri Technical University	1
Missouri University of Science & Technology	1
MIT	3
Naval Postgraduate School	1
Northeastern University	1
Northwestern University	1

[1]Based on 2011 Survey, Question 60. Survey covered awards made FY1998-2007.

College or University Name	Number of Mentions
The Ohio State University	3
Old Dominion University	1
The Pennsylvania State University	4
Prairie View A&M University (Texas)	1
Purdue University	4
Rensselaer Polytechnic Institute	2
Rice University	1
Rochester Institute of Technology (RIT)	1
Rutgers University	3
Stanford University	4
SUNY	1
Temple University	1
Texas A&M University	2
University of California, Berkeley	4
University of California, Davis	1
University of California, Riverside	1
University of California, Santa Cruz	1
Universities Space Research Association	1
University of Alabama	3
University of Alabama, Huntsville	2
University of Arizona	2
University of Arkansas	1
University of Central Florida	3
University of Colorado	2
University of Connecticut	1
University of Florida	2
University of Hartford	1
University of Hawaii at Manoa	1
University of Houston	3
University of Illinois at Urbana-Champaign	3
University of Kentucky	1
University of Maryland	2
University of Maryland at Baltimore County (UMBC)	1
University of Massachusetts at Lowell	1
University of Michigan	1
University of Minnesota	2
University of Mississippi	1
University of New Hampshire	1
University of New Orleans	1

College or University Name	Number of Mentions
University of Notre Dame	2
University of Pennsylvania	1
University of Reading (England)	1
University of South Carolina Nanotechnology Center	1
University of Tennessee	1
University of Texas	1
University of Texas at Austin	1
University of Texas Southwestern Medical Center	1
University of West Florida's Florida Institute for Human and Machine Cognition University of Maryland	1
University of Wyoming	1
Virginia Polytechnic Institute	2
Total	113

SOURCE: 2011 Survey, Question 60.

Appendix E

Case Studies

To complement its review of program data, the committee commissioned case studies of 11 companies that received Phase II Small Business Innovation Research (SBIR) and or Small Business Technology Transfer (STTR) awards from the National Aeronautics and Space Administration (NASA), undertaken in 2009-2011. Case studies were an important source of data for this study, in conjunction with other sources such as agency data, the survey, interviews with agency staff and other experts, and workshops on selected topics. The impact of SBIR/STTR funding is complex and often multifaceted, and although these other data sources provide important insights, case studies allow for an understanding of the narrative and history of recipient firms—in essence, providing context for the data collected elsewhere.

The committee studied a wide range of companies (see Box E-1). They varied in size from fewer than 10 to more than 500 employees and included firms owned by women and minorities. They operated in a wide range of technical disciplines and industrial sectors. Some firms focused solely on military applications, and others focused on commercialization either through the Department of Defense (DoD) or through the private sector. Overall, this portfolio sought to capture many of the types of companies that participate in the SBIR program. Given the multiple variables at play, the case studies are not presented as any kind of quantitative record, and only a limited number of case studies were completed as part of this study. Rather, they provide qualitative evidence about the individual companies selected, and although they are not intended to be statistically representative of NASA SBIR award winners or their award outcomes, they are, within the limited resources available, as representative as possible of the different components of the awardee population. The featured companies have verified the case studies presented in this appendix and have permitted their use and identification.

BOX E-1
Directory and Profile of Case Studies

Company Name	Location (Headquarters)	Year Founded
Advanced Cooling Technologies, Inc.	Lancaster, PA	2003
Continuum Dynamic, Inc.	Ewing, NJ	1979
Cybernet Systems Corporation	Ann Arbor, MI	1989
Eltron Research and Development, Inc.	Denver, CO	1982
Honeybee Robotics	New York, NY	1982
Intelligent Automation, Inc.	Rockville, MD	1987
Paragon Space Development Corporation	Tucson, AZ	1993
Princeton Scientific Instruments	Monmouth Junction, NJ	1980
Stottler Henke Associates, Inc.	San Mateo, CA	1988
Techno-Sciences Inc.	Beltsville, MD	1975
ZONA Technology, Inc.	Scottsdale, AZ	1985

ADVANCED COOLING TECHNOLOGIES, INC.

Based on interviews with Jon Zuo, CEO, October 19, 2009 and
William Anderson, Chief Engineer, September 24, 2015.
Lancaster, PA

Advanced Cooling Technologies, Inc. (ACT) is a privately held company located in Lancaster, Pennsylvania. ACT develops and manufactures heat management products and performs contract research for both the government and the private sectors. In addition to developing one-off custom designs for individual customers, it has had success converting such projects into low volume (production runs of 1-10,000 units), highly engineered products. These products have been used in applications ranging from spacecraft thermal control, to cooling of high performance electronics, LEDs and surgical instruments, to energy recovery in HVAC systems, at temperatures ranging from -150°C to 1,100°C. One of the most successful products has been the company's constant conductance heat pipes for aerospace applications.

ACT was founded by Jon Zuo (CEO) and Scott Garner (Vice President for Defense and Aerospace Products) in January 2003 after Zuo and Garner left Thermacore, another company located in the Lancaster, Pennsylvania area and also focused on heat management technologies. ACT was initially supported by research and development (R&D) contracts, including some from Thermacore. However, even during this period, Zuo and Garner intended for ACT to develop products and related services enabled by this R&D, and not simply to perform contract R&D.

The company has been growing profitably since its inception and currently has 95 employees. Continuing growth is expected based on an emphasis on low-volume, high-margin applications (see Business Model below). In August 2015, ACT expanded its manufacturing facilities to support the production of its energy recovery products for improving the efficiency of building HVAC systems.[1] The SBIR program has played a pivotal role in the development of new technologies and products, with the company having received 28 SBIR/STTR grants worth $5.6 million in 2013 and 2014 alone.

ACT Technologies

From an initial focus on heat pipe technologies, ACT has expanded into new technologies of heat management, especially thermal storage systems, modelling, and coatings.

Heat Pipes

Heat pipes are designed to move heat[2]. They consist of a vacuum tight tube containing a working fluid and a wick. The fluid evaporates under heat. The production of vapor at the evaporator end of a tube holding a vacuum creates a pressure differential between the evaporator and the condenser at the other end of the tube. The vapor flows towards the cooler section where the heat dissipates. The working fluid condenses and is recycled back to the evaporator section using capillary action along the wick. Because of the continuous condensation of the vapor, the pressure differential from one end of the tube to other is maintained.

As heat management systems, heat pipes have obvious benefits. They take no power, are low cost, are resistant to both vibration and freezing, and lastly will operate indefinitely as long as there is a temperature gradient between the evaporator and condenser sections.

This basic structure can be customized in several ways.

- Annular and planar configurations can be built where tubes are not optimal.
- Loop heat pipes and loop thermosyphons move the heat considerable distances, using additional mechanisms such as gravity feeds and

[1]ACT Announces Facility Expansion, http://www.1-act.com/news/act-announces-facility-expansion/.
[2]Heat Pipe Resources, http://www.1-act.com/advanced-technologies/heat-pipes/.

distant condensers. Loop heat pipes are currently used for thermal control in spacecraft.

- The heat pipe loop (HPL) uses an evaporator like a heat pipe and a distant condenser like a loop heat pipe.

Water is typically used at operating temperatures between 20°C and 270°C. Beyond these temperatures, heat pipes use various working fluids including methanol, ammonia, ethane, nitrogen, and hydrogen. ACT heat pipes operate at temperatures ranging from -150°C to 1,100°C. Similarly, the materials used in building the pipes vary based on performance requirements.

Pumped Liquid Cooling Technologies

Pumped liquid cooling is a standard approach for cooling systems as varied as automotive engines, avionics, and nuclear reactors. Typically, pumped

BOX E-2
Heat Pipe Technology History

Heat pipes enable the transfer of heat, often across distances of several meters in length. Early heat transfer technologies used pumps or gravity to return the working fluids to the evaporators. Heat pipes took advantage of the wicking capabilities of certain materials to do this passively.

Heat pipe technologies were originally invented at General Motors in the early 1940s but were not successfully commercialized. In August 1963 the national laboratory at Los Alamos independently developed a similar device which Radio Corporation of America (RCA) and other companies subsequently investigated for potential industrial applications.[a]

Because RCA did not believe the market was sufficiently large enough to meet the company's growth requirements, after a decade of work in the mid-1970s the company exited the heat pipe business. The technology was adopted by Thermacore, a new company founded by a former manager at RCA, Yale Eastman. Modine bought Thermacore in 2000. In 2003, Zuo and Garner left Thermacore and founded Advanced Cooling Technologies to focus on highly engineering heat pipes. Yale Eastman sat on ACT's board of directors

This history indicates that heat pipes have primarily been an industrial technology, not the fruits of academic research that were subsequently industrialized.

[a]For a detailed summary of early heat pipe technology, see G. Yale Eastman, "The Heat Pipe," *Scientific American,* vol. 218, no. 5 (1968): 38-46; http://www.1-act.com/wp-content/uploads/2013/01/east.pdf.

liquid cooling systems consist of a pump, a cold plate, a heat exchanger/sink and liquid lines. The pump circulates the fluid in the loop, which picks up the heat at the heat exchanger and dissipates it at the cold plate. High perfomance pumped cooling systems require high pressure to move the working liquid, sometimes on the order of hundreds of pounds per square inch (psi). Consequently, it is difficult to design systems that require minimal maintenance over long periods. Using techniques like osciliating liquid cooling and jet impingement, ACT is working to realize high performance cooling without the necessity for high pressure. Potential applications include power electronics and computer microprocessors.

Thermal Storage

Phase Change Materials (PCMs) store thermal energy by properly managing the phase change from solid to liquid. Because the latent heat of melting / freezing is at least 1-2 orders of magnitude larger than the energy stored as specific heat, PCMs are an effective means of thermal management. By smoothing the temperature observed in systems during non-continuous, pulsed operation, heat removal systems can be designed for the average heat load rather than the peak load. Because of the dynamic, time-dependent thermal properties of a PCM heat exchanger, advanced modeling capabilities and experience in thermal design are essential. ACT has designed PCM based cooling systems, ranging from milli-watts to kilo-watts for applications including energy weapons, pulsed electronics, missiles, and battery cooling.

Modeling

ACT engineers apply modeling both to develop products and as a service provided to customers. They use industry best-in-class finite element, CAD, fluid dynamics, and thermal analysis tools. In addition to commercial software tools, ACT has developed in-house models to evaluate the performance of specific applications related to the company's areas of technological and commercial strength such as heat pipes, heat exchangers, two-phase pumped loops, phase separation, and thermal storage.

ACT now performs advanced modeling as a service to its government and commercial customers[3]. ACT's Advanced Modeling Research focuses on developing a fundamental understanding of physical and chemical processes at the micron and sub-micron scale. These bottom-up multi-scale simulation approaches can link atomic-scale analyses to product scale performance. ACT has developed modeling competency in areas such as corrosion resistance, ab-

[3]Advanced Computational Methods and Modeling, http://www.1-act.com/advanced-technologies/advanced-modeling/.

initial modeling of ablation chemistry, and Boltzmann-transport based modeling of thermal and electrical behavior in single transistors.

Coatings

In addition to conducting thermal R&D, ACT has recently begun investigating the effect of different types of coatings on heat exchanger and cold plate performance. The earliest work developed a coating to prevent erosion and corrosion of the microchannels in copper heat exchangers used to cool laser diodes.[4] Additional research on surface coatings has increased the boiling heat transfer coefficient of heat exchangers in two phase systems by providing nucleation sites, and improved condensation heat transfer at cold plates by creating non-wetting condensation surfaces.

ACT has used SBIR awards to fund research in these advanced technology areas.

Business Model

The market for heat pipe technologies divides into higher volume standardized products and small-scale customized batch production design for individual customers. For example, heat pipes are an important component in cooling multicore processors in modern personal computers. They are produced in the millions for less than a dollar each. ACT does not participate in this end of the market. Instead, ACT focuses on highly engineered, low volume products. The company started in 2003 with passive heat pipe technology before diversifying later into related thermal control markets.

ACT's founders believed that high-volume heat pipe production would eventually migrate overseas, a belief which proved largely accurate. They did not believe that U.S.-based production could remain competitive in a commodity business. Bill Anderson observed that most of the contemporary high volume business in personal computers is served by plants in Taiwan and China.

Focusing on lower volume production required ACT to work hard to acquire more customers. ACT engages in a wide range of activities to attract customers, including the following:

- trade show appearances (and booths)
- scientific papers
- extensive use of the Internet, including ACT's deep website
- extensive efforts to attract publicity through traditional means (press releases, etc.)

[4]Advanced Coatings, http://www.1-act.com/advanced-coatings/.

Dr. Zuo believes that ACT's most successful marketing tool is its own high-quality customer service. He noted that ACT works hard to ensure that everyone at the company focuses on customer satisfaction. ACT performs regular customer service surveys and has data that strongly supports Dr. Zuo's assertion that word of mouth from satisfied customers is ACT's "biggest and cheapest" source for new customers.

Funding and Customers

ACT is now primarily funded by its own customer base. It has more than 300 current customers, divided between R&D contracts and commercial sales, and between civilian and military or prime contractor customers. ACT's government and nonprofit customer list includes the following organizations (not a complete list):

- Air Force Research Laboratory (AFRL)
- Army Tank Automotive & Armament Command (TACOM)
- Defense Advanced Research Projects Agency (DARPA)
- Department of Energy (DoE)
- Florida International University
- Lawrence Livermore National Laboratory (LLNL)
- Max-Planck Institute
- Missile Defense Agency (MDA)
- NASA Glenn Research Center (GRC)
- NASA Goddard Space Flight Center (GSFC)
- NASA Jet Propulsion Laboratory (JPL)
- NASA Johnson Space Center (JSC)
- NASA Marshall Space Flight Center (MSFC)
- National Institute of Standards and Technology (NIST)
- National Physical Laboratory of United Kingdom
- National Research Council of Canada
- National Science Foundation (NSF)
- Naval Air Warfare Center (NAWC)
- Naval Research Laboratory (NRL)
- Naval Surface Warfare Center (NSWC)
- Office of Naval Research (ONR)
- University of California, Los Angeles
- University of California, Riverside
- University of Canterbury (New Zealand)
- University of Nevada Reno
- University of Utah

Along with the successful run of SBIR awards (see SBIR section below), ACT has been successful attracting other research contracts. For example, in late 2003, a critical component of early funding for ACT was a $1.2 million contract from Glenn Research Center at NASA. Most recently, in May, 2015 ACT and its partners received a $3.2 million contract from ARPA-E at DoE to investigate efficient and scalable dry-cooling technologies for thermoelectric power plants. Coupled with an earlier $1.1 million from SBIR to study the coating technologies, ACT seems well positioned to build strong technical capabilities in this area.[5]

ACT has also had success working with prime contractors. For example, in July, 2015, ACT announced that it had received a contract from Lockheed Martin to help develop, test and ultimately field the Long Range Anti-Ship Missile (LRASM), a weapons program funded by DARPA, the U.S. Navy, and the U.S. Air Force. ACT is responsible for replacing the active pumped cooling system used to cool the targeting electronics with its passive thermal management technology. By reducing system complexity, ACT expects to achieve higher reliability.[6]

Knowledge Effects

ACT owns five patents as assignee,[7] and Dr. Zuo is named as inventor in 14 patents in total. The company also supports the publication of scientific and technical peer-reviewed papers as a part of its mission. The company website lists 123 journal and conference papers.

In 2001 ACT received the Tibbetts Award from the SBA and the Small Business Technology Council (SBTC) for excellence in technology research and commercialization. The citation recognized the company's valuable contributions in developing the Constant Conductance Heat Pipe products and technology.

SBIR

Dr. Zuo said that SBIR funding was "very important to the company's success during the early years, and continues to be important today." That importance is reflected in the pattern of SBIR awards.

ACT won its first Phase I award from DoD in 2003 and three more from DoD and NASA in 2004. Since then, it has been remarkably successful, winning 109 SBIR/STTR awards between 2003 and 2015 for total of $31.29M. (See Table E-1.)

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[5]"ACT Awarded $4.3M to Develop Technologies for Dry Cooling," (June 8, 2015), http://www.1-act.com/news/act-awarded-4-3m-to-develop-technologies-for-dry-cooling/.
[6]"ACT Receives Lockheed Martin Contract to Support Missile Development, (July 20, 2015), http://www.1-act.com/news/lockheed-martin-missile-development/.
[7]ACT Patents, http://www.1-act.com/resources/act-patents/.

TABLE E-1 SBIR/STTR Awards to Advanced Cooling Technologies by Program and Phase

Program/Phase	Number of Awards	Funding (Dollars)
SBIR Phase I	69	7,414,414
SBIR Phase II	29	20,360,130
STTR Phase I	6	569,254
STTR Phase II	5	2,944,022
Total	109	31,287,820

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed September 23, 2015.

Most (90 percent) of the funding that ACT has received through the SBIR/STTR programs has been SBIR awards. ACT has depended on four principal sources for its SBIR/STTR funding, receiving 42 percent of its funding from DoD, 31 percent from NASA, 23 percent from DoE, and 4 percent from NSF.

SBIR awards have had particularly significant effects on the company's development. Four in particular have resulted in the development of products that contribute substantially to the company's revenue stream. In 2015, approximately 2/3 of ACT's revenues were derived from product as opposed to research contracts. Of the product stream, Bill Anderson noted that about half is based on SBIR funded research.

ACT's core competence in heat pipes for spacecraft thermal control was developed in collaboration with NASA using SBIR funding. NASA was looking for a second source for thermal control in space craft. ACT received an SBIR contract, which generated very promising results. The company then undertook a market survey. In light of the results, ACT added self-funding to accelerate development. The funding was used to develop and launch products aimed at addressing needs expressed by other thermal control customers. [8] Getting ISO 9001 and AS-9100 quality certifications was also critical to successful market penetration. The resulting Constant and Variable Conductance Heat Pipe (CCHP and VCHP[9]) products have generated millions of dollars in

[8]NASA Phase I "Heat Pipe Heat Exchangers with Double Isolation Layers for Prevention of Interpath Leakage"; DoD Phase I "VCHP Heat Exchanger for Passive Thermal Management of a Fuel Cell Reforming Process."

[9]According to ACT, "Variable conductance heat pipes (VCHPs) are used to achieve temperature control. This is accomplished by blocking a fraction of the condenser with a small amount of non-condensable gas. When the heat load or the condenser temperature increases, the heat pipe temperature tends to rise. The increased vapor pressure compresses the non-condensable gas, exposing more condenser area and as a result increases the heat pipe conductance. The opposite happens when the heat load or the condenser temperature decreases. The variation of the conductance keeps the heat pipe operating temperature nearly constant over a wide range of heat inputs and condenser thermal environments."

revenue for ACT, for thermal control of both government and commercial satellites.[10]

ACT has continued to follow this pattern of technically successful Phase I and Phase II projects followed by market evaluation with self-funding where analysis shows potential for market acceptance. A cooling system for high performance LEDs (such as theatre or automotive lights) originated in a DoE SBIR project. Likewise, ACT's PCM heat sinks began life as a DoD Missile Defense Agency SBIR project to investigate passive heat management systems that could reduce the active cooling requirements of high energy beam weapons. PCMs are ACT's strongest selling product line currently with applications from thermal energy storage, to solar power plants, to electronics cooling.

Dr. Anderson also cautioned against reading too much into ACT's success with commercializing SBIR technologies. Although ACT has had notable successes productizing SBIR research, considering the number of technically successful Phase II awards that it has performed, the company has had a larger number of programs that stopped after the Phase II, without successful commercialization. On the other hand, this is true for of any early stage R&D organization. (Table E-2 reports ACT's conversion rates from SBIR Phase I to Phase II for different agencies. ACT has a good record of success, especially for NASA and DoE.)

Dr. Anderson also noted that depending on the agency, the commercialization problem is slightly different. As mission driven agencies, both DoD and NASA want ACT to solve a problem that they have. In a sense, you begin with one customer. Because DoE topics are driven by national energy strategy, they aren't usually the end customers and ACT has to come up with the complete commercialization pathway.

TABLE E-2 SBIR/STTR Awards to Advanced Cooling Technologies by Phase and Source (1979-2014)

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)	Total Funding By Agency (Dollars)	Agency Funding as Percent of Total	Phase I to Phase II Conversion Rate (Percent)
DoE	12	1,449,567	6	5,748,747	7,198,314	23	50
NSF	3	449,569	2	935,294	1,384,863	4	67
NASA	22	2,161,832	12	7,398,511	9,560,343	31	55
DoD	38	3,922,700	14	9,221,600	13,144,300	42	37
Total	75	7,983,668	34	23,304,152	31,287,820	100	45

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 8, 2015.

[10] Constant Conductance Heat Pipes, http://www.1-act.com/products/constant-conductance-heat-pipes/.

ACT expects its NASA SBIR awards to result in the take-up of ACT technology in NASA projects. However, Dr. Zuo noted that most NASA SBIR awards focused on projects still far from maturity and that the initial $1.2 million non-SBIR award from GRC, although technically successful, focused on a project that NASA subsequently cancelled. Dr. Anderson elaborated, noting that although a NASA or DoD award usually provides ACT with its first customer, successful commercialization requires identification of additional customers. This can be a challenge given the performance requirements of NASA/DoD designs and the cost constraints faced in commercial markets.

STTR

ACT has also received STTR funding. It constitutes about 10 percent of the $31.29 million received by ACT from SBIR/STTR programs. In general, STTR allows ACT to access university expertise more easily. In recent years, ACT has done quite a lot of modeling work in which university professors have deep expertise. Dr. Anderson cautioned that ACT also hires university consultants on SBIR contracts. The real advantage with STTR is if we need a lot of university expertise. He observed, "With SBIR, you can allocate about 1/3 of the budget to consultants. With overhead, that means only 25 percent of the budget becomes useful work done by the faculty member. If we need more than that, we would apply to STTR."

The biggest challenge with STTR is interacting with a large bureaucracy like a university. It takes time to get things approved. Also, Anderson noted, "Sometimes it's difficult to get the full attention and productivity of the faculty member, but that's unusual and besides it can happen with employees too." Also, negotiating IP sharing is an additional problem that you typically don't have with SBIR. Some agencies require that this be done prior to the proposal, some not. He preferred not.

Improving SBIR and STTR

Both Dr. Zuo and Dr. Anderson emphasized that agencies must continue to manage SBIR as a research rather than a development program and expressed concern that, while commercialization is important, the agencies are funding an insufficient number of high-risk, high-reward projects. Dr. Zuo noted that not every funded project can be a winner and that it is important for the agencies to continue to encourage experimental research with the program.

Dr. Zuo was strongly opposed to an increased award size if there is no additional funding to pay for the increase. He argued that, in funding early-stage research, the agencies should hedge their bets to ensure that research funding is not overly concentrated, because it is not possible to determine in advance which projects will be successful in the end. He was convinced that a reduction in the number of awards—even if each receives increased funding—will result in reduced outcomes. He also believed that a concentration of resources would favor certain companies. Dr. Anderson agreed.

Dr. Anderson observed that not all agencies treat STTR quite the same. For example, the DoE allows an applicant to make the same application to both an STTR and SBIR program. Another agency does not require the firm to have an IP agreement in place with the university at the time of application. He thought both innovations improved the utility of STTR applications.

CONTINUUM DYNAMICS INC. (CDI)

Based on interviews with
Dr. Alan Bilanin, Founder and CEO / Dr. Todd R. Quackenbush, Senior Associate on October 20, 2009, and Dr. Todd R. Quackenbush, Senior Associate on October 8, 2015

Continuum Dynamics is a privately held company located in Ewing, New Jersey. Founded in 1979 by Dr. Alan Bilanin, it currently has about 20 employees, with a strong emphasis on Ph.D. researchers. The company has worked for a wide range of clients including a number of Federal agencies, aerospace companies, nuclear power companies, and pharmaceutical companies. CDI's initial technical focus was in aerospace research, modeling rotorcraft blade performance and aircraft aerodynamics. Over the past thirty years, however, CDI has also built a substantial business providing testing and analysis services to the nuclear power industry.

Many of the underlying physical mechanisms of the fluid phenomena encountered by propeller blades and power turbines are similar, and a wide range of solution methods developed for one set of problems is transferrable to the other domain. For example, as part of SBIR efforts for the U.S. Army and NASA, CDI had developed algorithms to model coupled fluid structural systems. Unexpectedly, this solution proved to be of major value for the nuclear power industry. CDI teamed with General Electric to deliver testing and design services based on this technology to power utilities. As this component of CDI's business has grown, CDI has developed relationships with other equipment vendors.

Currently, CDI is receiving Phase III support from the Department of the Navy to commercialize fully a flight simulation module developed under SBIR. The company is working closely with program officers in Navy and the flight simulation software vendors to improve realism of simulated flight by integrating CDI's core fluid flow technologies into the vendor software, and it is expected that this simulation technology will be transitioned to Navy fleet trainers within the next year.

During its early years (1982-1999), CDI was located on an outlying campus of Princeton University, where it could access facilities and research staff. Several of the current staff members were drawn from the university.

Today, because of the growth of the company and the advent of more distributed research models facilitated by the Internet, locational issues are less significant.

Technology and Products

Based on its work in the aerospace sector, CDI has developed a portfolio of tools for advanced modeling and simulation of air vehicles, as well as novel flow control actuation systems using smart materials. CDI has applied these tools broadly in the analysis of flow patterns for fixed-wing aircraft, unmanned vehicles, and ship airwakes.

Many of these tools are the result of SBIR efforts funded by NASA, in particular projects that were sponsored by the Subsonic Rotary Wing and Supersonics elements of the Fundamental Aeronautics Program through NASA/Ames, NASA/Glenn, and NASA/Langley Research Centers. Also, in work with NASA and DoD to develop these tools, CDI has developed close working relations with large aerospace and defense contractors such as Sikorsky Aircraft, Lockheed Martin, Boeing, CAE, and General Electric Aircraft Engines.

CHARM

One key element of CDI's aerospace modeling capabilities is CHARM. CDI's Comprehensive Hierarchical Aeromechanics Rotorcraft Model (CHARM) is software that models the complete aerodynamics and dynamics of rotorcraft in general flight conditions, resulting from more than 25 years of continuous development of rotorcraft modeling technologies at CDI. According to CDI, CHARM incorporates "landmark technical achievements from a variety of NASA, DoD, and company-sponsored initiatives,"[11] including several SBIR awards from NASA in the 1980s and 90s for helicopter wake modeling played a central role.

CHARM supports advanced rotorcraft aerodynamic design, as well as research on emerging rotorcraft technologies. According to CDI's website, CHARM was designed to address a range of needs in advanced aerospace design. They include:

- Detailed prediction of rotor power and propulsive force as a function of thrust and flight condition
- Detailed prediction of rotor aerodynamic loads, blade motion and vibration
- Vortex wake modeling
- Time-accurate modeling of rotor/wake/airframe interact ional aerodynamics

[11]CDI, Comprehensive Hierarchical Aeromechanics Rotorcraft Model, http://www.continuum-dynamics.com/pr-charm.html. Accessed November 6, 2009.

- Coupled multiple rotor/multiple lifting surface solutions for realistic airframes
- Coaxial and ducted rotor unmanned aerial vehicle (UAV) design
- Simultaneous evolution of the aerodynamic and structural dynamic solutions to model rotorcraft response to pilot inputs
- Real-time free wake modeling for simulation applications
- Modeling of rotorcraft systems within wind tunnels and in ground effect
- Prediction of thickness and loading noise, including BVI noise, using an automated interface with NASA/Langley's WOPWOP
- Prediction of rotor wash in operations near the ground and ships to model multiple aircraft interactions and brownout."[12]

CDI has also developed a number of software packages complementary to CHARM, as shown in Table E-3.

VorTran-M

A more recent element of CDI's portfolio of software is the VorTran-M wake module is a "first-principles Eulerian vorticity transport wake module"[13] that provides enhanced ability to capture the "temporal and spatial structure of the rotor wake, when coupled"[14] to a wide range of Computation Fluid

TABLE E-3: Continuum Dynamics, Inc., Software Portfolio

Software	Description Drawn from Continuum Dynamics Website
EHPIC-HERO	"Rotor blade design software [uses] a unique "influence coefficient" method for fast, accurate performance optimization."
MAST	The Multiple Aircraft Simulation Tool (MAST) is a standalone, modular tool that simulates "real-time flight simulation of multiple aircraft with wake interactions."
VLA	The Visual Landing Aid (VLA) is PC-based "software for the design of shipboard lighting systems to [facilitate] rotorcraft landings at sea."
LDTRAN	"LDTRAN analysis software for predicting the entrainment and transport of hazardous biological/chemical agents by rotorwash."
VorTran-M	VorTran-M is a "first-principles Eulerian vorticity transport wake module that captures the true temporal and spatial structure of the rotor wake when coupled to Eulerian and Lagrangian [computational fluid dynamics (CFD)] tools."
BROWNOUT	BROWNOUT is a "standalone/modular software that provides a physics-based model of visual 'brownout' rendered directly in flight simulation and analysis software when rotorcraft land in sandy/dusty conditions."

SOURCE: Continuum Dynamics, Inc., http://continuum-dynamics.com/solution-ae-rtc.html?

[12]Continuum Dynamics, Inc., CHARM, http://www.continuum-dynamics.com/pr-charm.html. Accessed September 1, 2015.
[13]Continuum Dynamics, Inc., http://continuum-dynamics.com/solution-ae-rtc.html?
[14]Continuum Dynamics, Inc., website, http://continuum-dynamics.com/solution-ae-rtc.html?

Dynamics (CFD) tools (both Eulerian and Lagrangian). The wake module can also be used to define structures in space and time and model the fluid flow past those structures. As such, VorTran-M is a critical part of the CDI's ability to model the effect of the physical environment on aircraft. Using this module, CDI researchers can model interactional flows, such as those encountered in ground effect, formation flight, flights into "urban canyons," terminal area operations, and ship airwake-rotorcraft wake interactions.

Business Model

Over the past five years, CDI's business model has not qualitatively changed, though the balance of its revenue streams has shifted significantly It remains a 20 person company that gets revenues from three sources: 1) SBIR R&D, 2) Software (and other technology) licensing, and 3) Services. Since the company's founding, design and analysis of aircraft and rotorcraft has been the core of both CDI's business and its research activities in the aerospace and defense sector. Additionally, CDI has also long had a strong presence in supporting the nuclear power generation industry with critical niche capabilities in fluid-structure interaction. The company developed software based on its SBIR R&D activities, and its services have mixed contract R&D with consulting work applying CDI-developed software tools. Modeling work on coupled fluid structural systems that CDI performed for the Army and NASA has also proved useful to the nuclear power industry, as noted above.

Since 2010, the relative size of CDI's revenue streams within aerospace and defense work has shifted quite substantially. Over the past 5 years, the proportion of SBIR research (Phase I, II) has dropped. With new customers and new applications, CDI now receives a larger fraction of its revenue from services and software licensing activities. Whereas 50 percent of revenues derived from SBIR contracts in 2010, at present, software licensing and services (mostly contracts applying CDI tools) now comprise 65 percent of revenues. Also, the different business cycles of the two major sectors of CDI's customer base have continued to provide CDI with generally stable revenue streams. (See Table E-4.)

TABLE E-4 Continuum Dynamics, Inc., Revenue Mix (2010-2015)

	Percent of Company Revenue, by Year	
	2010	2015
SBIR R&D	50	35
Software Licensing	30	20
Services	20	45

SOURCE: Interviews with CDI Personnel.

The shift to services might have been even more pronounced had more formal sales and marketing capabilities been developed. To date, CDI has been successful selling services based on its research reputation, exploiting a very strong R&D brand. A major opportunity for CDI going forward is to develop a more disciplined approach to their sales and marketing work. As Dr. Quackenbush observed, “We are still in the process of figuring out an efficient process of determining to whom we should be selling.”

SBIR (Phase I and II)

NASA SBIR award (see Table E-5) have played a pivotal role in supporting both CDI and, indirectly, rotorcraft manufacturing in the United States. According to Dr. Bilanin, all U.S. manufacturers (and most of those overseas) now utilize CDI rotorcraft software in the design and analysis of helicopters. CDI has been highly proficient in winning SBIR/STTR awards, garnering a total of 196 awards worth $46.60 million as of 2015, though only a small part of CDI’s funding stream comes from STTR (less than 3 percent).

CDI has received SBIR awards from a number of agencies, including the Department of Agriculture (USDA), the Department of Defense (DoD), the Department of Energy (DoE), the Department of Health and Human Services (HHS), NASA, the Environmental Protection Agency (EPA), and the National Science Foundation (NSF). Awards from NASA and DoD accounted for just over 80 percent of CDI’s Phase II awards. (See Table E-6.) CDI maintains a solid record in converting Phase I awards to Phase II, including at DoD and NASA.

Dr. Bilanin also observed that CDI had built a longstanding and durable relationship with some NASA Centers, in some cases reaching back more than 30 years. The company’s collaborative work with NASA/Ames has, for example, resulted in numerous benefits not only for the company—including a steady flow of work and access to NASA expertise and facilities—but also for NASA, where CDI has consistently delivered modeling tools needed to solve some of NASA’s most pressing problems. In addition, the Center has helped link CDI to industry groups and companies that use the NASA/Ames facilities. This linkage was especially helpful during CDI’s early years.

TABLE E-5 SBIR/STTR Awards to Continuum Dynamics, Inc., by Program and Phase

Program/Phase	Number of Awards	Funding (Dollars)
SBIR Phase I	130	10,194,082
SBIR Phase II	61	34,834,937
STTR Phase I	3	269,894
STTR Phase II	2	1,298,768
Total	196	46,597,681

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 8, 2015.

TABLE E-6 SBIR/STTR Awards to CDI by Phase and Source (1979-2014)

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)	Total Funding By Agency (Dollars)	Agency Funding as Percent of Total	Phase I to Phase II Conversion Rate (Percent)
Agriculture	2	113,500	1	209,915	323,415	1	50
DoE	4	299,826	3	1,748,875	2,048,701	4	75
DoT	3	249,204	1	296,012	545,216	1	33
HHS	6	448,671	4	2,358,898	2,807,569	6	67
EPA	3	139,452	1	224,980	364,432	1	33
NASA	45	3,421,375	20	11,198,592	14,619,967	31	44
NSF	11	717,299	3	919,691	1,636,990	4	27
DoD	59	5,074,649	30	19,176,742	24,251,391	52	51
Total	133	10,463,976	63	36,133,705	46,597,681	100	47

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 8, 2015.

SBIR – Phase III

Through the Technology Assistance Program, the Navy offers additional commercialization support to a small number of successful Phase II projects. The program does not simply provide additional transition funding. It also introduces the company to potential customers, brings in program managers from DoD, and runs technology showcases aimed at various segments of the defense industry.

At present, the Technology Assistance Program has helped highlight Navy-funded Phase III work that is adapting CHARM for use in flight simulation. Air flow past an aircraft is complex, and in the past, the flight simulation vendors have approximated these effects using look up tables or other highly simplified aerodynamic models. With advances in computational power and accelerated algorithms, it is now possible to bypass these simplified models and do these calculations in real time with much higher physical fidelity during the simulation. Integrating CDI technology into flight simulations will allow better, more realistic training for U.S. pilots.

CDI's contribution is not limited to the modeling rotorcraft flight with CHARM, but also modeling the air flow generated by the environment. For example, simulating the flight of a helicopter landing on a ship requires modeling the air flows generated by the ship as well (typically using VorTran-M and CGE). The new technology offered by these coupled tools is modular. The flight simulation vendor doesn't have to swap out their simulation engine; instead they only have to drop in a new, pre-validated module in place of the look-up tables and their simulation will show an immediate improvement in physical accuracy.

SBIR has been a significant component in this. It funded the original work that developed CHARM, VorTran-M and CGE and is now providing the resources to enable commercialization. Dr. Quackenbush emphasized that “the Navy has been unusually forward looking in funding and organizing this work. The have provided transition funding, they’ve found program offices committed to continuing that funding, and they’ve introduced us to key flight simulation vendors. There has been a great deal of cross-fertilization.” CDI has self-funded some elements in this process, but mostly Navy dollars are supporting it.

Commercialization

Other downstream impacts of CDI technologies have been substantial. Carson Helicopters, of Perkasie, Pennsylvania, used CHARM to simultaneously increase the payload of its Sikorsky S-61 helicopter by 2,000 pounds and cruise speeds at 10,000 feet by 15 knots.[15] According to CDI, Carson is now selling rotor blades designed with help from CDI to commercial operators worldwide, as well as to the U.S. Navy and the U.K. Royal Navy. Significantly, the Carson rotor blades are now in use on the military version of the S-61 used for “Marine One” Presidential Helicopters, extending the life and improving the performance of these helicopters. Also, Sikorsky benefited from CDI’s work under NASA 1999 and 2002 awards, resulting in additional revenues of $24 million.[16]

CHARM has also been incorporated into a joint CDI-Army study focused on software to practice landing rotorcraft in sandy or dusty conditions (known as brownout), where sand and debris blinds pilots and can damage equipment.

BOX E-3
Successful Technology—Failed Commercialization:
The Case of Recycled Tires

Dr. Bilanin strongly emphasized that developing successful technical solutions is only a part of commercial success. CDI developed technology to recycle tires for use as bridge supports—helping the environment at the same time as solving a potentially catastrophic problem for thousands of bridges in the United States.

However, the CDI spin-off pursuing this project ran into insuperable political problems stemming from concerns about the downstream impact of the tires on the riverine environment. Dr. Bilanin argued that these concerns were misplaced, but they were sufficient to halt and eventually dissolve the project.

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[15]NASA, “Modeling Tool Advances Rotorcraft Design,” Spin-off 2007, http://www.sti.nasa.gov/tto/Spinoff2007/t_2.html.
[16]Ibid.

The wide range of software products developed by CDI has led to other less dramatic commercialization impacts. For example, SBIR awards from NASA Glenn Research Center in 1988 and 1993 supported development of software that predicts turbomachinery flutter. The wide ranging impact of SBIR research and development is apparent in the fact that elements of this software were subsequently adapted for use by customers as diverse as New Jersey pharmaceutical companies (for fluid flow analysis in medication delivery systems) and the Washington Public Power Supply System (for the study of engineering problems in fluid/structure interaction). CDI's products have also generated revenues from licensing and contract research.[17] NASA funding for aircraft wake studies supported development of an agricultural dispersal modeling tool (AGDISP) used by the Forest Service, the Federal Aviation Administration (FAA), and various agricultural chemical manufacturers, including DuPont.

Dr. Bilanin noted that other technologies developed with SBIR support have also been successfully commercialized, notably smart materials that generated more than $1 million in revenues from components for test facilities for aeropropulsion and the use of shape memory alloys to develop actuators. CDI anticipates the adaptation of this technology to new areas, including wind turbines and other energy applications.

Knowledge Effects

CDI has patented what it believes are important technical advances with commercial application; it is the assignee on 13 U.S. patents. Its patent library includes devices for rotorcraft and UAV flight control that use smart materials, vortex wake mitigation systems for jetliners, and advanced filtration hardware for the emergency cooling water systems for nuclear power plants. CDI also publishes extensively in peer-reviewed journals.

CDI personnel take an active role in the larger aeronautical research community. For example, at the 71st Annual Forum of the American Helicopter Society, in addition to demonstrating the flight simulation software that they are developing in collaboration with CAE, CDI staff also presented four technical papers and sat on three technical committees. CDI researchers are recognized as experts in their fields. A CDI staff member was the keynote speaker in October, 2014 at the annual Symposium on Overset Composite Grids and Solution Technology at Georgia Tech and will serve as Technical Chair for the upcoming 72nd Annual Forum of the AHS in May 2016. A review of its website shows 79 articles published between 1974 and the present.

CDI has also been recognized for its contributions to the SBIR program itself. In February, 2011, Senior Associate Todd Quackenbush received a "Champions of Small Business Innovation" Award from the Small Business

[17]NASA SBIR Success Stories, "Computational Method for Aeroelastic problems in Turbomachinery, http://sbir.nasa.giv/successes/ss/3-071text.html.

Technology Council for his energetic advocacy on behalf of the long-term reauthorization of the SBIR program in 2011.[18]

STTR

The greatest benefit of STTR to CDI is access to skilled people and to new ideas. Dr. Quackenbush emphasized that the benefit is not only gaining access to the faculty but also to the students. “We get exposed to new ideas, new approaches and potentially new employees. We really welcome that.”

The biggest challenge in developing an STTR proposal, however, is often the universities’ attitudes towards intellectual property rights. Funding agencies require that an IP agreement be developed within 60 days of the notice of selection for an STTR award. CDI finds meeting that deadline to be a challenge, and typically, there’s an argument about royalty levels. “Our most challenging experiences are in the intellectual property offices of the big research universities. They seem to have little understanding of the business situation of small businesses, being used to dealing either with the federal Government or major corporations.” Despite the formal requirements of STTR for collaboration, they don’t really do much to help CDI or other small businesses in this process. As a consequence, Quackenbush said, “We have generally steered away from STTR except in cases of truly special opportunities.” Indeed, only 3 percent of CDI SBIR/STTR awards are through the STTR program.

Drilling a little deeper, Dr. Quackenbush opined that many major universities would be happy if SBIR/STTR went away. “When it launched in the 1980s, SBIR was an unwelcome development as being competition for Federal sponsored research. Since then, the universities have never really embraced the program. It’s always been a cultural and organizational mismatch.” While CDI’s experiences have varied somewhat, in general the IP offices of many major universities do not seem prepared to work with small companies.

Improving SBIR and STTR

To improve the STTR/SBIR program, CDI management suggests that all agencies emulate the Navy’s Technical Assistance Program and also put aside more funding and support for Phase III projects. As Dr. Quackenbush put it, “Of course, self-funding does work but having Phase III as a legitimate possibility is a good thing.”

Also, if agencies are to broker introductions between small business and the defense primes, they need to address not only funding but also support. For example, from CDI’s perspective, the biggest problem in working with

[18]National Small Business Association, “SBTC Honors "Champions of Small Business Innovation” February 12, 2011, http://www.nsba.biz/content/printer.4422.shtml.

primes at the request of agencies is data rights. Because CDI can't patent its' simulation software, data rights are how CDI protects its intellectual property.

Somehow there's a view among the primes that because the technology was funded by the government, the prime shouldn't have to pay royalties or have any restrictions on the use of software supplied by a small business. For Phase III to work, the agencies need to be committed to backing the small business' rights. If a small business licenses to a prime, those licenses must get honored, and it is crucial for the agency to understand its role as an advocate.

CYBERNET SYSTEMS CORPORATION

Based on interviews with
Dr. Charles Jacobus, Chief Technology Officer and Co-founder
September 15, 2011; November 7, 2014
By telephone

Cybernet Systems Corporation (Cybernet) is a privately held company headquartered in Ann Arbor, Michigan. Founded in 1989 by Ms. Heidi Jacobus and Dr. Charles (Chuck) Jacobus, the company has completed a large number of DoD contracts and has been a certified 8(a) woman-owned small business and Tibbetts award winner. The company's vision has focused on amplifying human capabilities through the application of technology.

Utilizing the founders' expertise in robotics and human factors research, Cybernet has been a leader in robotics since its inception. It has provided innovative defense products in a number of areas and has applied its expertise in the health care sector.

Company formation was directly influenced by SBIR. The company was founded because Heidi Jacobus had won Phase I awards related to her PhD thesis. In 1990 Cybernet received its first Phase II award, which was sufficient to hire Chuck Jacobus and to permit a move to new premises.

The company initially focused on force feedback and human factors research, and it filed its first patents for force feedback in game controllers in 1992. By 1996, the company had 40 employees, largely Ph.D.s, with the work closely centered on robotics, sensors, and remote applications. During this period, SBIR awards opened the door to a number of sponsors especially in DoD and NASA.

Markets and Capabilities

Cybernet's capabilities are all oriented around the core vision of amplifying human performance through the advanced application of technology. Commercial products and services cover a range of product areas. Key milestones for the company include the following:

- 1996: First portable robot control stations

- 1996: First Internet-enabled medical device
- 1998: License/spin-off of force feedback to Immersion Corporation
- 1998: NetMAX™ product launched—national distribution in 1999
- 1999: Immersion initial public offering (IPO) (NASDAQ: IMMR)
- 2001: Cybernet Medical launched for MedStar product
- 2004: First Automated Tactical Ammunition Classification System (ATACS).

Selected Cybernet Technologies

Cybernet has worked with every major branch of the U.S. military. The following list includes a number of defense technologies developed by Cybernet.

ATACS

One important product has been the Automated Tactical Ammunition Classification System (ATACS). ATACS is a tactical small arms ammunition sorter designed to completely automate the rapid sorting and inspection of loose small arms ammunition ranging from 4.6 mm to 50 calibers. ATACS operates at a rate of 12,500 rounds per hour, in contrast to traditional, time-consuming methods of hand sorting by military personnel.

ATACS was developed using existing commercial-off-the-shelf (COTS) components and the company's Projectile Identification Systems (PIDS), based on a previous SBIR award. ATACS can determine chambering dimensions to include length, width, height of primer, concentricity, bent bullet tips, dents, corrosion, and perforation in cartridge case and/or bullet.

ATACS is portable enough to cost-effectively employ in the field. Within 60 days, Cybernet quickly developed and fielded the ATACS for the U.S. Army at Camp Arifjan, Kuwait, where the product was used to reclaim serviceable ammunition through this faster, safer, and more consistent inspection process. Cybernet is currently building its sixth ATACS for Army.

This rapid delivery was made possible in part by the SBIR compete clause, which permitted the Army to sole source the contract to Cybernet based on the competition for the previous SBIR award.

LCAR

The Large Caliber Automated Resupply (LCAR) program aimed to apply robotics technology to store, supply, and replace ammunition for military vehicles such as tanks on the battlefield. This product automatically load the ammunition into the vehicles, and unloads unwanted casings or ammunition, reducing the danger associated with manual re-supply efforts in volatile situations by removing soldiers from vulnerable exposure.

This project addressed the need to automate loading in the Future Combat Systems program. Boeing had in fact selected Cybernet as a supplier when the FCS was cancelled. The design package remains relevant for future programs. This program also derives from the Projectile Identification Systems (PIDS) SBIR award.

VSIL

According to Cybernet, the Virtual Systems Integration Lab is a virtual prototyping package for modeling "vehicle systems and components, developed by Cybernet and [Army's] Tank-Automotive Research, Development and Engineering Center (TARDEC). VSIL leverages its commercial virtual-design technology—pioneered in the automotive industry—to simulate Army vehicles and perform rapid trade-off analysis for soldier safety and operational effectiveness."[19]

A subsequent follow-on project focused on providing Navy with automated tools for the system test and repair of submarines, to augment the ability of system maintainers to prevent and repair system faults in a timely manner. The objective is to release war fighters from the burden of performing routine diagnostic and maintenance, allowing them to focus on the mission at hand.

Health Care Technologies

NASA also, in part, funded the technology development that would lead to MedStar™, a web-based system for outpatient care that collects physiological data from personal patient devices and sends the data to a web-based electronic patient and data management system. Cybernet launched the MedStar in 2001, and it has been distributed nationwide since 2006.

The system collects physiological data from patients and their in-home devices (such as scales, respirometers, pulse oximeters, glucometers and blood pressure cuffs) and records it in Cybernet's web-based electronic patient and data management system. This provides physicians, nurses, pharmacists, and other health care professionals with immediate access to updated outpatient information, regardless of location.

MedStar appears to have had particular relevance in rural communities, where specialist (or even general) medical help may be remote. For example, the MedStar system has been piloted by the Oklahoma City-based INTEGRIS Rural Telemedicine Project. According to Cynthia Miller, director of the project, remote vital sign monitoring can help eliminate the distance barrier and provide nurses with more timely information. It has helped prevent unnecessary trips to the emergency room, and patient quality of life has improved.

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[19]Cybernet Systems Corporation website, http://www.cybernetsystems.com.

Although other competitors have largely sealed off the Veterans Administration—a substantial potential market—Cybernet has had more success breaking into the hospital systems market, in which diversified hospitals offered the best market. MedStar helps to keep chronic but not seriously ill people out of expensive beds and lowers the cost of nursing. Many diversified hospitals run home care programs or are affiliated with preferred provider organizations (PPOs) and therefore have interests that align with Cybernet solutions.

Overall, while the original NASA need focused on tracking the metabolic state of astronauts, using unobtrusive monitoring technologies, this did not quite amount to medical instrumentation, and Cybernet found that NASA needs did not overlap much with market demand for medical monitoring: NASA wanted data, while the private sector wanted tests that could attract fees. Going forward, Dr. Jacobus said that Cybernet plans to follow its strategy for other projects and license the technology to ensure wider distribution.

Automated Transportation Technologies

Cybernet has also focused on addressing the federal mandate[20] that one-third of operational ground combat vehicles be unmanned by 2015. Cybernet converted a minivan into an autonomous ground vehicle and was 1 of only 35 teams worldwide invited to the National Qualifying Event for the 2007 DARPA Urban Challenge.[21]

Cybernet has developed an approach that uses COTS technology to implement driverless autonomy, an approach that can be rapidly and directly inserted into Army's existing fleet of medium tactical trucks currently used in convoy operations.

Cybernet has contracts to build robotic forklifts. The company transitioned its DARPA Urban Challenge technology to build these automated forklifts for the Army. There is a potentially significant market for this technology in mid-sized warehouses that are too big for fully manual operation and too small for installation of a fully automated materials movement system. Automated vehicles know traffic rules, and sense people, other vehicles, and obstacles out to 30 meters from the vehicle, which permits them to find and fetch materials safely in mixed human and machine environments. Other Army bases are interested in using the technology to handle ordnance.

Sensors and Robotics Technologies

Cybernet has been working in this area for more than 20 years. Currently available products include those based on the company's computer

[20] 2001 National Defense Authorization Act.

[21] The 2007 DARPA Urban Challenge was the third in a series of competitions held by the Defense Advanced Research Projects Agency (DARPA) to foster the development of autonomous robotic ground vehicle technology that can execute simulated military supply missions. The 2007 competition was held in a mock urban area.

vision systems that can be used to recognize objects (e.g., spacecraft, parts, grasp points, docking targets, or anything that can be defined by a computer aided design [CAD] drawing or description) from views taken from one or several cameras.

As noted on the Cybernet website, "NetMAX Robotics focuses on product sales and commercial development of robotics, situational awareness systems, and embedded sensor products."[22] Although the company was originally focused on networks and Linux-based software development, this Cybernet subsidiary changed direction in 2007 and has become the deployment mechanism for Cybernet technologies "in robotics, sensor systems integration, and algorithm development, man-machine interface design,"[23] modeling and "simulation (with focus on massive multiplayer scale simulations), and network appliances and security."[24] Earlier work in this area included the force feedback work that eventually led to licensing by Immersion, Inc.

Currently, Cybernet is working on leading-edge applications in gesture recognition from video streams. One product in use today is GestureStorm™, which allows TV meteorologists to control their on-air weather displays through purposeful gestures.

Cybernet and NASA

NASA has been interested in force feedback for decades. Effective force feedback is required to operate robots in space, and as a result NASA has been a leader in this field. Cybernet's work in this area has, according to Dr. Jacobus,[25] been directed primarily at space science where the company works on "sensors and advanced robotics," focused on manufacturing and manipulation.

As a result, Cybernet's work has been most fruitful when NASA is pursuing a manned space program. Robotics is, in general, about convenience, safety, or productivity, and in space, because the cost of using humans is so high, NASA has strong incentives to find ways to automate processes where possible, as well as to use remotely guided robots.

In the early 1990s, NASA was preparing to build the space station, which required advanced robotic arms. The Mars mission accelerated this process, because it required NASA to develop the capability for human life on another planet, which in turn required new technologies for utilizing local resources (mining, growing food, etc.).

Cybernet received a number of early NASA SBIR contracts to work on force feedback, but this did not immediately lead to large-scale

[22]Cybernet Systems Corporation website, http://www.cybernet.com/index.php/products/netmax-robotics?
[23]Ibid.
[24]Ibid.
[25]Dr. Jacobus previously headed the NASA Center for Commercial Development of Autonomous and Man-Controlled Robotic and Sensing Systems in Space (CAMRSS). CAMRSS developed robotics and sensing technology for use in space applications and spin-offs.

commercialization. About 5 years after Cybernet's NASA contracts concluded, according to Dr. Jacobus, Cybernet's technology for managing force feedback became a new tool for toys and games—most notably the market for game joysticks eventually dominated by Microsoft.

Cybernet and Immersion Inc. emerged as the two leading companies in the provision of technology for integrating force feedback into game controllers. While the two companies competed for Microsoft's business (Microsoft was the leading game controller company at the time), the latter was able to use that competition to push down prices and limit commitments.

In 1998, Cybernet decided that it would be best to license its technology to Immersion in exchange for royalties and some equity—a decision that led Microsoft to announce an agreement with Immersion within weeks of the deal. Even though Cybernet did not directly commercialize its SBIR-supported force feedback technologies, they were eventually deployed by Immersion and are now found in a majority of mobile phone handsets as well as many game controllers. Cybernet itself benefited substantially from the subsequent Immersion IPO in 1999.

The licensing strategy adopted by Cybernet works well with the bootstrap strategy often adopted by Michigan companies, where venture or angel funding remains difficult to acquire. Even though Cybernet raised $5 million in funding for its force feedback projects in the late 1990s, Dr. Jacobus considers this to be the exception rather than the rule.

Cybernet's portfolio-based strategy is quite different to the Silicon Valley/venture capital model. Dr. Jacobus likens Cybernet's strategy to farming—where some years are better than others but no project ever really dies, in contrast to the prune-and-focus approach of the venture model.

Overall, Dr. Jacobus observed that this example shows how the SBIR program could be credited with the development of entire industry sectors. Technology development primarily initiated by NASA funded everything in the force feedback industry. Game controllers would not have been developed without NASA SBIR funding. Although initial work was funded by the Army, tactile output was the result of NASA funding. Today, it is fair to say that 100 percent of game controllers, plus a considerable share of buzzers and haptic feedback on phones, has resulted from SBIR investments.

Patents and Awards

Cybernet has developed more than 20 original devices and systems that are currently in use across a spectrum of commercial and defense clients, with more than 200 completed contracts and 45 awarded patents, with more patents pending.

In addition to its patents, Cybernet has won a number of industry and government awards. These include a Tibbetts Award in 2006, three NASA spin-off awards, the Army commercialization recognition awards, and others.

Licensing and Spinouts Strategy

Cybernet's substantial patents portfolio has permitted the company use of licensing as a core commercialization pathway. The company's experience also shows that commercialization with SBIR funding is rarely the simple linear process sometimes expected.

Cybernet has discovered that while in a Phase I project it is almost always necessary to find a marketing partner to enter specialty markets. According to Dr. Jacobus, those partners are rarely prepared to pay for technology development. It is in that context that the SBIR program continues to play a key role for Cybernet—funding the technology development that can later be licensed or spun out.

Comments on the SBIR program and NASA

General Comments on SBIR

Dr. Jacobus said that he was speaking personally, not on behalf of Cybernet. Overall, he believes that the SBIR program is grossly undervalued by many people in the government. It provides funding and access to small, agile businesses, which employ more technologists than the university system, and focuses on technology transition where research to commercial employment process is weakest. University researchers do good work based on the priorities of their own peer groups; big companies do well at scaling. But in the middle there is in almost every industry a dead man's zone between research labs and the big companies. This is in part because the manufacturing technologies needed for new products are missing, as the demand does not yet exist.

He observed that the small business community has always been good at addressing these needs, and the SBIR program in general has always funded a considerable amount of research that does not yet have a clear market—frequently, it takes 10 years or more before the technology eventually finds an appropriate use. Thus the SBIR program creates a resource flow to this weak link in the technology pipeline. It was weak even when Bell Labs existed and, in his experience, at Texas Instruments where he worked prior to Cybernet. It takes five times more money to take an idea to market as it does to research the idea in the first place. Funding for that part of the process is very scarce: investors do not want to put money into something that is not yet real.

Dr. Jacobus said that the SBIR program has been willing to fund technology across a broad set of technical areas. This is critical for non-software technologies: Dotcoms do not need SBIR funding; they have private money. But no private funding is available for small businesses to develop a new kind of plastic. In addition, not every idea will be a success; the point is to ensure that enough people are working on the right sort of things. Some of them will be successful.

Overall, Dr. Jacobus believes that the SBIR program provides a critical connection between small business and government acquisitions programs. Small business cannot break into the acquisitions business on its own, and it usually cannot reach larger DoD contacts without the help of the SBIR program, which supports direct contact with government, which would otherwise view companies such as Cybernet as much too small.

The NASA SBIR Program

Under the NASA SBIR program, linkages to centers and personnel have changed in recent years. Dr. Jacobus said that connections to NASA staff used to be informal—a researcher could suggest some ideas and some might find their way into a topic. Today, the competition is much more formal, and researchers have little contact with NASA until after the contract is awarded. Although this opens the door to new entrants, it excludes from the process potentially useful sources of expertise and insight. The focus is on ensuring that the competition is run fairly.

Dr. Jacobus noted that NASA can be viewed as a halfway house between basic research agencies and the highly applied technologies needed at DoD. Some of NASA's work seemed closer to that of the National Science Foundation (NSF)—sometimes, NASA staff are only interested in the technology and topic areas and are seeking good ideas. In these cases, the agency is open to any good idea, and if a researcher can find the NASA staffer running the study group, then the idea could be proposed and adopted. At other times, NASA is seeking specific solutions to identified problems, although even in these cases NASA needs less applied research than does DoD.

Detailed Recommendations for the SBIR Program

To address the bifurcation between investigatory and applied research, Dr. Jacobus suggested that NASA consider moving to two solicitations per year, one focusing on NASA's immediate technology needs and the other providing more room for exploratory research along the lines of NSF. The National Institutes of Health (NIH) currently offers separate solicitations for grants and contracts, which might be a model for NASA. Simply identifying these two directions would in itself make for a better selection process.

In addition, Dr. Jacobus suggested that NASA adopt the DoD open discussion period, where DoD technical staff are available to discuss topics for a short time after the solicitation is published. This opportunity helps to guide potential respondents, reducing wasted effort for both the companies and the reviewers.

- Regarding award size, Dr. Jacobus believes that results would be optimized by keeping Phase I SBIR awards as small as possible, while ensuring Phase II funding is sufficient to complete prototype development or a similar level of technology exploration.

- Regarding incentives for commercialization, Dr. Jacobus said that there was no need for additional incentives and pressure—in his experience, commercialization is what business people do and few companies are satisfied with simple technology development. The point of being in business is commercialization.
- However, he also noted that finding ways to better connect to the acquisition process would be a key to improving results. This for him was always the most difficult part of technology development, and he noted that successful connection to government initiatives especially in acquisitions would elevate the stature of SBIR program managers.
- Nonetheless, Dr. Jacobus noted that it is possible—perhaps necessary—to view the parameters of success in SBIR differently than in strictly commercial development. It does not make sense to apply venture capital benchmarks to SBIR outcomes, because the circumstances and objectives are different.
- Regarding commercialization support programs, Dr. Jacobus noted that, although he had participated in almost all of them over time, they provide limited value to experienced executives. Like any strategic planning process, they have some value, but no more than any similar exercise. However, he strongly supported activities such as the Navy Opportunity Forum, which specifically focused on connecting SBIR companies to the acquisition programs and prime contractors (primes).
- More generally, Dr. Jacobus said that every program office, particularly at DoD and NASA, should have an SBIR strategy. Currently, topics are usually generated by staff familiar with current programs, and hence the topics address current problems. But, by the time the Phase II has been issued and completed, those programs are in the past and the SBIR company is stranded.
- Dr. Jacobus offered two more suggestions for improving the program:

    - Allow the program offices to allocate a percentage of funding for efforts to expand outreach to small business. In his view, this would be more useful than commercialization training.
    - Allocate some SBIR funding via the primes, that is, allow the primes input into the development of topics and the selection of awards.

ELTRON RESEARCH AND DEVELOPMENT, INC

Based on telephone interviews with
Paul J. Grimmer, CEO and majority owner
April 7, 2010 and September 22, 2015

Founded in 1982, Eltron Research is a materials research company located in the Denver, Colorado area. Eltron won its first SBIR award in 1983. Since 1983, the company has won over 300 SBIR and STTR awards, especially from the Department of Energy (DoE). In June, 2005, the company was purchased. Over the past ten years, the company has moved to an industry-funded business model and eliminated its SBIR as a source of funding. The company has not started an SBIR project since mid-2013 and now submits only 1 to 2 SBIR proposals per year (as opposed to the 186 submitted in 2005 when ownership changed).

Prior to 2005, while Eltron actively pursued SBIR funding, the company had developed a substantial portfolio of intellectual property (IP) based on SBIR funding. It did not, however, commercialize any of these technologies. Indeed, until 2005 Eltron was a prime example of a "lifestyle" SBIR company, one in which revenues were largely generated from SBIR awards, and where minimal efforts were made to commercialize the results of SBIR-funded research. At Eltron, as at many companies, the previous owners had used SBIR to cover its costs for research, recover overhead and G&A costs related to research, and make a small (4.5 percent) profit. They spent very little on pre- and post-SBIR project work necessary to commercialize technologies invented in these projects successfully.[26]

This lack of commercialization activity provided a substantial opportunity for new ownership. Eltron had more than 70 technologies already in its IP portfolio of which 30 might be commercially viable. The new strategy was to look for industry partners that would fund and enable commercialization.

To do this, Eltron added three business development professionals to engage industry and find companies willing to fund additional R&D on the already-invented SBIR technologies. In return, Eltron planned to offer favorable licensing terms when and if the technologies were commercialized. Eltron also hired engineering staff to plan and manage scale-up as these technologies shifted to mass production. Finally, management directed its scientists to support commercialization efforts by making samples and test units based SBIR technologies for evaluation by prospective clients.

From 2005 to 2011 the company not only pursued more SBIR projects but also tried to engage industry in "Phase III" funding of its SBIR technologies. Eltron made product samples for prospective clients, spent internal funds to improve upon the SBIR technologies in the lab, created business plans, and tried

[26]Note that profits are in addition to direct labor costs for principal investigators and other company staff and are also in addition to recoverable overhead and G&A costs defined in the FAR.

to attract angel funds to advance these technologies. Eltron spent approximately $5 million of its own funds in these efforts. Unfortunately, the company was unable to interest any third parties in any SBIR-funded technologies.

In 2011 Mr. Grimmer, Eltron's CEO and majority owner, concluded that a business based on SBIR technology would not be commercially successful and that the company needed to change significantly. "SBIR provides small business "free money" with very little, if any, risk. Unfortunately, the technologies created using this vehicle are not needed by industry," he said. Because Mr. Grimmer is not interested in doing research but in commercializing new products, he began exiting the SBIR business.

By 2014, Eltron had essentially left the SBIR program. The number of Phase I applications had dropped to zero from a peak of 179 in 2005. For a company that has done 333 SBIR/STTR projects in its 31 year history, this was a significant and fundamental change. The company continues to be reliant on industry for funding its R&D activities. This has not been an easy change but is one that Eltron management believes was absolutely necessary.

Eltron management believes that in its current form the SBIR program is largely a waste of taxpayer money and is of questionable value to the companies themselves. It could be changed but the change would be difficult and would be opposed by the many people who benefit from the current program both inside and outside of the agencies administering the programs.

At present Eltron Research has approximately 15 employees with PhDs, Masters, and Bachelors in engineering and the sciences.[27] The company's workforce has dropped substantially from the 50 employees, 20 of whom held PhDs, who worked at Eltron when it was purchased.

Technologies and Products

Eltron is a materials company based on the application of chemistry, materials science, and engineering to problems managing the production of energy. It has strong capabilities in membranes and catalysis, among other areas of materials science. Table E-7 describes its core areas of technical competence.

Across these core competencies, Eltron continues to look for corporate partners either to sell or license Eltron technologies or to fund further development of Eltron technology in return for future license or purchase.

Eltron's patent portfolio contains 71 patents which broadly cover intellectual property in materials, catalysts, sensors, catalytic membrane reactors, electrolytic systems, and electrical storage systems. The company has licensed 29 of these patents to other companies (see Box E-4 for examples).

[27] "Eltron Research and Development, Incorporated," https://www.sbir.gov/sbirsearch/detail/155281.

TABLE E-7 Eltron Research and Development Core Technology Competencies

Core Competency	Description
Catalysts	Eltron has developed hundreds of heterogeneous/homogeneous and supported/unsupported catalysts. Eltron personnel can design, synthesize, evaluate and scale-up catalysts in fields such as energy, propulsion, chemicals, polymers, and the environment.
Advanced Materials	Eltron integrates broad capabilities in materials science, chemistry, and engineering experience to develop, produce and analyze custom materials such as polymers, membranes, coatings, ceramics, nanostructures, and multifunctional composites.
Energy and Fuels	Eltron has substantial expertise in the development of technologies to enable clean and sustainable energy. Based on Eltron's expertise with catalysts, Eltron has developed systems for novel biofuels synthesis, fuel reformation, fuel gasification, and carbon sequestration.
Environmental Technologies	Related to its research on biofuels and carbon sequestration, Eltron has developed green systems for electrolytic water treatment, contaminant remediation, and pollution sensing and response.
Chemicals and Chemical Processing	Eltron personnel are also expert in the design and implementation of both ambient and high temperature chemical and electrochemical processes.

SOURCE: Eltron Research website, "Company Overview," http://www.eltronresearch.com/company.html.

Company personnel publish actively in peer-to-peer journals. The company website lists 96 publications ranging from as early as 1997 up to the present.[28]

Business Model: From SBIR Toward Industry-Sponsored Research

Following the current owner's purchase of Eltron in June 2005, Eltron aggressively promoted Eltron's SBIR funded IP portfolio, attempting to license and/or sell the technologies and partner with licensees to commercialize those technologies. Mr. Grimmer believed when he bought the company that he could license or sell some of the technologies which in turn would enable further development of other company technologies which would then be sold or licensed. Unfortunately, very few of the company's technologies were sufficiently developed to be desirable by industry and the rest were simply of no interest to industry.

The investment by SBIR in Eltron was substantial. Since the company's founding in 1982, Eltron received 333 SBIR/STTR awards with a total value of $68.1 million. The Department of Energy provided 44 percent of

[28]"Technology Licensing Opportunities," http://www.eltronresearch.com/techb.html. Accessed October 15, 2015; "Licensed Technology," http://www.eltronresearch.com/licensed_technologies.html. Accessed October 15, 2015.

BOX E-4
Technologies Licensed by Eltron Research

Eltron has licensed the following technologies. Commercializing materials technologies is difficult, and Eltron has struggled to realize income from its licensing activities.

In most cases, the terms provided no cash upfront and only a promise to pay when and if the technology was commercialized. With the exception of a $100,000 lump payment, the company has not received any income from its licensing activities.

- Solid State Oxygen Anion and Electron Mediating Membrane and Catalytic Membranes Containing Them
- Two Component-Three Dimensional Catalysis
- Glass Ceramic Seals for Membrane Chemical Reactor Application
- Ceramic Membranes for Catalytic Reactors with High Ionic Conductivities and Low Expansion Properties
- Microfluidic System for Measurement of Total Organic Carbon
- Mixed Ionic and Electronic Conducting Ceramic Membranes for Hydrocarbon Processing
- Materials and Methods for the Separation of Oxygen From Air
- Methods for Separating Oxygen from Oxygen-Containing Gases

SOURCE: Eltron Research, October 12, 2015.

this amount, the Department of Defense delivered 22 percent, and the National Aeronautic and Space Agency funded 14 percent. The remainder came in combination from the National Science Foundation, the Environmental Protection Agency, the Department of Health and Human Services, and the Department of Agriculture.[29]

To support commercialization of the results of these 333 projects, between 2006 and 2013 Eltron spent an additional $5 million of its own funds trying to secure Phase III funding from industry. These funds were spent on internal R&D (IR&D) to progress technologies to a point of interest to industry and also on business development for prospective licensors or purchaser, on generating test samples, and on writing business plans. Mr. Grimmer emphasized that **not one** of Eltron's 333 SBIR projects has ever received industry funding for a Phase III. "Not one!" Fundamentally this is why Eltron has exited the SBIR system.

[29]"Eltron Research and Development, Incorporated," https://www.sbir.gov/sbirsearch/detail/155281.

The time series of SBIR awards for Eltron shows the extent of this structural transformation since Eltron's purchase in 2005. There was fairly continuous upward growth in the number of SBIR awards received by Eltron from its founding in 1983 until 2002. In 2002, the number of SBIR awards received peaked at 32 awards worth $6.3 million. For the next five years until 2007, Eltron averaged about 17 SBIR awards annually worth on average about $3.4 million. Between 2008 and 2013, SBIR activity dropped steeply. Eltron has not received any awards for the years 2014 or 2015. SBIR documentation shows that through 2010, Eltron employed 50 people and as recently as 2013 employed 40 people.

The reasons why Eltron's potential licensees did not partner or invest in Eltron's SBIR technologies are two-fold:

- **Insufficient Relevance:** Potential licensees did not invest because they did not view Eltron's SBIR technologies as being relevant to their businesses. According to Mr. Grimmer, industry does not appear to have expressed need for the SBIR topics at the time of Phase I submissions, at Phase II submissions or post Phase II.
- **Insufficient Performance:** The level of technology development enabled by a pair of SBIR grants is insufficient to push a technology to a level of performance where development risks are sufficiently low to entice industrial investment.

Other than providing employment for several hundred people over 33 years of operations, Mr. Grimmer believes that the government expenditures through his company have not yielded anything of value for the public.

Although it is difficult to engage industry to support R&D, since 2005 Eltron has had some success developing technologies in industrial partnerships addressing non-SBIR funded technologies. The company has done over $25 million of development work funded by the DOE, Eltron, and corporate partners. In addition, the company has funded 2 internal projects that cost $14 million, again with funds that did not come from SBIR.

Commercialization

Like all companies attempting to commercialize SBIR-developed technology, Eltron faces a fundamental problem in commercializing its technologies. This challenge is an inability to access funding for Phase III transition or private market commercialization. Mr. Grimmer outlined three ways in which Eltron is addressing this capital gap:

- By looking for large industrial companies with market share with whom to partner during the technology development and commercialization process;[30]
- By identifying federal or state funds to help reduce the development cost burden to the industrial partner and Eltron; and
- By investing personal funds provided from the current owners to convince an industrial partner to fund full technology development and commercialization.

In working to commercialize SBIR-based and non-SBIR-based technologies, Eltron has attempted essentially all of the above. None have been successful for SBIR-based technologies.

Industrial Partnerships

Core to Eltron's growth strategy was the creation of industrial partnership to fund commercialization and drive growth. Eltron expected that partners would provide resources to develop and market the technology licensed from its IP portfolio. In addition to ample resources to back development, Eltron looked for partners with deep market knowledge, customer relationships, and sales and operations entry to facilitate market entry.

Eltron management always accepted that this model necessitated patience building relationships with a potential partner. It would not be easy, but Grimmer envisioned a three stage process taking up to four years. First, Eltron had to determine whether the potential partner had a real need for innovative technology. Then, Eltron had to determine whether the partner was willing to outsource the technical development process, and finally Eltron had to convince the partner that even though a small business, Eltron could deliver.

Despite substantial internal investment, Eltron had no success interesting companies in funding commercialization of SBIR projects. Even non-SBIR technologies have proven challenging. As an example, Eltron's partnership with Eastman Chemical shows the challenges faced in managing a partnership of government funders and industrial customers even when the commercial partner holds a clearly defined problem.

In 2005, DoE initiated funding for Eltron of a non-SBIR technology to develop membranes for carbon capture and hydrogen separation from a mixed gas stream. This technology offered the potential to reduce the capital and operating costs of producing industrial hydrogen while simultaneously ensuring

[30]A partnership can involve a variety of different relationships. The industrial company may be the technology as-is or undertake development and then buy it. It may fund Eltron to perform development, license the technology, and then take the technology to market by itself. Joint-ventures between Eltron and the industrial partner are also possible.

CO_2 capture and storage. Ultraclean hydrogen energy generated from coal seemed within reach.[31]

Unlike SBIR programs, the DoE initiative required an 80/20 cost share that forced Eltron to commit $500 thousand of its own funds annually to receive $2 million from the government. After three years of successful research, Eltron convinced Eastman Chemical to come into the project and pick up the cost share. By then, Eltron had sunk $1.5 million sunk into the technology. In 2010, DoE extended funding for the project by another $8 million.

Interestingly, Eastman Chemical did not partner with Eltron to develop a CO_2 capture technology. Unlike the DoE sponsors of the program, they were interested in separating carbon monoxide (CO) from a mixed gas stream to be used as input stock for other chemical processes. Despite early technical success, as the project shifted from laboratory prototyping to a demonstration plant and capital costs rose, tensions in the partnership began to emerge. Eastman had agreed to demonstrate the technology at its coal gasification plant in Kingston, Tennessee to test CO capture. Although DoE had agreed to generous 97/3 split contract to provide $72 million in Recovery Act monies to set up a pilot system, their goal remained CO_2 capture.[32] Eventually, Eastman withdrew from the project.

Despite DoE's continuing commitment to allocate $72 million, Eltron was unable to find a partner willing to pay the ~$2 million in cost share. Eltron spoke with most of the U.S. and European oil and gas companies, the coal companies, the electric power utility companies through via their research institute, EPRI, and even Cleantech VC's. Although most agreed that in the long run carbon capture technologies would be necessary, they did not want to foot the bill for a technology for which there may be no market for 10 or 15 years. Then, at the same time as an ammonia company expressed interest in piloting Eltron's membrane system to removing H_2 from the waste streams emitted by ammonia plants, the Obama administration pulled funding of all technologies developed for clean coal production.

Even when a customer clearly articulates a need, developing technologies as capital intensive as carbon capture is difficult. Industrial partners will not invest where there needs are not addressed. DoE was unwilling to budge from its requirement that these technologies address carbon capture. Eastman was willing to fund the early research in this area because there was some indication that it would be applicable to CO capture. But when costs increased and they saw their needs not being addressed, they withdrew support. Shopping a grant for nearly $70 million in government support, Eltron was unable to replace Eastman as a pilot site. Mr. Grimmer comment, "None of these

[31]"Eltron Research & Development and Eastman Chemical Company Team for Joint Development and Pilot Testing of Membrane System for Hydrogen Production and Carbon Capture," (August 4, 2010), http://www.eltronresearch.com/eltron_eastman_press_release.pdf.

[32]Industrial Carbon Capture Project Selections (September 1, 2010). http://energy.gov/sites/prod/files/2013/04/f0/iccs_projects_0907101.pdf.

technologies can be brought to market with an investment of less than $50 million. They're materials that require prototyping, testing, scaling up. At every stage, costs increase, and without a real need commitment from industry attenuates."

Eltron Spin-off Companies

Another potential strategy for commercialization at Eltron has been the formation of spin-off companies. Eltron has formed three subsidiaries, Eltron Water Systems, Continental Technologies, and The BioCompactor Company.

Eltron Water Systems (EWS) focuses on water purification and disinfection. At present, EWS has developed two products, a peracetic acid reactor for onsite production of peracetic acid (ImPAACT) and semi-permeable, nanofiltration membranes (Duraflex). The peracetic acid reactor is licensed to three commercial companies, and before the end of 2015, the first products ever derived from Eltron technology will enter the market. All technology development was done with internal funding without government support. Three other products are currently in development. EWS does not appear to have attracted outside funding.[33]

Continental Technologies (CT) designs, fabricates, and tests skid-mounted (transportable) pilot plants for the oil, gas, and chemical industries. Unlike EWS, CT is not intended to commercialize intellectual property developed by Eltron Research. Instead, CT is designed to build on Eltron's engineering expertise designing pilot plants and provide this service to its customers. CT also supports implementation of Eltron technologies marketed to other companies.

The BioCompactor Company (TBC) is not technically a spin-out. The company licenses a technology developed in Brazil that uses sugar cane waste, called bagasse, as a fuel source for power generation. TBC provides turnkey plants to convert bagasse into uniform, energy dense briquettes which can be easily transported, handled and stored. TBC has piloted the technology in the United States at the Graceland sugar refinery in Louisiana. Furthermore, it has tested the briquettes produced by the process at Colorado's Valmont coal-fueled power plant.[34]

Improving SBIR

The absence of Phase III funding from industry for SBIR developed technologies is why Eltron left the SBIR program. In discussion with Mr. Grimmer, he expanded in some detail on the challenges confronting a company that hopes to take SBIR developed technologies to commercial markets. He

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[33] "Water Treatment and Disinfection Systems and Membranes," http://www.eltronwater.com/products.php.
[34] "News," http://www.biocompactor.com/news.htm.

believes that other SBIR recipients are unlikely to discuss these problems frankly for fear of "biting the hand that feeds them." Mr. Grimmer no longer has that constraint.

To explain the inability of Eltron to attract industrial interest in SBIR-funded technology, Mr. Grimmer highlighted the following:

1. **Commercial Relevance of Topic Lists.** Across many agencies, the topics lists generally address problems that are not of interest to industry. In the mission-oriented agencies (primarily in DoD) the topics are selected to address problems specific to the agency, not to industry. For other agencies such as DOE, the topics are motivated more by long term policy goals than immediate needs. Mr. Grimmer pointed to Eastman Chemical and the longstanding entry on the DOE topic list of CO_2 capture. For 10 years, Eltron received DOE funding to investigate carbon capture. Over that period, Eltron was unable to attract anyone in industry to spend more than token amounts when commercialization of this technology would require tens of millions of dollars. Although it's clear that as a long-term tool for reducing global warming, CO_2 capture technology is necessary, industry won't spend money on compliance enabling technologies when it isn't clear that such regulations will ever be required.

   Topic lists should be generated with commercial need as the primary concern. Grimmer stated, "SBIR needs to be reformed, so that it's driven by actual commercial (and not future policy) needs. Without need, there is no way industry will support Phase III. Topic list should be developed in partnership with the corporate sector. If you want to see commitment from industry, ask for technology that industry will buy and not simply write a meaningless commitment letter."
2. **Proposal Costs.** A rough accounting of proposal costs shows that the Eltron lost money on each Phase I proposal that it won. Eltron prepared and submitted over 2,350 Phase I SBIR/STTR applications, each taking 50 hours of Principal Investigator time to write and an additional 15 hours of support staff time. Each application cost approximately $7,100. Because the success rate for a Phase I award is only 10 percent and the "winners" have to cover the costs of the "losers", the 9 losers at $7,100 each add up to an additional $63,900 that has to be covered. The total cost of submission for a successful Phase I award is $71,000, almost half of the $150,000 Phase I award.[35]

   To make up this shortfall, SBIR recipients have three options: 1) accept the losses, 2) reduce the costs of submission by sloughing some of the proposal development time and costs onto other funded projects, or 3) increase success rates dramatically. The first option is difficult to rationalize unless there is a significant probability of

[35]Eltron provided this analysis (November 19, 2015).

commercialization. This has not been borne out by Eltron's history. The second option compromises commitments made to the funders of the other projects. The third option of increasing success rates dramatically (to perhaps 70 percent or more) is not possible unless the company can influence topic list selection which is prohibited. Mr. Grimmer's view is that SBIR recipients regularly resort to all three tactics, thereby pushing their company into the red, shortchanging other contract holders, and breaking program regulations.

3. **Submission Time.** The time between topic list release and proposal submission is typically 2 months. Although this may be sufficient time to develop a technical solution, it is insufficient time to also develop an understanding of the commercial opportunity. Most challenging is identifying an appropriate partner that might be interested in the technology and engaging them to the point where they will commit to the proposal. If the development of a commercializable technology is the goal of the SBIR program, more time is needed.
4. **Low Funding Levels.** Eltron is a materials science company. Successful development of a materials technology requires far greater investment than a SBIR grant can provide. For example, Eltron licensed to Air Products, Inc. an oxygen separation technology. With DoE, they spent $300 million to commercialize the technology without success. In the physical sciences world, the $1.15 million maximum provided through a successful Phase I/Phase II project hardly scratches the surface and generally is not even enough to show the progress in reducing technical risk necessary to engage outside investors.
5. **Long Development Timelines.** From Phase I through the end of Phase II is typically a 3 year process in which only $1.15 million is spent. If a new technology were of real use to industry, this is much too low a spend rate. Any company producing technologies for a real market need must move quickly to develop the technology, create a defensible patent position, and get to market before its competitors do. SBIR does not enable this.
6. **Influencing Topics on the Topic Lists.** Eltron believes successful companies influence the contents of the topic lists. Even when the topics are not specifically written for a company, it appears to Mr. Grimmer that many companies become involved with the agencies very early in the process and know about topics long before everyone else does. The SBIR system is supposed to be organized so that participants don't influence the topic lists or have sweetheart deals. Grimmer believes this happens frequently driven by the economics and constraints of the proposal writing process.
7. **SBIR Phase I Development at Proposal Time.** Ten to 15 years ago, Phase I SBIR funding could be obtained to test a concept. According to Mr. Grimmer, while theoretically this is still the case, in practice this rarely happens. At present, it's difficult to win a Phase I grant unless

you have already done an amount of work equivalent to a Phase I award. Although it could be argued that this is simply the government selecting the most competitive applications based on the work they have done, in Mr. Grimmer's opinion, this trend is driving a massive change in SBIR that has largely gone unnoticed.

Most small businesses don't have funds to develop new ideas on their own and, even if they did, there isn't time to do sufficient work when there is only 2-3 months total to develop a proposal. What this means is that Phase I winners are often those who have already worked on a topic with funding from elsewhere. Typically those winners are university professors who have received NSF funding and are spinning off a small business to get SBIR funding to do more research (but generally not product development.) Over the 10 years that he has owned Eltron, Mr. Grimmer sees an increase in the number of small, university-based spin-outs receiving grants. Lacking commercial track records and engineering capabilities, he believes that this trend to fund faculty researchers may actually be lowering the commercialization success rate for SBIR as a whole (which is already low in his mind).

8. **Evaluation process.** Grimmer is extremely concerned about the transparency of the review process and the potential for reviewers to appropriate ideas developed by small businesses. Because all agencies forbid communication between agency personnel and SBIR applicants, companies do not even know who the reviewers are. Although there are good reasons for doing this, there must be a middle ground. Grimmer is convinced that several Eltron outside-the-box proposals that were rejected showed up several years later in other proposals, particularly from professors who he believes had been reviewers of those earlier Eltron proposals. Without winning an award, Eltron lacks resources to patent everything, so it is relatively easy for a reviewer to pick off new technologies especially when Eltron doesn't know who its reviewers are and no complaint process exists.

   Other concerns with reviewers include a lack of commercial expertise, a lack of technical expertise, and a lack of capacity for real-time response to criticism. Grimmer admitted that there had been improvements in the past ten years—in selecting, for example reviewers with commercialization experience—but he believes that at its core, the process remains opaque and easily abused.

In the end, the measure of SBIR's success is the measure of Eltron's success commercializing SBIR technologies developed at Eltron. He emphasized, "I would bet we received $75 million in SBIR funding, and it was stupid, a complete waste of time. None of the SBIR projects have produced a successful project." Grimmer is not against the concept of government funding for small businesses commercializing technology. But he is strongly critical of the current implementation. "In and of itself, providing R&D funding to small businesses is not a bad idea, but it's very poorly implemented and has created numerous poor incentives. As it currently operates, it's a racket for the researchers, it's of no value to the tax payer, and it has only the most miniscule return on investment."

HONEYBEE ROBOTICS

Based on telephone interview with
Ms. Irene Yachbes, Director of Technology Development, October 11, 2010,
and e-mail exchange with
Mr. Kiel Davis, President, October 25, 2015
New York, NY

Honeybee Robotics is a privately held company located in New York, New York. Founded in 1983 by Stephan Gorevan and Chris Chapman, the company originated in the co-founders' deep interest in advanced robotics and automation. Over 32 years of operation, Honeybee has created strong ties with NASA and the aerospace primes on the basis of its reputation for high quality research and development, design, manufacture, and testing. Despite strategic uncertainty in the direction of the U.S. space program, space robotics remains the primary focus of this company.

Honeybee began as a systems integrator focusing on the space robotics market and utilizing off-the-shelf robots. Some of its early projects included robotic arms and robot end-effectors for large companies such as IBM, Allied Signal, The Salk Institute, Merck, and 3M. Honeybee received its first NASA contract in 1986, and since then, the company has focused on the design and development of innovative and reliable systems for use in space. It has worked on more than 100 NASA projects at nine NASA Centers. Over the past 15 years, Honeybee supplied NASA with critical technologies for each of the last three Mars missions, the Mars Exploration Rovers (MER), the Mars Phoenix Lander (MPL), and the Mar Science Laboratory (MSL).

In 2015, Honeybee has over 55 employees and generates more than $11 million in annual revenues. At the company's headquarters in Brooklyn, New York, in addition to its manufacturing facilities, it operates a machine shop, a Class-100 clean environment for assembly, and testing chambers that simulate the extreme environments encountered in space. In 2008, Honeybee opened an additional office in Longmont, Colorado to perform satellite mechanism and sensor development. The company opened a third office in 2010 in Pasadena, California that specializes in geotechnical work for NASA and various commercial partners in the mining, oil and gas sectors.

Technology

The company's strategy has been to parlay its successful space exploration robotics technology and expertise into mainstream spacecraft product and services for next generation space systems. To support the design and manufacture of robotic systems, the company's core technological competencies extend across a broad range of systems, electrical, mechanical, and manufacturing capabilities. These are described in Table E-8.

Honeybee Robotics owns seventeen patents in technologies ranging from high temperature electric motors, to spacecraft docking systems, to dust tolerant electric connectors.

Products and Services

Focusing primarily on space robotics, Honeybee's main customers operate in an industrial and technological ecosystem with NASA at its center. Mr. Davis noted, "We focus on selling products and services to the primes and lower tier space contractors as well as directly to government agencies such as NASA or DoD." Key partners include the numerous flight and research centers at NASA, Lockheed Martin, Boeing, 3M, Siemens, Johns Hopkins, and UCLA. See Box E-5 for a partial list of customers and other partners). In addition to its

TABLE E-8 Honeybee Robotics Core Technology Competencies

Core Competency	Description
Systems Engineering	To ensure effective project management, Honeybee has invested deeply in systems engineering and has strong capabilities in specification development, requirements flow-down, configuration management, and in the overall management of project costs, timelines, and risk.
Mechanical Design	To design high performance robotics systems requires deep competence in mechanical engineering. Honeybee technologists are expert in solid modeling and 3D design, event simulation, finite element analysis, fault analysis, operational testing, and subsystem integration.
Electrical Design	Electrical design enables the control and monitoring of space systems. Honeybee has extensive expertise in the design and layout of both analog and digital printed circuit boards, harnesses, and electrical ground equipment.
Software Development	Control of complex space systems also requires expertise in software coding, both in the development of resource efficient algorithms and embedded software. Honeybee also has broad experience designing data acquisition, processing and visualization tools.
Manufacture	Honeybee builds its own robotics system at its manufacturing facility in Brooklyn. The facilities are ISO9001 and AS9100C process compliant. Its technicians are certified to NASA 8739 standards. The company assembles in Class-100 and Class-10,000 clean room environments.
Design Validation	Quality is built into both the design and manufacturing processes. Honeybee has procedures for full verification and validation of its systems, environmental testing (thermal, electromagnetic, and vibrational), load testing, and functional/operational testing in space analog environments.

SOURCE: Honeybee Robotics website, "Technical Capabilities," http://www.honeybeerobotics.com/services/technical-capabilities/.

BOX E-5
Customers and Partners of Honeybee Robotics

NASA
NASA HQ
Jet Propulsion Laboratory
Various flight and research centers

Department of Defense
Air Force Research Laboratory (AFRL)
Missile Defense Agency (MDA)
Army Research Laboratory (ARL)
U.S. Army Corps of Engineers
Defense Advanced Research Projects Agency
Naval Surface Warfare Center
Naval Research Laboratory (NRL)

Aerospace and Defense Contractors
Lockheed Martin
Boeing
Hamilton Sundstrand Space Systems
SAIC

Industry
Rio Tinto
ConEdison
3M
Siemens
IBM

Academia and Laboratories
Cornell University
Princeton University
UCLA
Johns Hopkins University
University of California, Berkeley
Applied Physics Laboratory (JHU/APL)

SOURCE: Eltron Research, October 12, 2015.

main business providing products and services to the aerospace industry, Honeybee also provides robotic technologies to the defense, oil and gas, mining, and healthcare industries.

Based on over a 100 projects for NASA, Honeybee has produced numerous successful mission critical products used in NASA space programs. Two particularly successful projects produced the Rock Abrasion Tool (RAT) and the Icy Soil Acquisition Device (ISAD).

Designed, developed, and manufactured by Honeybee Robotics as a part of NASA's 2003 Mars Exploration project, the RAT uses grinding wheels of diamond dust and resin to gently abrade the surface of Martian rocks. This system enabled the discovery of mineral formations strongly suggestive of the presence of water and substantially enhanced Honeybee's reputation in the space community.[36]

The RAT meets a number of critical mission needs. To begin with, it is compact and low power. Using three small motors, the RAT requires only 11 watts of electricity to cut into Martian rock. The RAT weighs 685 grams and is 7 cm in diameter and 10 cm long—about the size of a soda can.[37]

According to Ms. Yachbes, Honeybee was originally brought into the Mars mission by the principal investigator (PI), Steve Squyres, to implement some preliminary ideas about a rock abrasion tool. This developed into a project to design and build the system. As built in the Mars Exploration Rovers (MER), RAT was the first machine to access rock interiors on another planet to develop data about the properties of Martian rocks.

Remarkably, the RAT has continued to perform long beyond its design life in the dusty Mars environment. In fact, the RAT was originally designed to open 1-3 rocks. Ms. Yachbes noted that during its initial operations, it completed more than 100 grinding and brushing operations and was instrumental in some of the key Mars discoveries—notably blueberries (hematite concretions), which on Earth are found only in the presence of large amounts of water.[38]

The Icy Soil Acquisition Device (ISAD) flew on NASA's 2007 Phoenix Mission. The ISAD—or the Phoenix Scoop as it is sometimes called—is both a soil scoop and a precision ice sampling tool integrated on the end of the Phoenix lander's robotic arm.[39] The ISAD was used to dig into the surface surrounding the lander and to acquire icy soil samples, which were then delivered to science instruments for examination.

Honeybee designed, built, and tested the ISAD in only 14 months in response to an urgent request from NASA for improved methods of gathering samples from very icy soil targets. According to Ms. Yachbes, this was possible in part because Honeybee maintains the facilities and expertise for simulating extreme environments. Only Honeybee had the capacity to prepare and test tools

[36]"Rock Abrasion Tool," http://www.honeybeerobotics.com/portfolio/rock-abrasion-tool/.
[37]See http://marsrover.nasa.gov/mission/spacecraft_instru_rat.html.
[38]See http://marsdata1.jpl.nasa.gov/gallery/photoContest/index.cfm?pollContentID=7&getDetails=Yes&showHeader=Yes.
[39]See http://phoenix.lpl.arizona.edu/index.php; also, "Icy Soil Acquisition Device," http://www.honeybeerobotics.com/portfolio/phoenix-scoop/.

quickly in an environment that simulated the soils and temperatures that these systems would face on Mars.

Current Projects

At present Honeybee is focusing its commercialization efforts on a line of motion control products that includes actuators, actuator components and drive electronics. Past and ongoing SBIR/STTR funding is an important element in supporting company efforts to reduce technical risk and commercialize these projects.

Market research done by Honeybee indicates that there is a real need for low cost, high reliability motion control devices. As cost constraints increase driven by federal budget concerns, this need will only greater. Commercialization of these products is a long drawn out process, partly because of the extensive qualification testing that NASA requires for space missions and partly because the market requires several successful space missions before wide spread market adoption is possible. Honeybee is committed to developing motion control devices and continuously seeks opportunities to get feedback from its customers to update these product requirements and commercialization strategy. In this approach, SBIR/STTR funding is one step in a continuous cycle of improvements based on market information. Mr. Davis wrote, "The company leverages SBIR/STTR funding in part to pay for product development activities and mission non-recurring engineering."

Based on technologies developed during the Mars missions, Honeybee owns two proven actuator technologies—the ESPA Solar Array Drive Actuator and the MSL Carousel Actuator—and a range of as yet unproven ones. Actuators are critical to high-performance robotic and mechanical systems, making components move properly even under harsh conditions. Operating temperatures can range from as much as 350˚C to as little as -150˚C. This poses a major challenge in designing actuators and other components such as motors and gearboxes. Actuators that can operate under such conditions are an enabling technology for a broad range of aerospace applications—enhanced geothermal well bores, surface exploration of Venus, and positioning actuators for space-based optics—as well terrestrial operations in various industries such as oil, gas, and mining. Specific innovations by Honeybee include a gear bearing system designed for low temperature operations and a patented motor designed for high temperature operation. Both technologies were the result of SBIR/STTR projects undertaken between 2007 and 2009.[40]

[40]"Gear Bearing Transmission for the Lunar Environment," (2007 / Phase I), https://www.sbir.gov/sbirsearch/detail/182553; "Brushless DC Motor and Resolver for Venusian Environment," (2007 / Phase I, 2008 / Phase II), https://www.sbir.gov/sbirsearch/detail/182563.

Manufacturing and Quality Systems

Because spaceborne missions have effectively zero tolerance for failure, Honeybee has developed extensive quality controls. Honeybee's Quality Management System is certified to ISO 9001:2008 and AS9100 Revision C. Ms. Yachbes observed that the fact that Honeybee is a NASA-approved supplier of flight hardware reflects the agency's belief in Honeybee's commitment to these design and quality standards.

Honeybee's facilities include small-scale mechanical and electrical test equipment calibrated in conformance with MIL-STD-45662 and ISO 17025. Equipment includes a FARO GagePlus articulated-arm coordinate measuring machine for precise measurement of large or complex parts, optical comparators and microscopes, digital micrometers, gages, and precision balances. The Quality Control room also features ultrasonic cleaning equipment for parts processing and secure storage in preparation for flight.

SBIR and STTR

The SBIR program has made a critical difference to the development of Honeybee, to its technology, and to the success of NASA missions flown using Honeybee equipment. Especially in Honeybee's aerospace activities, SBIR/STTR has been and continues to be an important source of funding for early stage development of mission technology.

Since its founding in 1983, Honeybee has received 92 awards under the SBIR/STTR programs worth $24.4 million. NASA and DoD have been the principal funding agencies for Honeybee. As Table E-9 shows, NASA has provided 70 percent of the funding, DoD 29 percent, and the remaining 1 percent through a lone NSF grant in 2014. Honeybee has been exceptionally successful converting Phase I into Phase II grants with an overall conversion rate of close to 50 percent. Finally, over 99 percent of SBIR/STTR funding to Honeybee has come through the SBIR program.

TABLE E-9 SBIR/STTR Awards to Honeybee Robotics by Phase and Source (1983-2015)

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)	Total Funding By Agency (Dollars)	Agency Funding as Percent of Total	Phase I to Phase II Conversion Rate (Percent)
NSF	1	149,883	0	-	149,883	1	0
NASA	43	3,924,073	21	12,777,136	16,701,209	68	49
DoD	19	1,769,932	8	5,787,149	7,557,081	31	42
Total	63	5,843,888	29	18,564,285	24,408,173	100	46

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 8, 2015.

Over the past 5 years, SBIR funding as a percentage of revenues has dropped from 30-35 percent in 2010 to 20 percent in 2015. Partly this reflects the overall growth in the company and successful development of other revenue sources. Corporate revenue increased from $8 million to $11 million annually over the same period. At the same time though, the absolute amount of SBIR awards going to the company has dropped from around $2.6 million in 2010 to around $2.2 million in 2015. Mr. Davis explained this transition, saying, "SBIR/STTR topics are usually very mission specific and in many cases are not likely to yield commercializable technology. As Honeybee Robotics has gained commercialization traction with its products, the company has opted not to pursue SBIR/STTR funding unless there is a strong link to its current product line initiatives."

The company continues to seek SBIR funding. Because of its close ties to NASA, it frequently comes close to the five award annual limit that NASA enforces for Phase I awards. In the seven years between 2008 and 2014, Honeybee received four or five Phase I awards from NASA four times. Honeybee also maintains good relations with many elements within DoD, most notably the Air Force Research Laboratory, and has received many SBIR awards from DoD.

Improving SBIR and STTR

From Honeybee's perspective, the biggest change to the SBIR program has been in the increase in Phase I award size. Because Honeybee frequently breadboards proposed Phase I technologies, the proposal writing process is expensive. Phase I projects were often run at a loss. Mr. Davis explained that "The increase in Phase I award amounts is particularly important because it allows a more thorough evaluation of a technology's value and feasibility. As a result our Phase II proposal quality is higher and Phase II programs are better positioned for success."

Another important change, especially for a company focusing on technology commercialization, was the creation of the minimum transition benchmark. As winners of multiple SBIR awards, Honeybee must demonstrate that it has met or exceeded a minimum level of successful commercialization transitions over a moving multi-year window of time. The process of analyzing and evaluating the commercialization outcomes in terms of revenue, patents, and other success variables has helped Honeybee. Mr. Davis emphasized that this process has sensitized Honeybee to those SBIR/STTR funded programs most likely to result in commercial success. He explained, "It has made us smarter about which topics we pursue and what our commercialization strategy should be."

Honeybee supports the DoD concept of bridge funding and recommends its implementation in NASA. It also approves the notion of a 9-month Phase I, because some necessary work simply takes longer than 6 months. Ms. Yachbes noted that this timeline is in reality even shorter, because

Phase II preparation must begin well before the application is due and usually depends on Phase I results.

Honeybee is comfortable with the NASA annual solicitations and believes that the timing works well in the industry. NASA meets its timelines, and hence contracts and funding flows are predictable. In contrast, DoD suffers from "proposal crowding," with numerous deadlines close together. Overall, SBIR applications are very time consuming to complete.

Honeybee would like the program to better support its efforts to develop relationships with NASA's prime contractors. For example, in Honeybee's work on the now cancelled U.S. Orion Service Module effort, NASA assisted Honeybee with developing and strengthening its relationship with Lockheed Martin. From Honeybee's perspective this was advantageous both in the short run to deliver the contracted technology modules but also in the long run to create an ongoing source of business. Ms. Yachbes elaborated, "This process is rather hit and miss currently. We would benefit from more structured support from the SBIR program officers."

INTELLIGENT AUTOMATION, INC.

Based on an interview with
Dr. Vikram Manikonda, President and CEO, October 15, 2015

Intelligent Automation, Inc. (IAI) is a technology innovation company headquartered in Rockville, MD. IAI specializes in providing advanced technology solutions and R&D services to federal agencies and corporations throughout the United States and internationally. Leveraging agile R&D processes, a multi-disciplinary collaborative environment, and its substantial intellectual property portfolio, IAI specializes in developing technology platforms to support market-focused products and customer-driven solutions. Founded in 1987 by Drs. Jacqueline and Leonard Haynes, IAI is a privately held woman-owned small business, with offices in Rockville MD, Rome NY, and Orlando, FL.

IAI's research activities are led by Dr. Vikram Manikonda, IAI's President and CEO, and supported by a cross-disciplinary team of more than 150 research scientists and engineers, with backgrounds in Computer Science, Cognitive Science, Experimental Psychology, Human Factors, Education, Electrical Engineering, Mechanical Engineering, Robotics, Aerospace Engineering, Optical Engineering and Physics. More than 75 percent of IAI's technical staff has advanced degrees and 50 percent of the staff holds Doctoral Degrees.

Historically, IAI might best be understood as a diversified R&D "think tank." Since 2009 however, IAI has expanded beyond state of the art, multi-disciplinary collaborative R&D to aggressively transition the results of its R&D into products, licenses, and/or productized services. IAI is a Small Business

Innovation Research (SBIR) program leader and has successfully executed more than 1,000 SBIR and non-SBIR R&D contracts as the prime contractor.

IAI's current core R&D areas include Air Traffic Management, Big Data and Social Media Analytics, Control and Signal Processing, Cyber Security, Education and Training Technologies, Health Technologies, Modeling and Simulation, Networks and Communications, Robotics and Electromechanical Systems, and Sensor Systems.

Over its 27 year history IAI has served clients in government agencies, the prime contractor community, and commercial organizations. Federal customers include the Department of Defense (DoD), National Aeronautics and Space Agency (NASA), National Institutes of Health (NIH), Department of Homeland Security (DHS), National Institute of Justice (NIJ), Federal Aviation Administration (FAA) and Department of Education.

IAI pursues technology transition through programs, partnerships, products, and spin-off opportunities. IAI participates in programs as a valuable partner to prime contractors. The company utilizes disparate contract vehicles, beyond SBIR, to meet its customers' needs. For some technologies, IAI actively pursues partnerships with market leaders to license its technology. IAI's corporate partners include first tier integrators such as BAE Systems, Boeing, Booz Allen Hamilton, CSC, Exelis, General Dynamics, Lockheed Martin, Northrop Grumman, Raytheon, and SAIC. IAI also has active relationships with more than 50 top universities.

Working directly with its customer or through collaborations with industry leaders, IAI has transitioned its technologies into several programs of record. Examples of such program transitions include NAVEODTECHDIV AEODRS Program, Joint Service Small Arms Program, NASA ECOSAR Program, Army Future Combat Systems (FCS), NASA's Airspace Concept Evaluation System, NASA LITES and GESS III programs, Joint Strike Fighter Program, Centers for Disease Control CIMS Program, ADL SCORM S100D testbed, and NAVAIR PMA 268 Scalable Network Access Protocol Program, DHS/AFRL Cyber Security programs, and DOD Data Analytics programs.

IAI also develops IAI-branded products, generally in niche areas, and uses government R&D programs to reduce risk. IAI is aggressive at patenting critical technologies that support product development efforts. Some examples of IAI's current products include CybelePro® (agent-based infrastructure for large scale modeling and simulation), ARGUS™ (wireless perimeter security), RFNest™ (wireless network emulation system), and Scraawl® (social media analytics tool).

Finally, for certain technologies that have exceptional market potential and a strong market position, IAI raises external funds and launches spin-off companies for focused commercialization. IAI recently launched Cryptonite, LLC, a cyber security spinoff for commercializing IAI's innovative Self Shielding Dynamic Network Architecture (SDNA™) technology for cybersecurity.

Technology

IAI's ability to develop internal research products, tools and frameworks in each of its core technology areas has been Integral to the company's vision as a recognized leader in the research and development community. These products, tools and frameworks encapsulate and formalize the company's intellectual capital, thus enabling an unusual degree of technology reusability and research agility. IAI's core competencies are described in greater detail in Table E-10.

Products and Services

IAI's original strategy for product development generally involved technology development coupled with partnership with companies already positioned in specific markets. IAI licensed its technology and benefited indirectly. This reduced the burden on IAI to develop its own marketing and distribution channels. Examples of IAI technologies productized in this way include:

Technology	*Description*
BulletTrax 3D	BulletTrax 3D is two- and three-dimensional forensics imaging equipment for matching bullets and is integrated into Forensic Technology, Inc.'s IBIS TRAX HD3D system used by police forces and forensics labs worldwide.
GradAtions®	GradAtions® is an intelligent literacy tutor designed to help learners improve their reading proficiency. IAI licensed this technology to university and training centers for marginalized and ESOL students.

Although licensing has provided a reasonable return on investment, IAI recognizes that developing IAI-branded products and starting spin off companies provides a stronger strategy for driving long term profitable growth.

Since 2009, IAI has adopted a more aggressive strategy of developing, funding, and marketing products based on the technologies it develops. Examples include:

Technology	*Description*	*Phase III Funding*
CybelePro®	CybelePro® is an Intelligent Agent Framework licensed by most NASA labs and leading aerospace companies for modeling and simulation of Air Traffic Management related technologies.	$5M+ in NASA contracts
RFnest™	RFnest™ is a laboratory-based test and evaluation environment for mobile networks. It enables accelerated development and fielding of new wireless protocols and network solutions. Principal customers include primes and government agencies.	$5M+ including Rapid Innovation Fund award

ARGUS™	ARGUS™ uses a network of unattended wireless sensors to create a wireless "trip wire" around a perimeter and provide early warnings against intrusions. IAI sells directly both in domestic and international markets. Customers are government agencies interested in border protection.	$2M+ including Rapid Innovation Fund award
Scraawl®	*Scraawl® is a social media analytics platform that allows analysis of tweets, social presence, influence and sentiment.* IAI currently has over 1000 users across the government, private and individual subscriptions.	$3M+ including DARPA, JIDA programs
SDNA®	SDNA® provides an IPv6-based integrated security architecture that enhances network security before, during, and after an attack. It creates a network secure by default. IAI recently spun off this technology as a separate company called Cryptonite, LLC.	$2.5M+ including DHS and Air Force programs

All of these products developed from successful SBIR Phase II projects and benefited from subsequent Phase III funding from the Rapid Innovation Fund, IDIQ contracts, NASA NRAs, DOD BAAs, and DARPA programming/BAA, with augmentation by internal R&D support from IAI.

In addition to product development, IAI also integrates SBIR technology into service modules for delivery within custom contracts overseen by prime contractors. IAI calls these activities productized services. In offering such services, IAI can either operate as part of a bid team for the contract or as a vendor providing technology and services for integration into the larger project. The company has developed close relations with a number of prime contractors such as BAE Systems, Honeywell, Northrop Grumman, Boeing, and Raytheon.

Business Model

IAI has diversified its revenue streams as a strategy for growth. While SBIR revenue has remained reasonably constant, the growth in product revenues and especially productized service revenues has grown substantially over the past five years. In 2010, 75 percent of IAI's income derived from SBIR awards. By 2015, only 51 percent of IAI's revenue was from SBIR funding. The 3 year moving average of IAI's SBIR funding in 2014 is $16.1 million, less than 5 percent lower than the same number in 2010. Table E-11 shows this long term shift in the company's business model.

TABLE E-10 Intelligent Automation, Inc., Core Technology Competencies

Core Competency	Description
Air Traffic Management	IAI has considerable expertise in Air Traffic Management (ATM), in developing cutting-edge tools for both NASA and the Federal Aviation Administration (FAA), and using them to solve topical problems in the aviation community. IAI's team of researchers and engineers have experience developing several tools, including NASA's Airspace Concepts Evaluation System (ACES), NASA's Multi-Aircraft Control System (MACS), the Department of Transportation's (DOT's) Aviation Environmental Design Toolkit (AEDT), the FAA's TARGETS system, and NASA's Air Traffic Operations System (ATOS). In addition, IAI has expertise in developing a number of visualization and analytical tools to better understand and translate the large quantity of data produced by these models into actionable information for aviation decision makers.
Controls and Signal Processing	IAI applies controls and signal processing expertise in the areas of machine learning, prognostics health monitoring, and transportation. In machine learning, IAI applies cutting edge techniques for sophisticated audio, image, and video analysis. Within transportation, IAI is active in developing innovative traffic management, monitoring, and safety solutions. IAI is also focused on operator safety. In prognostics, IAI utilizes predictive algorithms to address DoD health maintenance challenges.
Cyber Security	IAI provides practical and customized solutions for protecting the network, information, and the overall system. IAI utilizes advanced technologies and has extensive hands-on experience with wireless network security, cyber-attack analysis and mitigation, and cyber security testing and training. IAI's practical research and development is guided by the latest cryptographic theories.
Big Data Analytics	IAI has developed and commercialized innovative data analytics tools. With expertise in data mining, natural language processing, text analytics, and social media analytics, IAI's has developed solutions in scientific data analysis, health informatics and intelligence analysis.
Education and Training Technology	IAI applies the latest research in computer, behavioral and learning sciences, game design, engineering, and mathematics, to develop innovative solutions in education, in training and performance enhancement assessment methods, and in improving human-computer and human-machine interfaces. IAI personnel are leaders in creating Immersive Training Environments that provide effective, intelligent, and adaptive training in all spheres of instruction, including the military and the K-12 community. IAI also develops innovative Human System Integration products, using human factors engineering principles to improve human-system interfaces.
Health Technologies	IAI is actively engaged in research, development and the transition of health related applications, systems and technologies. IAI is a leader in developing mobile health solutions that fully engage the user by going beyond basic interactions and providing new functionalities that leverage the power of mobile platforms. IAI is active in health-IT and informatics focused on the areas of clinical decision support, Geographic Information Systems (GIS), health data mining, and natural language processing. IAI uses its extensive experience in developing innovative sensors, devices, and systems for biomedical applications.
Modeling, Analysis, & Simulation	IAI is a leader in the development of distributed simulations that emulate the behavior of physical systems and large complex networked systems. IAI's modeling and simulation expertise includes: aircraft and missile flight dynamics, flight trajectories, unmanned aircraft and ground vehicle performance and trajectory modeling, modeling and simulation of the

	behaviors and interactions of entities in the National Airspace (NAS), communication and network modeling, and agent-based highly scalable simulations for planning, scheduling, and logistics.
Networking and Communications	IAI specializes in the design, development and production of a wide spectrum of networking and communication technologies for both military and civilian applications. IAI provides solutions in domains ranging from the battlefield to rear echelon computer systems, and from wireless and satellite communications to local- and wide-area network protocols. Working from the physical through the application layer, IAI designs advanced networking and communications systems to support advanced wireless networking, network analysis and management, network evaluation, and advanced radio communication and antenna technologies.
Robotics and Electro-mechanical Systems	IAI has considerable expertise developing custom solutions for high performance machine vision, machine autonomy, human-machine interfaces, and remote robotic manipulation and inspection. IAI develops state-of-the-art simulation and control software with a focus on high-degree-of-freedom systems. IAI is actively applying this software to a wide range of applications to enable remote robot operators to perform advanced dexterous manipulation for inspection, maintenance, repair, EOD, material handling and others complex tasks.
Sensor Systems	IAI specializes in developing advanced sensor systems for military, transportation and medical applications. Areas of focus include radar, location and tracking, non-destructive evaluation/structural health monitoring, and electronic systems. IAI has extensive experience with a wide range of sensor modalities including electromagnetic, acoustic, optical, and electrical as well as the simulation, test, and evaluation of sensor systems.

SOURCE: Intelligent Automation, Inc., “Products and Services,” http://i-a-i.com/?product.

TABLE E-11 Intelligent Automation, Inc., Company Revenue Mix (2010-2015)

	Percentage of Company Revenues, by Year	
	2010	2015
SBIR R&D	75	51
Productized Services	23	41
Products	2	8

SOURCE: Interviews with IAI Personnel. Numbers are approximations.

To support a more structured product development and commercialization process, IAI has also invested in its sales and marketing function. IAI has staffed a formal technology transition team that includes Dr. Vikram Manikonda, President and CEO of IAI; Thomas Wavering, Vice President, Strategic Technologies; Dr. Peter Chen, Senior Director of Advanced Technology; and Ms. Ilene Godsey, Vice President of Operations. Previously Vice President at a technology company that he helped take public, Mr. Wavering joined IAI in 2009 and leads IAI’s business development and technology transition activities. Dr. Chen was a senior executive of a series of business units focusing on defense programs and joined IAI in 2012. He leads

IAI's product development efforts including ARGUS™ and RFnest™. In addition to being VP of Operations Ms. Godsey is also IAI's in-house General Counsel, and works closely with the product development and transition team on issues related to intellectual property, patents, export control, and compliance.

IAI's ongoing transition to a product-oriented approach has required reorganizing itself so that it can develop and market products more relevant to its customers needs. At the same time, increased support of commercialization by DOD and the U.S. government in general has accelerated this transition.

SBIR

IAI is among the most prolific winners of awards in the SBIR program. Over a period of nearly 30 years, it has won over 800 awards. It has been particularly successful in NASA competitions where it is among the Top 10 winners of Phase II awards.[41] IAI has had particularly close relationships with NASA-Ames (related to Air Traffic Management (ATM) systems), NASA-Goddard (related to Airborne SAR radar for biomass measurement), NASA Langley and NASA Glenn (related to ATM and UAS systems).

Table E-12 shows that in total, IAI has received slightly over $200 million in SBIR awards as of year-end 2014 from 596 Phase I awards and 213 Phase II awards. Approximately 73 percent of this funding was from DoD and another 16 percent was from NASA. The remainder was shared between nine other agencies, including the Department of Homeland Security (DHS), the Department of Commerce (DoC), the Department of Energy (DoE), the Department of Transportation (DoT), the Department of Education (ED), the Department of Health and Human Services (HHS), the National Institute of Standards and Technology (NIST), the National Oceanographic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF).

The distribution of Phase I awards by year and agency for 1987 through 2015 shows consistent long term growth in the number of SBIR Phase I awards won by IAI. After 2007, however, broadly speaking the number of awards plateaus at between 30-50 awards annually.

Looking more closely at data in the last 5 years (Table E-13), IAI's Phase II conversion rate is comparable to the national average across all agencies. For NASA, IAI's Phase II conversion rate is significantly higher than average since 2009.

Having won most of its SBIR awards from NASA and DoD partially explains IAI's approach to contract research during the early years of its existence. IAI has been highly successful in meeting these agencies' research needs, demonstrating that the agencies find significant value in

[41] SBA tech-net database. Accessed November 1, 2009.

TABLE E-12 SBIR/STTR Awards to Intelligent Automation, Inc., by Phase and Source (1979-2014)

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)	Total Funding By Agency (Dollars)	Agency Funding as Percent of Total	Phase I to Phase II Conversion Rate (Percent)
DoE	6	700,000	0	0	700,000	0	0
HHS	14	1,649,366	4	3,281,816	4,931,182	2	29
DHS	5	499,998	4	3,294,998	3,794,996	2	80
DoT	16	1,824,999	8	5,189,880	7,014,879	4	50
NOAA	1	95,000	1	400,000	495,000	0	100
NSF	18	1,412,815	2	501,985	1,914,800	1	11
DoC	8	384,729	2	489,153	873,882	0	25
NIST	3	270,000	1	300,000	570,000	0	33
ED	5	210,000	2	650,000	60,000	0	40
NASA	90	6,943,314	40	25,332,611	32,275,925	16	44
DoD	430	40,293,414	149	106,325,557	146,618,971	73	35
Total	596	54,283,635	213	145,766,000	200,049,635	100	36

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 16, 2015.

TABLE E-13 Intelligent Automation, Inc., Phase II Conversion Rate (2009-2013) by Agency

	Conversion Rate (Percent)	
	All	IAI
All Agencies	45	43
National Aeronautical and Space Administration	41	55
Department of Defense	50	41

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed November 6, 2015.

companies that successfully address difficult research topics within the relatively limited budgets afforded by the SBIR program. Like many companies dependent on DoD and NASA SBIR funding, in its early years, IAI found it difficult to find a successful model for transitioning and productizing the technologies that it developed. However, since 2009, with its new initiatives and corporate reorganization and focus on productization and transition, IAI now has multiple successful products, productized service offerings, and recently even raised external funding to launch its first spin-off company.

BOX E-6
NASA SBIR Phase III Funding

IAI has participated in over 30 Phase III programs, with NASA based on successful SBIR Phase II projects with different NASA agencies. Phase III funding has included both NASA NRAs and also task orders under NASA contract vehicles such as the NASA LITES, GESS 3, UARC, Bio Astronautics, and HHPC. These have included program support to NASA centers in areas related to ADS-B weather avoidance radar, CNS models for the NAS, airspace merging and spacing, development of UAS performance and communication models and frameworks, trajectory prediction analysis, integration of advanced concepts and vehicles into the NAS, and the development of SAR instruments to measure ecosystem structure, biomass and water.

Some specific examples of such transitions are:

- **Adoption of CybelePro® in NASA's Airspace Concept Evaluation System (ACES):** For the past 10 years, IAI has supported NASA's Airspace Systems Program in the Aeronautics Research Mission Directorate (ARMD) in software development and maintenance of ACES. ACES is currently used by several organizations including NASA Ames, Langley and Glenn, JPDO, FAA and several aviation companies to support Air Traffic Management (ATM) research. IAI led the development of the agent architecture design and implementation for ACES and a wide range of modeling and decision support tools. As a member of the ACES team, IAI received the NASA team achievement award and the NASA Space Act Software Release Award for contributions to the development of ACES. Applications of CybelePro® are not limited to ATM research, and other companies and agencies have licensed the software for applications in distributed robotics and logistics scheduling.
- **Adoption of IAI ATM modeling and simulation technology in FAA's Integrated NAS Design Procedures Planning (INDP):** As a subcontractor to Exelis, IAI led the INDP effort within the FAA's SE2020 program to study the benefits, costs, and impacts of implementing advanced capabilities in the National Airspace. Working closely with other stakeholders such as Delta Airlines, ExpressJet, American Airlines, United Airlines, Rockwell Collins, air traffic controllers (from FAA), and independent consultants, IAI evaluated different airspace designs using the Hartsfield-Jackson Atlanta International airport (KATL) and surrounding airspace as the candidate metroplex. IAI evaluated new route structures for arrivals and departures using NextGen applications and procedures expected to be available by 2018 (3D/4D TBO, Airport CDM, CAVS, CEDS, DataCom, DS, IM-DI,PBN & TSA), accounting for current and future predicted commercial flight traffic volume and assuming ongoing operator investments in flight-deck capabilities.

Knowledge Effects

IAI has patented technical advances that have commercial application; it is the assignee on 15 U.S. patents. IAI also has over 200 publications in journals, conferences, books and magazines and several "Best Paper" awards at major conferences.

IAI has been recognized by its customers and peers for excellence, receiving the Northrop Grumman Information Systems Supplier Excellence Award and the Most Innovative Communicators Award from Northrop Grumman, two National Tibbetts Awards from the U.S. Small Business Administration, the Administrator's Award from U.S. Small Business Administration, Raytheon Supplier of the Year award from Raytheon, the NASA team achievement award and NASA Space Act Software Release Award from NASA, and the Best of Rockville Award from the City of Rockville for its advances in Aerospace Technology.

IAI has also been recognized for its contributions to the SBIR program itself. In February, 2011, IAI won a "Champions of Small Business Innovation" Award from the Small Business Technology Council for its work in helping realize the long-term reauthorization of the SBIR program in 2011.[42]

STTR

IAI has worked extensively with universities and university faculty on many projects. IAI has used the STTR program to access the expertise of universities and university faculty. Of the $200 million in funding received by IAI through the SBIR/STTR programs, about 10 percent has been through the STTR program. While the STTR program provides access to university partners, finding the right partners is challenging. Also, because of university policies regarding export control regulations and restrictions on publication, many university professors won't or can't participate.

Although IAI works extensively with universities, the company prefers to use SBIR over STTR funding when the transition customer or product is a DoD agency. Constraints on publication stemming from SBIR/STTR awards and constraints on team composition because of export restrictions limit the number of universities willing to participate in STTR-funded programs. Non-DoD agencies tend to be more flexible on the issue of publication. Dr. Manikonda thought that given a choice, for several DoD agencies, IAI would choose an SBIR contract over an STTR. "In the end, you just have more flexibility with whom you can work in SBIR. Also, SBIR provides more flexibility when it comes to transitioning the technology to DoD customers."

[42]National Small Business Association, "SBTC Honors "Champions of Small Business Innovation" February 12, 2011, http://www.nsba.biz/content/printer.4422.shtml.

Improving SBIR and STTR

Overall, IAI believes that the SBIR program provides great value to the small business community, serving as an invaluable source for seed funding to support development of innovative and high risk technologies, to meet the needs of the government and commercial sector.

Recently, some agencies have begun committing additional program funds to SBIR Phase II funding to accelerate commercialization. IAI supports this interesting innovation. For example, in 2013, IAI was awarded a $4M SBIR Phase II program (the usual ~$1 million for an SBIR Phase II augmented by an additional $3M in program monies) to support the need, voiced by the F-35 program office, for a system to inspect jet exhaust ducts. By program's end, IAI will have taken the technology to TRL6 while positioning it on the F-35 roadmap through close interaction with the government, Pratt & Whitney, and the Lockheed Martin Integrated Product Team. IAI would like to see more programs that provide extensive funding for SBIRs that closely map project results to program needs.

In many cases, STTR contracts require that the prime contractor and subcontractors (the university) receive permissions and approvals from the agency before publishing their results. Although IAI supports the need of the agency to review publications, this practice is a serious concern to university professors and students for whom career advancement depends on the publication of research results. According to Dr. Manikonda, on several occasions, despite a winning application, university faculty members have withdrawn from proposal teams because they would not accept restrictions on publication. "Relaxing these publication clauses on STTRs would significantly increase the value of the STTR program and enable more universities to participate in the STTR program" said Dr. Manikonda.

The SBIR program's sole-source provision allows an agency to avoid competitive bidding and give preference to a company with a technology that fully serves the agency's needs when that technology was originally funded through a competitive SBIR or STTR process. Although IAI has had success in identifying Phase III funding for many of its Phase II SBIR projects, IAI has had limited success in using the sole source provision in the SBIR funding program to receive Phase III funding. Historically only NASA has awarded IAI Phase III funding under the sole source provision. Dr. Manikonda believes that the limited use of sole sourcing in practice stems from an incomplete understanding of this provision by contracting officers in some of the DoD program offices.

IAI continues to see no reason to limit the number of applications a company can make by solicitation or year. Dr. Manikonda thinks that this policy limits the number of quality ideas to which the government is exposed, which is bad for innovation. "Quality and merit should be the standards," said Dr. Manikonda. "Some SBIR challenges require a cross disciplinary solution that is only possible by small businesses that have the breadth of R&D expertise and resources to meet those challenges." Restricting the number of applications results in suboptimal SBIR solutions for government customers.

An issue that surfaced in 2013 and 2014 (largely due to the impact of sequestration), and has continued to prevail in some agencies is the amount of time taken to deliver funding following the announcement of selection for a Phase II award. "In the worst cases, this can take a year" said Dr. Manikonda. While larger small businesses like IAI can withstand such delays, this can be devastating for smaller companies, as it puts the employees hired to work on these projects at significant risk. "Reducing the time between the end date of the Phase I and start of a Phase II would greatly benefit small business participating in the SBIR/STTR program" said Dr. Manikonda.

Another recommendation from IAI is related to the metrics for measuring commercial success. Since 2010, SBIR has implemented the minimum transition benchmarks. While IAI has no trouble meeting these benchmarks (given its strong record for transition), and agrees that these are valuable and much needed metrics, Dr. Manikonda felt that, in its current form, many small businesses often do not receive full credit for transitioning technology to what IAI terms productized services. As productized services, SBIR technologies are often central to a large prime program's success. However, the SBIR company only gets limited credit for providing this key technology. For example, if an SBIR technology enables a $1 billion program but the small business only gets a subcontract worth $10 million from the prime, at present, the small business only gets credit (in transition /non-SBIR revenue) for the $10M paid in licensing/subcontracting revenue. In many situations, Dr. Manikonda noted that what limits larger participation in the program of record by the small business are certifications (e.g. CMMI), clearances levels, and maturity at the time of transition. Dr. Manikonda suggested that the SBIR program should consider weighting the total value of the transition program and the role of the SBIR technology in its success as one of the metrics for the transition benchmark, "If the SBIR technology is integral to the success of the transition program, the small business should receive more credit than simply its subcontract value for the transition," suggested Dr. Manikonda.

Overall, IAI views the SBIR program positively. Dr. Manikonda affirmed that SBIR funding provides critical seed funding that allows high-risk, high-value projects to be explored and completed. SBIR funding has been integral to IAI's growth and success.

PARAGON SPACE DEVELOPMENT CORPORATION

Based on interview with
Mr. Grant Anderson, President and CEO and co-founder
and Dr. Volker Kern, Senior Director of Programs
December 19, 2014
Tucson, AZ

Paragon Space Development Corporation (Paragon) is a small business headquartered in Tucson, Arizona, with additional offices in Houston, Texas, and Denver, Colorado. The company provides environmental controls for extreme and hazardous environments, including life support systems and thermal control products for astronauts, contaminated water divers, and other extreme environment adventurers, as well as for unmanned space and terrestrial applications. Paragon is headquartered in a 21,500 square-foot facility near the Tucson International Airport, close to the University of Arizona. Approximately 9,000 square feet of Paragon's facilities are devoted to an easy-access high bay, plus laboratories, with a 4,500 square foot workshop, a bonded storage, and a ~200 square-foot class ISO Class 7 clean room. The remainder of the building is used for engineering design a conference room and offices.

Paragon was founded in 1993 by a small group of scientists and engineers who realized that the engineering and aerospace communities differed sharply in outlook from the biosciences- and life sciences-related communities. In their view, physics and engineering were in "clean hard science," while biosciences was still a more intuitive field, so they modeled the Paragon business to combine the thinking of both types of disciplines.

Mr. Anderson observed that these cultural differences run deep: the two communities speak different languages and in some ways see each other as too lax or too rigid. They even tend to have different social views and dress code. So a core objective for the company was to bring together these two scientific/engineering cultures.

Paragon started by developing a small closed ecosystem, which it patented. The ecosystem involved controlling the nitrogen and carbon balance in ways analogous to the control exerted by a central bank over currency. Paragon used these systems to undertake the first completed animal breeding and life cycle in space. Its experiments were used to explore the role of innate and learned capabilities by examining animals swimming outside the gravity well and to compare those animals born in space with those that experienced gravity then adapted. In addition, those animals born in space were also observed adapting to gravity once they returned to earth.

During the 1990s, NASA work in biological sciences testing in space did not expand as expected because of delays in the International Space Station as a science laboratory and because of priorities, according to Mr. Anderson. In response, Paragon's emphasis shifted toward life support and thermal control, which was where market demand could be found.

During the late 1990s, Paragon became part of the team working on the shuttle's replacement and soon became involved in the Orion program, and more generally in space capsule life support design.

Paragon's dive suit project offers an excellent example of understanding the biology and physiology needed to keep a person alive while solving difficult issues of material compatibility and use. Paragon adapted space suit design for diving applications in contaminated waters where total isolation of the diver is required. This constituted an early effort by the company to explore options outside space.

Paragon has encountered some business problems in part because it has remained primarily a government contractor working for NASA. As such, funding is uncertain and margins are low, which make it difficult to weather difficulties with funding cycles (government funding is authorized on an annual basis) and limit the ability to take products to wider markets. When times become difficult, the company usually does not have a significant backlog of work, resource base, or reserves to fund internal R&D.

NASA and DoD SBIR funding help to partially close the R&D gap by providing resources for developing technology. However, this technology is usually attractive only to the small market interested in the directed topic, and, in NASA's case especially, tends to be directed toward meeting the agency's needs, which contributes to the funding cycle problems noted above.

The company has worked successfully in life support and space fields for more than 20 years. Even today, it is deeply involved in work on the next generation of space suits the Orion vehicle for NASA, while supporting private space and other life support initiatives, such as the recent successful development of a "Stratospheric Explorer" for Google executive Alan Eustace.

Current Strategy

Paragon is working diligently to diversify its customer base, according to Dr. Kern (see Annex E-1). However, the company was to a large degree founded around human life support, and its founders and employees are passionate about that mission. Therefore, diversification introduces some tensions as well as benefits. Company strategy has recently shifted from contract R&D and integration of systems of components, usually made by other companies, to development and deployment of components and products for larger systems suppliers such as Lockheed, Boeing, and other established aerospace companies.

Both Mr. Anderson and Dr. Kern are concerned about the future of space flight and space development in the United States. They argued that Congress (and to some degree NASA) realize neither the importance of these capabilities to the nation nor the role of the small companies that provide the management and the technical innovation required. Today, most modern spacecraft are made in China and by commercial suppliers, and the United States has shut down its only human launch capacity for the near term—perhaps for more years than estimated when the shuttle was retired in July, 2011. The country is entirely dependent on Russian infrastructure for manned operation of the International Space Station (ISS).

Markets/Products

Paragon's market is life support and thermal control products and systems, which can be divided into three areas, although systems often include elements of all three areas to provide a complete life support system:

1. Air revitalization
2. Thermal control
3. Water management, recovery and conditioning

Paragon is a cutting-edge company. Its technologies have been used for a number of ground-breaking scientific and technical efforts, including the following:

- ***The "first commercial experiment on ISS***. Paragon designed, fabricated, tested, and prepared"[43] this experiment for flight in only 10 weeks, utilizing a Russian Progress vehicle. Paragon claims "this work was the pathfinder for all future commercial projects involving the RSA/Energia and SPACEHAB."[44]
- ***"The first animals in space to perform complete life cycles***."[45] Paragon managed "complete life cycles from birth, to adulthood, to procreation"[46] and subsequent generation births. It "did so during a [4-]month experiment"[47] on the Russian Mir Orbital Station. This "first multigenerational animal experiment in space is [still] the longest [duration] microgravity animal experiment"[48] to date at more than 18 months.

  Subsequent experiments on four space flights (shuttle, ISS, Mir) used Paragon's Autonomous Biological System (ABS) to deploy the "first aquatic angiosperms to be grown in space; the first completely bioregenerative life support system in space; and, among the first gravitational ecology experiments"[49] in space. The "first full-motion, long-duration video (4 months, 60 minutes) of plant and animal growth on orbit was accomplished with a Paragon-designed digital camera

[43]Paragon Space Development Corporation website, http://paragonsdc.com.
[44]Ibid.
[45]Ibid.
[46]Ibid.
[47]Ibid.
[48]Ibid.
[49]Ibid.

system using a Paragon-specified Sony DCR-7 digital camera with custom EPROM."[50]

- ***Turn-key air revitalization system for the NASA Commercial Crew Development project.*** The system handles trace contaminant control, carbon dioxide removal, humidity removal, and cooling to a cabin air environment. The humidity control portion has been adapted for Boeing's commercial CST-100 manned vehicle.

Recently, Paragon-made tubing and instruments flew to outer space as part of the Orion EFT-1 test flight. This tubing was for water, ammonia, thermal fluids, and oxygen and nitrogen supplies. Paragon also supports the NASA Constellation Space Suit System (CSSS), also known as the C-SAFE, through thermal analysis, thermal system component design and fabrication, and testing of specific components.

Paragon also continues to develop the Paragon Dive System (PDS) which allows divers to dive safely in highly contaminated water that includes jet fuels, ship fuels (diesel oil), sewage, heavy metal contaminants, biological warfare agents, and chemical warfare agents.

Paragon and the SBIR Program

During its first 7-8 years of existence, Paragon did not apply for SBIR funding; in fact, it operated with more commercial contracts at that time. Among its projects, it worked for a German airship company, and was funded by Japanese research organizations to develop and manage experiments on Mir. Paragon used the space shuttle to transport the payload to Mir, completed its research program and then sold the research and samples to a consortium of Japanese universities and researchers.

Paragon's first SBIR award was for the diving suit project noted above. This project was for the State Department, which did not fund Phase II. The U.S. Navy picked up Phase II 3 years later. The project has progressed through Phase III and other development efforts and is now in Phase III driving toward certification of the system across the Navy.

Overall, the SBIR program has made three crucial contributions for Paragon, according to Mr. Anderson. First, it provides seed funding to explore an idea. Paragon usually loses money on Phase I, and sometimes loses money on Phase II, so SBIR is a supplement to internal funding rather than a profit center (i.e., "subsidized R&D"). Second, the program allows Paragon to mature technologies so that they are more attractive to potential customers. Finally, it helps Paragon develop working relationships with people running programs that might be customers. According to Mr. Anderson, this latter contribution is "as important for our ability to work with NASA as the funding for research."

[50]Ibid.

Overall, Paragon believes that a substantial share of discretionary R&D at NASA would not be funded without the SBIR program. In fact, the program remains the research seed corn at the agency; for a long time, almost all of the non-program-specific research has been funded by SBIR.

Problems with Data Rights

The SBIR program funded another project to work on a spacecraft radiator. The Phase III for this project was indirectly picked up for the Orion program. In this case, there were difficulties with ownership of data rights and requests from NASA to release the technical data from company proprietary limits. Previously, NASA contracts stated that the summary "quad chart" required with the final report should be free of proprietary information, which was reserved for the technical report itself. However, NASA rejected Paragon's final report because it contained proprietary data. This presented significant difficulties because, by definition, a technical report on the program must contain confidential information to be sufficient for evaluation by the contracting officer's technical representative (COTR).

Recent changes to NASA SBIR contracts provide some improvements, but they are still sufficient from the company's perspective. The company shared the following clause from its most recent SBIR award:

> *(1) The Final Report shall include both a single-page project summary as the first page, identifying the purpose of the research, a brief description of the research carried out and the research findings or results, and a "Final Phase 1 Accomplished/Updated Briefing Chart." The summaries shall be submitted without restriction for NASA publication. Proprietary data shall not be included in the final report nor contain proprietary restrictive markings unless authorized by a Contracting Officer (CO). Instructions for the electronic submission of the project summary and a sample of the Summary Chart are posted on the NASA SBIR EHB located in the NASA SBIR/STTR Forms Library. For instructions for completing the accomplished/updated briefing chart and a template see Attachment 2.*

Although Paragon agrees that distribution of the summary chart should not be restricted, a requirement that the contracting officer approve inclusion of proprietary data runs counter to the program's purpose of the program. It also raises concerns about the possible distribution of the report to other parties outside NASA.

Paragon is also concerned about the new technology report (NTR). Sometimes, Paragon creates new technology, but would like to retain it as a trade secret because a patent would not necessarily provide the best protection. But the NTR submission is governed by this clause:

> *NEW TECHNOLOGY REPORT (NTR)*
> *In accordance with 1852.227-11, the contractor is required to disclose subject inventions and when new technology is developed. A final disclosure is required at the end of the performance period of the contract when new technology is developed. Additional information can be viewed at http://invention.nasa.gov*

As stated, NASA requires the company to make a determination on whether to patent a technology to maintain its rights, or to relinquish those rights at the end of the performance period. This not only conflicts with the data rights section of SBIR reauthorization, but also with the relevant sections of the Bayh-Dole Act on which NASA appears to be relying. Mr. Anderson said that the NTR clause in NASA contracts should be further reviewed.

Recommendations for Improving SBIR

Mr. Anderson said that DoD's funding structure works much better for Paragon than does NASA's. NASA funds Phase II awards steadily in small amounts over 2 years, and therefore all Phase II projects take 2 years even if they could be completed in less time. Some of Paragon's DoD awards were completed in less time—in one case within 9 months. It could be argued from the company's perspective that NASA's approach represents the worst possible contracting model. It often provides set funding limits per year for 2 years, payable month by month based on invoices for work completed. Effectively, it is a time and materials contract, but one with a fixed fee and an annual funding cap. Recipient companies must account for every hour of work; therefore, any acceleration would incur risk.

Paragon would prefer payment for milestones accomplished. This is the approach adopted under Space Act agreements for commercial crew, where a $1.4 million contract to Paragon was milestone based.

The current approach prevents NASA from investing more rapidly and effectively in projects that are succeeding. The alternate approach has been applied by other agencies, the Navy in particular, which Paragon considers to be a very positive development. Phase II could be used as a more flexible mechanism, with some funding held back for additional investments in successful projects. In general, one size does not fit all, and flexibility is critical.

Other possible improvements include the following:

- Variable funding size: Some projects require more than the standard award, and others require less. Paragon sees the Navy model as a compromise on this issue.
- Reapplying for funding. Companies should be permitted to reapply for Phase II funding (along the lines of NIH).

- Multiple solicitations. The NASA solicitations should be released twice a year, as in many other agencies. The current approach imposes substantial application burdens on NASA-centric companies, especially those with limited senior staff time. The influx of proposal work during the November to January timeframe burdens companies and NASA and invariably leads to squeezed time at the company and delays of evaluation and award.
- Phase I-II bridging funds. Paragon recommends that NASA adopt the Navy model. NASA has recently developed some Phase II alternatives (E and X funding), which are helpful but not as flexible as the Navy model.
- Award size. Paragon believes that SBIR awards should be larger in size, even if this means fewer awards. The larger awards would encourage NASA to focus more clearly on its top priorities, which would in turn lead to better connections between SBIR and Phase III opportunities.
- Program review. Paragon noted that NASA technical reviews are usually high quality, although they vary by contract officer. Paragon insists that its NASA clients participate in the review process and sign off on the technical review documents. NASA should mandate that they do so.

Finally, Paragon sees publication in peer-reviewed journals as integral to maintaining its competitiveness. Mr. Anderson observed, "We often publish, because it shows our quality and sometimes scares off the competition when they know how far ahead you are," and added that it is not enough to win a Phase II award—the target community must accept the proposed technical solution as well. Peer review is a key element of acceptance, so holding back on publication is a strategic mistake. Paragon's strategy is to create some IP cover using patents, and then to publish. This strategy seems to have helped Paragon during the review process.

Annex E-1
Paragon Customers

- Andrews Space
- Bigelow Aerospace
- Boeing
- CargoLifter
- Draper Laboratory
- Excalibur Almaz
- GPC
- Inspiration Mars Foundation
- JPL

- Jacobs
- Lockheed Martin Aeronautics, Skunkworks
- Lockheed Martin Astronautics
- Mars One
- MIT
- MineShield
- Moon Express
- NASA
- Naval Sea Systems Command
- Oceaneering Space Systems
- Odyssey Moon
- Raytheon
- Rocketplane COTS
- Rocketplane Kistler
- SPACEHAB
- SpaceX
- SPARTA
- Toyo Engineering
- United States Navy
- University of Arizona
- World View

PRINCETON SCIENTIFIC INSTRUMENTS

Interview with
John Lowrance, CEO.
October 20, 2009
Monmouth Junction, NJ

NOTE: Princeton Scientific Instruments is no longer in business following the death of CEO and founder, John Lowrance. The following case study was completed in 2009. The firm's closing demonstrates the impact on small firms of the loss of key personnel.

Princeton Scientific Instruments (PSI) is a privately held company located in Monmouth Junction, New Jersey. John Lowrance founded PSI in 1980, after working at RCA on satellite-based TV cameras, including a camera used in the Apollo program, and for the Advanced Physics program at Princeton University.

In 1980, Dr. Lowrance helped the European Southern Observatory design the specifications for a solid state camera, which he was subsequently asked to build. Along with a contract from the Max Planck Institute, this contract formed the basis for the new company, PSI. The company was originally founded to design and build charged coupling device (CCD) cameras for astronomical observing and other scientific imaging applications, although initially PSI was only a part-time venture.

In 1984-1985, PSI found out about the SBIR program (from a competitor). PSI won an initial SBIR award from the Army at the Aberdeen Proving Grounds to work on improving the ability to track muzzle deflection in tank turrets. This initial award led to others (see SBIR section below) and allowed the company to fully launch. Since then, the company has focused on a series of projects, most of which have been successful technically, but anticipated markets have failed to fully materialize. PSI has therefore remained largely a contract R&D company, focused on a series of projects to a considerable degree defined by SBIR awards.

Products and Projects

Ultra-Fast CCD Camera

PSI was in part founded to build an ultra-fast CCD camera. For some applications, extremely high frame rates are required to capture changes in target characteristics—up to 1,000,000 frames per second. At the time, digital technology did not allow for capture and transmission of these data at sufficient speed to permit these frame rates.

Consequently, PSI built an analog camera with memory sufficient to capture and retain locally a fixed number of frames—originally 32 and later expanded to more than 300. The camera refilled the analog memory on a continuous basis, discarding older frames as new frames were captured.

Results allowed for the capture of very rapidly changing targets. For example, a figure from PSI shows the results of applying the camera (set at 1 million frames per second) to a Mach 2.5 jet of air/carbon dioxide mixture. The figure depicts four adjacent pixels in the array. Each pixel consists of a photo detector and a CCD type charge storage memory array. In one clocking cycle, photoelectrons generated in the photo detector shift into the adjacent charge storage site of the pixel's memory array, thereby acquiring a frame. Each frame is separated by one micro-second. PSI has several versions of the camera available for sale.

The camera has been adapted for use in a number of scientific environments, including Princeton’s Plasma Fusion Lab. In 1992, a PSI digital CCD camera system was adapted for use in ionospheric observations as part of the Combined Release and Radiation Effects (CCRES) program.

Lightning Mapping Sensor

Lightning strikes are a significant target for weather-oriented applications. Lightning activity can be continuously monitored from geostationary orbit satellites, but the ~38 kg weight and ~140 W power consumption of current CCD-based lightning mapping systems have discouraged their use on synchronous orbit satellites.

PSI is developing a solid state complementary metal-oxide semiconductor (CMOS) array of "smart-pixels" that circumvents the problem of high data rate operations (and attendant high power requirements) by detecting and measuring the optical pulse associated with lightning transient events prior to array readout. This approach reduces power consumption and weight by an order of magnitude.

Similar "smart pixel" arrays, with the ability to detect, locate, and measure unpredictable events, have applications in other scientific research, such as cosmic ray shower detection and in military weapon systems. Some of these applications have also attracted SBIR funding.

PSI's LMS system was regally by a Navy SBIR award focused on detect laser activity. Although the technology was successfully tested by the Navy, it was not adopted for acquisition. PSI then adapted the technology for use by NASA's lightning detection group, but the technology did not perform to specifications.

Automatic Muzzle Reference System (AMRS)

The AMRS accurately measures the angular motion of the muzzle of a tank-mounted cannon relative to its trunnion at any elevation angle, while the tank is in motion and as the round exits the muzzle. This system allows for the accurate re-calibration of the gun muzzle for enhanced accuracy, in near real time.

The AMRS is based on viewing the muzzle from the cannon trunnion. The optics assembly consists of an autocollimator-type instrument mounted on the trunnion of the gun, and a mirror rigidly fastened to the muzzle. A beam of light projected by the autocollimator telescope reflects off the muzzle mirror and passes back through the telescope to be re-imaged on a solid state position-sensitive detector located in the focal plane. The AMRS generates analog signals representing muzzle azimuth and elevation.

The AMRS has to some extent been a source of both promise and frustration to PSI. The system has performed as predicted technically and has produced a substantial increase in accuracy of use.

Initially, the system was expected to be installed as part of an anticipated upgrade to the Arm's Abrams M-1 tank. However, after passing technical tests, the Army made the decision not to perform a full upgrade, and the AMRS system was one component that was not adopted.

PSI received more than $1 million in funding to adapt the AMRS to the upcoming new lightweight tank planned by DoD as part of the Future Combat System (FCS). Again, the AMRS was technically successful and included in preliminary designs for the new tank. More importantly, PSI developed a good relationship with General Dynamics (GD), the likely prime contractor for the new tank. PSI successfully built and delivered a working prototype. PSI's strategy was not to build the device itself, but to team with a military hardware developer such as GD.

Unfortunately for PSI, the new tank was abandoned by DoD, and the AMRS system was once again not adopted for acquisition by DoD—after more than 20 years of work dating back to 1985. Dr. Lowrance noted that the design could still be adapted for use with subsequent generations of DoD tank technologies.

Therefore years of technically successful R&D at PSI, primarily supported by several SBIR awards from DoD, did not lead to deployment of a commercially successful product. This experience once again illustrates some of the difficulties faced by SBIR companies in matching SBIR technologies to DoD's acquisition needs.

Client Base

According to PSI, current customers include the Air Force, Navy, Army, NASA, and the Department of Energy. CCD camera customers over the years include the European Southern Observatory, Max Planck Institute of Astronomie, Tokyo Observatory, University of Arizona Lunar and Planetary Laboratory, Princeton University, Cornell University, and Lawrence Livermore National Laboratory. Most of these systems have been custom designed or modified for the customer's application.

Dr. Lowrance observed that the economics of businesses involving sensors are tilted against small companies. Typically, the cost of such systems is heavily influenced by the yield from silicon-based sensor fabrication, which is contracted out to foundries in small batches. Although large companies making high-volume applications such as microprocessors can afford to fine-tune the process to generate high yields, PSI typically could only afford one batch and had to accept the output whatever the yield.

PSI continues to seek new avenues for R&D and technology development. Currently, it is working with Johnson and Johnson on advanced testing systems for condoms and on a skin analysis project. PSI also has two current SBIR awards.

SBIR Awards

As shown in Table E-14, PSI has successfully won a series of awards from four agencies: DoD, DoE, Department of Health and Human Services (HHS), and NASA. The initial series of awards focused on a new approach to improving the accuracy of tank guns (see AMRS above). PSI claims to be the only U.S. company working in this area (its international competitor from Israel) and that this work was entirely funded by SBIR awards. This work followed a winding path both technically and in the market, developing systems for testing

TABLE E-14 SBIR Awards at Princeton Scientific Instruments: Summary Table

Agency	Number Phase I Awards	Phase I Funding (Dollars)	Number Phase II Awards	Phase II Funding (Dollars)	Year of First Award	Year of Most Recent Award
DoD	23	1,726,524	13	7,664,269	1986	2008
DoE	8	674,363	4	2,400,000	1992	2004
HHS	6	334,622	4	1,922,632	1989	2001
NASA	7	459,303	4	2,181,248	1991	2002
Total	44	3,194,812	25	14,168,149	1986	2008

SOURCE: SBA Tech-Net database.

and using SBIR to address specific technical issues. In all cases, Phase III contracts proved elusive. The awards span more than 20 years, from 1984 to 2008, and average about $800,000 annually, which appears to constitute a significant percentage of PSI revenues.

SBIR Comments

As reflected in testimony given in 1992 before the House Small Business Committee, Dr. Lowrance believes that the program's emphasis on the commercialization of technologies provides a substantial advantage to larger "small companies." These firms have more in-house commercialization capability and can also afford to maintain staff on site at National Laboratories, where many SBIR topics originate.

Dr. Lowrance considers the SBIR program to be a highly successful effort to tap the energies of small creative businesses. He noted that topics in general focus on identified problems and provide sufficient funds to pay for the necessary R&D. Working with the labs often opened doors for projects that were too small to interest the prime contractors or large acquisition programs. Funding through the SBIR program is typically not available from other sources.

Dr. Lowrance said that he supported changes in the award size, even if offset by a decrease in the number of awards. He believed that current sizes were in some cases simply not sufficient to fund prototype development.

His biggest concern with the program focused on the quality of referees, as reflected in their reports on applications. PSI experienced considerable variation in quality, especially at DoD, which is a substantial problem for the program.

Dr. Lowrance was especially critical of reviewers' comments about commercialization plans in Phase I applications. He believes that reviewers focus on this aspect of the project in part to avoid addressing technical issues that they may not feel qualified to judge. He recommended that the emphasis on commercialization plans in Phase I selection decisions be sharply reduced, or the need for a plan eliminated altogether at this stage. He did not express similar concerns about commercialization plans for Phase II projects. Dr. Lowrance observed that Phase I commercialization plans are of very limited value because companies often have to change their commercialization strategy along the way: for example, he noted that PSI never sold a CCD camera system for the original purpose defined in the SBIR application, but had adapted and sold systems to meet other researchers' pressing needs in other areas.

STOTTLER HENKE ASSOCIATES, INC.

Interview with
Mr. Dick Stottler, CEO
August 17, 2009
San Mateo, CA

Stottler Henke Associates, Inc. (Stottler Henke) is a privately held company headquartered in San Mateo, California. Founded in 1988, Stottler Henke applies artificial intelligence and other advanced software technologies to deliver software for planning and scheduling, education and training, knowledge management and discovery, decision support, and computer security and reliability. Stottler Henke's clients include government agencies, manufacturers, retailers, and educational media companies.

Since 1990, Stottler Henke has won 158 Phase I awards and 60 Phase II awards, from four federal agencies (although almost all are concentrated in DoD and NASA).[51] Currently, SBIR funding accounts for about 50 percent of Stottler Henke annual revenues, and has ranged from zero at its inception to as much as 95 percent over a decade ago. In 2008, Stottler Henke won nine Phase I awards and four Phase II awards, all except one NASA award from various components at DoD.

Stottler Henke can be described as technology-driven rather than revenue-driven. It was founded to explore technical opportunities identified by the founders. There are no explicit goals for the company, and management has at times reined in growth to avoid upsetting existing organizational structures. Most technical staff have been with the company for more than 10 years. Currently, Stottler Henke employs about 50 people. This continuity is important to the business. New technology projects are built on the basis of previous projects. All training systems are, for example, customized for each application, but are built on existing software code and applications.

SBIR Awards at Stottler Henke

As shown in Table E-15, Stottler Henke has been the recipient of more than 100 SBIR awards from several agencies. In some respects, Stottler Henke's role is to perform closely specified research for NASA and DoD, plugging gaps

[51] SBA Tech-Net database. Accessed September 10, 2009.

TABLE E-15 SBIR Awards to Stottler Henke

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)
NASA	25	2,227,781	5	3,323,752.00
NSF	3	94,515		
HHS	3	299,999		
DoD	127	10,063,334	55	36,829,253
Totals	158	12,685,629	60	40,153,005

SOURCE: SBA Tech-Net database. Accessed September 10, 2009.

and meeting rapid turn-around requirements, while the agencies use the SBIR program to fund this work. Mr. Stottler observed that for Stottler Henke, Phase II awards usually result in operational software, rather than the preliminary prototypes often delivered at the end of Phase II in other (non-software) sectors. This is not unusual in the software sector.

Clearly, Stottler Henke's consistent success in winning SBIR awards from multiple agencies (and especially DoD and NASA) indicates that the company has been highly successful in meeting agency needs by providing these kinds of services. Utilizing its core code library, the company is well placed to deliver customized applications based on its basic scheduling and learning technologies. The extent of this success is underlined by the detailed analysis of two products developed for NASA, discussed in more detail below.

Other Awards and Publications

In 2004, Stottler Henke received a "Brandon Hall Excellence in Learning" award for innovative technology. For four consecutive years, Stottler Henke was named by *Military Training Technology* magazine as a "Top 100" company making a significant impact on military training. In 2005, Stottler Henke received a Blue Ribbon award for industry-leading innovation.

Seven Stottler Henke systems have been designated as SBIR success stories. Four systems have been listed in *Spinoff*, NASA's showcase of successful spin-off technologies. In 2006, NASA released a Hallmarks of Success video[52] that showcases innovative scheduling and training technologies that Stottler Henke developed for NASA.

Stottler Henke's website also lists more than 100 published academic papers.

SBIR at NASA

Mr. Stottler sees NASA SBIR awards as falling into two categories:

[52]See http://www.stottlerhenke.com/company/nasa_hallmarks.htm.

- SBIR supported by operational groups with clear needs and objectives. These are often successful and usually generate the necessary follow-up funding.
- SBIR sponsored by research-oriented components within NASA, which are often not connected to end users and often may fail to find useful take-up within the agency.

Mr. Stottler observed that SBIR awards are often used by agencies to fill gaps and holes. Although this use has value, it leaves major problems with sustainability. Because SBIR-funded projects are not part of the standard budgeting process at the agency, there is typically minimal or zero follow-on funding even for maintenance. Good projects are therefore sometimes left to die.

Stottler Henke has considerable experience with NASA applications and awards. Mr. Stottler believes that the selection process has a considerable random element, in part because of wide variability in the quality of reviews. However, he believes that NASA applications require a minimum level of quality—some applications identified by the company as lower quality have been funded at DoD but not at NASA.

NASA topics are not provided in searchable database form, according to Mr. Stottler. In recent years, the solicitation has been published in html only; in 2009 it appeared as a MS Word document. His analysis suggests that NASA topics change very little—2009 topics are very similar to 2008 topics. In contrast, DoD topics are almost always new with each solicitation, which has benefits but also drawbacks.

Stottler Henke has experienced significant Phase 1-Phase II gaps with NASA awards, which would have been damaging absent other work. Mr. Stottler observed that Stottler Henke is fortunate to have non-SBIR work to support project staff salaries during the gap period.

Comments on SBIR

Mr. Stottler noted that during the 1990s the main perceived metric for SBIR success at NASA was the acquisition of follow-on Phase III development funding. However, this metric was of limited relevance in areas such as those addressed by Stottler Henke, where the objective of a Phase II award was to deliver an operational product. Phase III funding was rarely required, as the cases of Aurora and AMP described below indicate.

Stottler Henke has also won more than 50 Phase II awards from DoD. Mr. Stottler noted that considerable rhetoric in DoD has focused on dual use of defense technologies in the civilian sector, which in his view is largely a myth: almost all Stottler Henke-developed DoD applications had minimal application in the civil sector. However, he did note that Stottler Henke retains the code library and reuses code as much as possible.

Possible Improvements to SBIR

In Mr. Stottler's view, annual solicitations are no longer sufficient. Technology and requirements move too rapidly, and given the topic-driven nature of the process at NASA, it is entirely possible that promising approaches will have to wait 2 or more years before they can be used for an application. He also observed that the process of adding a topic may be too onerous at NASA; although it may be appropriate to repeat broad topics, that practice becomes a problem when topics are tightly defined and exclude other potentially important technologies.

The quality of reviews would be considerably improved if applicants were encouraged to provide feedback about reviewers, which would be used to retain the best reviewers and replace less capable ones.

Mr. Stottler is not in favor of increasing the size of Phase I and Phase II awards. He believes that high-quality work can be accomplished at existing award levels that a tradeoff of fewer but larger awards would not be positive.

Mr. Stottler strongly approves the DoD pre-solicitation period during which COTRs are available for discussion and would like to see similar "communications windows" opened during the solicitation process at other agencies, particularly NASA.

NASA Successes

Stottler Henke has been highly successful in using NASA SBIR awards to develop tools that the agency has in turn adopted for operational use. These tools have been in use since the early 1990s.

Automated Manifest Planner (AMP)

The Automated Manifest Planner (AMP) "automatically makes scheduling decisions based on knowledge input by expert schedulers."[53] It "automatically schedules long-term space shuttle processing operations and sets launch dates at Kennedy Space Center"[54] and was designed using artificial intelligence (AI) "techniques, allowing expert shuttle schedulers to input their knowledge to create a working automatic scheduling system."[55]

As noted by NASA, "Planning and scheduling NASA space shuttle missions is no small task. The complex, knowledge-intensive process, [commencing] anywhere from 5 to 10 years prior to a launch, requires the expertise of experienced mission planners. [T]he many factors that the long-term

[53]National Aeronautics and Space Administration SBIR website, http://sbir.gsfc.nasa.gov.
[54]Ibid.
[55]Ibid.

plans must reflect include the resources required, constraints, work shift requirements, intervals between launches, and maintenance issues."[56]

NASA Kennedy Space Center (KSC) used AMP "to develop optimal manifest schedules, which support ongoing shuttle program efforts to reduce labor costs."[57] Reported commercial sales totaled "$400,000, exceeding NASA's SBIR investment,"[58] along with private investment at $50,000.

Further, according the NASA SBIR website, "In 1994, the Mission Planning Office was dissolved and the long-term planning component was transferred to United Space Alliance (USA), the primary shuttle contractor at KSC. The AMP system allowed personnel unfamiliar with long-term scheduling to maintain it without years of previously required training. AMP has now been used on a daily basis for [15] years to maintain manifests, perform advanced ["what if"] studies, and produce manifest reports for all NASA field centers."[59]

NASA notes that AMP is also used to schedule the "short- and long-term external tank/solid rocket booster [(ET/SRB)] processing."[60] The ET/SRB scheduling process is "much faster and more accurate [than] the previous manual process. […] An extremely flexible and user-friendly tool, AMP plans orders of magnitude faster than existing tools. One user reported performing over 100 planning studies in a year, a task that would have been impossible without AMP."[61]

As noted on the NASA SBIR website, automated "scheduling is common in vehicle assembly plants, batch processing plants, semiconductor manufacturing, printing and textiles, batch processing, surface and underground mining operations, and maintenance shops, where scheduling the use of different pieces of equipment that work together impacts production rates and costs."[62] Stottler Henke is marketing this software tool and other related products to industries involved with many resources, activities, and constraints, particularly when it is desirable to plan and project changes for many cycles or years ahead.

Aurora Scheduling System[63]

The Aurora project originated from KSC and received a Phase I award from NASA in 1999. This sophisticated scheduling system combines a variety of scheduling techniques, intelligent conflict resolution, and decision support designed to make scheduling faster and easier.

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[56]NASA, Spin-off 2002, http://www.nasatech.com/Spinoff/spinoff2002/ct_5.html. Accessed September 10, 2009.
[57]National Aeronautics and Space Administration SBIR website, http://sbir.gsfc.nasa.gov.
[58]Ibid.
[59]Ibid.
[60]NASA, Spin-off 2002, http://www.nasatech.com/Spinoff/spinoff2002/ct_5.html. Accessed September 10, 2009.
[61]Ibid.
[62]National Aeronautics and Space Administration SBIR website, http://sbir.gsfc.nasa.gov.
[63]This section draws on the documentation prepared for the NASA Success Story published at http://sbir.nasa.gov/SBIR/successes/ss/10-020text.html._Accessed September 10, 2009.

The proof-of-concept prototype supported by the SBIR program was completed in the summer of 2001, and Aurora was deployed at KSC in 2003 after the end of the subsequent Phase II, where Aurora was applied to the specific scheduling needs of the Space Station Processing Facility (SSPF). SSPF scheduling features a variety of unusual features, most notably the importance of spatial relationships among elements being scheduled.

Aurora is used to schedule floor space and other resources at the Space Station Processing Facility (SPFF), where International Space Station components are prepared for space flight.[64] Customized support for this scheduling problem was developed in tandem with the more general Aurora scheduling system, which can be easily adapted to a range of scheduling problems.

Aurora also supports a system that generates short- and long-term schedules for the ground-based activities that prepare space shuttles before each mission and refurbish them after each mission. This system replaced the AMP product used by NASA since 1994.

Aurora applies a combination of AI techniques to produce a system capable of rapidly completing a near-optimal schedule. Integrating sophisticated scheduling mechanisms with domain knowledge and expert conflict-resolution techniques, it also addresses problems unique to KSC, such as the need to schedule floor space and maintain certain spatial relationships among the tasks and components. Aurora then graphically displays resource use, floor space use, and the spatial relationships among different activities. Scheduling experts can interactively modify and update the schedule, and can request detailed information about specific scheduling decisions. This allows them to supply additional information or verify the system's decisions and override them, if necessary, to resolve any conflicts.

Aurora was incorporated into other major systems when further applications of its core technology emerged after its development for use by KSC:

- Aurora will be included by United Space Alliance, LLC in Temporis, an on-board scheduling system to be used by NASA crew members aboard the next generation Crew Exploration Vehicle. Aurora is also used by companies to plan complex, large-scale manufacturing operations.
- Aurora/AMP replaced AMP. Because the shuttle spacecraft and ground-based facilities are very expensive, increasing the number of shuttle launches by just one is worth hundreds of millions of dollars, so finding near-optimal schedules is critical. Stottler Henke claims that

[64]For more details on Aurora's use at NASA, see NASA, *Spin-off* magazine 2006, http://www.sti.nasa.gov/tto/Spinoff2006/ct_2.html. Accessed September 10, 2009.

rapid generation of near-optimal schedules enables NASA to efficiently perform what-if studies to analyze numerous alternate scenarios.

- The Boeing Company adopted Aurora to help optimize factory production of its new flagship Boeing 787 Dreamliner™ commercial airliner by balancing resource capacities with manufacturing requirements and constraints.

TECHNO-SCIENCES, INC.

Interview with
Professor Gilmer Blankenship, CEO June 1995-June 2009, Chairman June 1995-May 2014

Techno-Sciences, Inc. is a high-technology company headquartered in Beltsville, Maryland. Lee Davidson, a professor of electrical engineering at the University of Maryland who specialized in information theory, founded the company in California in 1975. The company was created to provide systems engineering services to the U.S. government and prime contractors in communications, signal processing, and search and rescue. In 1988 Techno-Sciences merged with Systems Engineering, Inc., a company founded by Gil Blankenship and Harry Kwatny.

Until the late 1980s, Techno-Sciences was largely a contract research house that used government contracts, including SBIR awards, as a way to fund investigator-initiated research and as a basis for R&D in the U.S. Search and Rescue Satellite Aided Tracking (SARSAT) program. In the mid-1990s, the company underwent a major shift of emphasis. Professor Davidson retired, and Professor Blankenship[65] became CEO and chairman.

In 1988, the company developed its first significant product—search-and-rescue command center satellite ground stations for international search-and-rescue programs. The new product line formed the basis for a new company. Since then, Techno-Sciences has become a company with a global market, selling ground stations and mission control centers in more than 20 countries, most of which have retained Techno-Sciences for ongoing management and maintenance, often for decades.

In the early 2000s Techno-Sciences rolled out a second major product line, the Trident Integrated Maritime Surveillance System (IMSS). This was sufficiently successful to create a new operating division for the company, called Trident Maritime. The Trident IMSS is now deployed on more than 3,500 km of coastline in Southeast Asia and North Africa—one of the largest such deployments in the world.

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[65]Dr. Blankenship is also Professor and Associate Chairman of the Department of Electrical and Computer Engineering at the University of Maryland, College Park.

As a result of these successful products, Techno-Sciences transitioned from a contract research house to a company primarily concerned with the development, deployment, and support of new products.

In May 2014 Techno-Sciences was acquired by the Orolia Group.

Company Structure

Prior to its acquisition, Techno-Sciences had three divisions:

- SARSAT, which provides ground stations for search and rescue at sea and over land. Techno-Sciences' SARSAT products are now mature systems, backed by an experienced staff with a well-developed process for scoping projects, deploying systems, and following up with effective maintenance and support. In short, the division has a smoothly operating ISO 9000-certified model of what it takes to deploy and support these systems on an international basis. Working with the NASA and the National Oceanic and Atmospheric Administration, the SARSAT division developed the next generation SARSAT ground systems based on MEOSAR satellite technology. Techno-Sciences has sold these important new systems in the United States, Australia, New Zealand, and Algeria. Many additional sales are expected as the COSPAS-SARSAT community changes to this next generation technology.
- Trident, which sells coastal and ship-based surveillance and security systems, is active in Southeast Asia and North Africa. It has installed about 35 coastal stations, several command centers, and multiple shipboard systems. The coastal station network in Indonesia and Malaysia covers more than 3,000 km of coastline along the Strait of Malacca and around the Celebes Sea. Trident has also installed surveillance and security systems on oil platforms in the Middle East. The Trident coastal stations include dual band radars, automatic identification systems (AIS), long-range day and night vision cameras, and command-and-control and communications systems. Trident Maritime Operations Centers feature remote access and control functions and extensive cybersecurity systems. Because most of the stations are installed in extremely remote regions, the Trident division also manufactures and installs grid-free power systems using solar, wind, and generator units.
- Advanced Technology, which undertakes both contract research and supports Techno-Sciences' products and services. The division has worked in software, sensors, control systems, and active materials, including magneto-rheological fluids for semi-active dampers. Supported in large part by the SBIR program, the division has investigated a wide range of areas, some leading to new products for Techno-Sciences (elements of the coastal stations) and two spin-off

companies. The division has strong ties to universities and has funded several million dollars of university-based research and development. Innovital Systems, Inc. acquired the Advanced Technology division in 2013.

Spin-offs

Techno-Sciences has spun off three companies: TRX systems, which focuses on the ability to track personnel in GPS-denied areas, a specific application of Techno-Sciences tracking technologies; Innovital Systems, which designs novel medical devices, including an implantable ventilator for persons with impaired diaphragm function; and E14 Technologies, Pvt. Ltd., a Mumbai based company that produces custom electronics for a wide range of applications.

TRX's personal location and tracking products are based on years of research following the disaster of 9/11 in which hundreds of firefighters were among those lost in the collapse of the World Trade Center buildings. From the outset, TRX's research focused on meeting stringent operational requirements for first responders. The system had to be low cost, highly portable (i.e., laptop-based "command center"), built largely from off-the-shelf components, and able to work in 3-D without building maps.

TRX systems met these requirements. Its products are deployed in several countries with firefighters and the military. TRX is now working on location and mapping services for consumer applications using handheld technology.

Innovital Systems has leveraged Techno-Sciences' defense-based technologies to design novel medical devices, including an implantable ventilator for people with diminished diaphragm function. The Innovital DADS system employs pneumatic muscle technologies to move the diaphragm to support breathing. As a small business, Innovital has made use of the SBIR program to fund its basic research.

Techno-Sciences Products and markets

Satellite-based Search and Rescue (SARSAT)

A wide array of information is available to search-and-rescue (SAR) personnel. Integrating and managing the data from Mission Control Centers (MCCs), for SAR crews on land and in the air, and other sources is crucial to saving lives. The faster SAR resources are mobilized, and the more efficient the response, the greater the potential for saving lives. TSI's SARSAT system automates the coordination of SAR information and resources.

The COSPAS-SARSAT system generates distress alert and location data for SAR operations. Emergency transmitters (distress beacons) are detected by polar orbiting, geosynchronous, and medium earth orbiting satellites, and these signals are relayed to ground facilities, where they are processed for location and identification and ultimately distributed to Rescue Coordination Centers (RCCs), which perform the actual search-and-rescue missions.

SAR personnel require accurate, concise, information that can be accessed quickly and easily. SAR missions may involve high-risk rescuers and costly resources. Therefore accurate, reliable, and timely data are critical. The SARSAT system links information from the international search-and-rescue system (COSPAS-SARSAT) via MCCs that have database, communications, and 3-D graphical information systems (GIS). Data drawn from comprehensive digital maps of the world help rescuers understand the search requirements in the specific locality (e.g., roads, rivers, lakes, population centers, airports, geographic elevations, ocean currents).

Tech-Sciences' RCCs maintain an extensive, automated database that manages all received alert information. New alert information generates alarms, and the map display highlights recently updated locations. Users can easily access data by time (most recent) or for a specific incident. Messages are tracked and archived automatically.

The MCC is a command and communications system based on a client server structure, which gathers data from satellite ground stations (Local User Terminals), aggregates and manages the data through its server and proprietary software, and delivers the data for display and analysis in a graphical interface and 3D GIS. By using a standard client-server architecture based on standard Microsoft/Intel technologies, costs are reduced and reliability enhanced. Proprietary software provides the competitive edge needed by Techno-Sciences.

International sales have always been important to Techno-Sciences, because search-and-rescue systems are sold on a national (or sometimes regional) level. The company's record as a highly trusted supplier of SARSAT systems has allowed it to penetrate other markets including those for maritime safety and security (see below) and the personal location technology developed by TRX Systems.

Techno-Sciences has worked to limit the cost of initial installation with the objective of developing long-term maintenance and upgrade contracts and customer retention. This approach has been successful, with almost all SARSAT and Trident customers purchasing long-term contracts from Techno-Sciences. Some have been customers for more than 20 years.

Trident

The Trident division provides Techno-Sciences' Integrated Maritime Surveillance System. This system is designed for governments and other authorities that need to manage the complex flow of traffic and information around crowded, vital coastal regions. The system " … deploys a tightly integrated network of ship and shore based sensors, communications devices, and computing resources that collect, transmit, analyze and display a broad array of disparate data including automatic information system (AIS), radar, surveillance cameras, global positioning system (GPS), equipment health monitors and radio transmissions of maritime traffic in a wide operating area. Redundant sensors and multiple communications paths make the system robust and functional even in the case of a major component failure."[66]

The system can be sold as an integrated package or in component elements. In 2004, the Indonesian Navy bought the first Techno-Sciences coastal radar system. This was the result of $7.5 million in R&D investments, primarily from the U.S. government and to a considerable degree from the NSF and DoD SBIR programs. Specifically, the core technologies for the Trident system were derived from a single NSF SBIR (Phase 1 and II) award.

The NSF awards allowed Techno-Sciences to develop the technology that would go into a ship-based system. A subsequent SBIR award from U.S. Special Operations Command (SOCOM) supported the adaptation of the system for use by Navy Seal operations to track the precise location and status of Seal boats.

The sole-source advantage conferred by these SBIR awards had a significant effect on the subsequent decision by U.S. Space and Naval Warfare Systems Command (SPAWAR) to deploy the technology in the United States. Overall Techno-Sciences received more than $70 million in contracts to install coastal systems as SBIR Phase III awards, and it has received more than $100 million in contracts in this business area.

Other Advanced Technologies

In the Advanced Technology division, Techno-Sciences worked on a wide array of technology areas including software engineering, operations scheduling (for maintenance operations), sensors and actuators, wireless networks, and many others. One particularly interesting application area involved the use of magneto-rheological (MR) fluids for (semi-) active dampers for vehicles and occupant safety. Using MR dampers for soldier seating, Techno-Sciences and its partners at the University of Maryland demonstrated dramatic improvements in occupant safety when the vehicle was subjected to a dramatic shock such as an improvised explosive device (IED) explosion. Both SBIR and BAA funding supported this research.

In parallel, Techno-Sciences used SBIR funding to develop solutions using flexible hoses and air to provide air-driven mechanical operation of flaps on aircraft wings. The air-driven hoses ("pneumatic muscles") can deliver 300 lbs or more of force, while avoiding the weight penalties of hydraulic systems. SBIR projects, performed jointly with the University of Maryland, were used to support research on pneumatic muscle applications. One project funded by the U.S. Army, as a part of the development of a robot for battlefield rescue of wounded soldiers, led to the development of a powerful robotic arm. The

[66]TSI: the Trident Maritime Integrated Marine Surveillance System, http://www.technosci.com/trident/imss.php, accessed October 30, 2009.

pneumatic muscle-powered arm could easily pick up a 300 lb person (including equipment) using 90 psi of air pressure.

In other applications Bell Helicopter has tested pneumatic muscle-controlled wing flaps in the University of Maryland wind tunnel. If adopted, then this technology would revolutionize helicopter design. However, it has other potentially important applications as well. Wind turbine efficiency could be substantially improved through the adoption of automated flaps; the weight and cost of hydraulic systems have made this impractical thus far.

SBIR and TSI

Prof. Blankenship stated that SBIR awards have played a pivotal role in several different ways at different times in the company's life cycle. Initially, SBIR awards supported investigator-initiated research and the growth of the company and its personnel during its early years.

As the company transitioned toward a product-driven model, the SBIR program funded the research that led to both of the company's core product lines—SARSAT search and rescue and Trident ship-based monitoring. It also supported the creation of two of Techno-Sciences' three spin-off companies: TRX Systems and Innovital Systems.

The Advanced Technologies Group is now part of Innovital Systems, which submits several SBIR applications each year. SBIR projects are now supporting Innovital's push into new technologies and new markets for next generation medical devices.

SBIR and Advanced Staff Training

According to Professor Blankenship, SBIR awards assisted in developing Techno-Sciences' human resources. He observed that SBIR projects provided an ideal training ground for project managers. Techno-Sciences research groups typically hired PhD researchers soon after graduation, at which point they were technically trained but had little understanding of how to manage projects, support clients, or work to fixed schedules.

SBIR projects at Techno-Sciences were treated as standalone projects and were often handed off to staff not yet ready for a major commercial projects. In the course of managing one or two SBIR awards, these staff acquired critical management skills, which were then applied to commercial projects and eventually to the management of entire product lines.

For example, TRX Systems is a spin-off from Techno-Sciences. Its CEO, Dr. Carol Teolis, was hired by Techno-Sciences as a new Ph.D. from the University of Maryland. She was assigned to several SBIR projects before entering senior management as Vice-President of Engineering. Her experience at Techno-Sciences—which included complete management responsibility for a research project for the U.S. Mint, and other key customers—allowed her to develop skills in customer development and support. Her skills translated into several million dollars of research contracts that supported the development of TRX Systems. Two other employees followed a similar path and now lead their own companies (Innovital Systems and E14 Technologies).

SBIR and Skills Acquisition

Professor Blankenship also considers the SBIR program to be a means of acquiring technical skills and know-how that, while not necessarily directly commercialized, may have significant uses downstream on other projects.

For example, Techno-Sciences won an SBIR award to build high-performance gun turrets. As part of the project, Techno-Sciences built a prototype that required a high-performance gimbal. Commercially available gimbals were not suitable, so Techno-Sciences learned to build its own high-performance gimbal. Although DoD did not pick up the gun turret technology for acquisition, the gimbal design knowledge was later applied to coastal surveillance systems, supporting the Trident long-range cameras. Similarly, Techno-Sciences now builds high-performance cameras, which are sold as a part of its integrated systems, and grid-free power systems for installations in remote areas lacking reliable power.

Phase IIB

Techno-Sciences' spinoff company TRX Systems won one of the first Phase IIB awards from NSF. This $500,000 award matched $1 million in investments by strategic partners and sales of the company's products to key customers. This project helped to create what is now TRX Systems main line of business.

SBIR Improvements

Professor Blankenship indicated that the current award size is acceptable, although he is confident that Techno-Sciences would not suffer if the award size was increased and the number of awards reduced. He noted that the gap between Phase I and Phase II awards had been a problem for many smaller companies; however, the introduction of optional tasks to bridge the gap has remedied this problem.

Professor Blankenship was somewhat concerned about what he called Phase I SBIR mills, which win numerous Phase I awards but in general fail to convert them into Phase II awards or to commercialize the research. Techno-Sciences focused heavily on converting Phase I awards, and according to Prof. Blankenship, it typically matched a Phase I award with an additional 50 percent internal funds to ensure that the result was good and that Techno-Sciences had a strong case for a Phase II award. Techno-Sciences' commercialization record for SBIR projects achieved and sustained the maximum rating.

Professor Blankenship also observed that larger small businesses (those with more than 100 employees, for example) had a smaller need for SBIR awards, which should first be focused on very small firms (those with less than 10 employees), and then on smaller and mid-size small firms. The government is often the only investor willing to take a chance on a new company. Indeed, as Techno-Sciences grew, SBIR contracts supplied only about 5 percent of revenue.

Techno-Sciences Transitions

In May 2014 the Orolia Group, a rapidly growing French group, acquired the SARSAT and Trident divisions of Techno-Sciences. This acquisition followed a period of sustained rapid growth for the company. Over the period beginning in 2005, the company grew rapidly both in revenue and number of employees. In June 2009 Jean-Luc Abaziou joined the company as CEO, with the mission of managing growth and increasing the value of the company (Prof. Blankenship continued as Chairman of the Board and Principal Scientist). Mr. Abaziou led Torrent Networks prior to its acquisition by Sony-Erickson. He later worked at Highland Venture Capital. Under his leadership, Techno-Sciences was among the Deloitte Fast 500 Technology companies for 3 years in a row. In 2010 the company was named the High Tech Company of the Year in Maryland. Several companies expressed interest in acquiring Techno-Sciences. The company entered into negotiations with the Orolia Group in 2013, and the deal closed in May 2014. Since the acquisition, the SARSAT division was merged with the McMurdo subsidiary of Orolia. McMurdo is one of the world's leading manufacturers of emergency beacons for the COSPAS-SARSAT program. The merged company is "vertically integrated," offering beacons, ground stations, and rescue planning systems to a global market.

Prof. Blankenship retired from Techno-Sciences in June 2014. He has since started two new companies, one working in sleep health and the other in medical devices. Both have received SBIR funding.

ZONA TECHNOLOGY, INC.

Interview with
Ping-Chih Chen, CEO/CTO, Darius Sarhaddi, CFO, and Jennifer Scherr, Director of Operations
November 8, 2010, September 29, 2015

ZONA Technology, Inc. (ZONA) was founded in 1985, by Mr. Ping-Chih Chen and his now-retired partner, Dr. Danny D. Liu, a faculty member at Arizona State University (ASU). ZONA develops software for the design, analysis, and modeling of aeroelastic systems. Aeroelasticity is the physics of the interactions between the inertial, elastic, and aerodynamic forces that affect an elastic body exposed to a fluid flow. Because aircraft are not rigid, accurate predictions of their performance requires the capability to model aeroelastic effects. Mr. Chen only began full-time work at ZONA in 1996 after a period as a consultant in Taiwan. With the company's first Phase II award in 1999, ZONA started a period of rapid growth and expansion of share in the aeroelastic market.

The SBIR program has played a critical role in the development of the company. SBIR funding from the Air Force and NASA funded the development of the company's first product, ZONA51. This product led to a spin off product called ZAERO, which quickly became a commercial success. The company followed ZAERO with a number of other modules focused on simulating the performance of aerodynamic surfaces and objects, and in particular on modeling unsteady aerodynamic performance.

After these modules had been developed, the Air Force became interested in creating a toolset that would integrate all of these technologies into a unified system. SBIR awards from the Air Force Research Laboratory funded ZONA to integrate its aeroelastic and aeroservoelastic technologies into the ASTROS (Automated STRuctural Optimization System) software which were also included in the commercially available version of ASTROS.

ZONA is currently using SBIR funding to develop technologies that enhance the computational efficiency and accuracy of its modeling of aeroelasticity.

Technologies and Products

The ZONA core product line currently consists of the following five software programs for modeling phenomena related to aeroelasticity. (See Table E-16.) Each product is influenced by multiple SBIR projects that produced a general capability and expertise at ZONA for modeling aeroelasticity phenomena.

TABLE E-16 ZONA Technology, Inc., Product Line

Product	Description
ZAERO	ZONA's core software product enables modeling, design and analysis of advanced aeroelastic and thermoelastc effects.
ZONAIR	ZONAIR is a software package for computing aircraft flight loads including aeroelastic effects.
ZEUS	ZONA's Euler Unsteady Solver (ZEUS) solves various aeroelastic problems using an Euler solver to limit the need for large scale computer resources.
ZMORPH	ZMORPH is used to morph geometrically NASTRAN structural finite element models during multidisciplinary optimization problems.
ASTROS	The Automated Structural Optimization System is a multidisciplinary design/optimization environment that combines finite element techniques with efficient optimization to reduce the time required for aircraft design.

SOURCE: http://www.zonatech.com. Accessed October 11, 2015.

The ZAERO/ASTROS products are the financial backbone of the company, and currently (more than 15 years after their launch) generate around $2.5 million annually in licensing revenues. Licensing revenues continue to grow with ZONA continually adding new capabilities and software enhancements.

ASTROS was originally owned by a company called UAI with whom ZONA had partnered to take its ZONA51 product to market. UAI merged with a larger firm, MSC Software, and following the merger, MSC Software ceased development and support for ASTROS. At the request of the Air Force, ZONA continued support of ASTROS. The ASTROS system is an integrated design package supporting the preliminary design of new aircraft and spacecraft, as well as subsequent design modifications based on the NASTRAN data standard. ASTROS is the primary tool for accessing the ZAERO modeling system.

ZONA continues to have a positive commercial relationship with MSC Software, developer of the NASTRAN code. MSC resells ZONA51 with its NASTRAN code as the Aero II Option.

Knowledge Effects

ZONA Technology owns two patents. Because the company focuses on producing modeling and simulation software for aircraft, it has not patented much technology. Indeed, one of the patents it received for its method for creating a virtual wind tunnel has yet to been licensed. As Mr. Chen remarked, "We're much better at licensing software than patents." The company also supports the publication of scientific and technical peer-reviewed papers as a means of promoting and validating its software.

ZONA has published over 200 journal and conference papers published between 1988 and the present.

SBIR

ZONA has used the SBIR program since the late 1990s to fund development of its technologies. Mr. Chen said that he would not have been able to join ZONA full-time without the funding provided by the first two Phase II awards. Mr. Chen and Ms. Scherr emphasized that the company would not exist without the SBIR program, which provided support at a number of pivotal stages in its development. For ZONA, the SBIR program provides a useful revenue stream and funds the innovation that drives growth for the company, in the form of new technology that can be commercialized.

DoD awarded ZONA its first SBIR Phase I award in 1997. Since then, the company has won an additional 79 SBIR/STTR awards—more than 4 per year—worth in total $22.80 million. (See Table E-17.)

Like almost all SBIR/STTR recipients, most of ZONA's awards come from SBIR. However, a surprising amount of funding (29.1 percent) comes from STTR sources. Most SBIR/STTR recipients average less, typically around 10-12 percent. Ms. Scherr observed and Mr. Chen confirmed that this was probably because of the basic research orientation of ZONA's work.

ZONA has depended on two sources for its SBIR/STTR funding, receiving 45 percent of its funding from NASA and 55 percent from DoD (mostly the Air Force). Also, the company has had good success converting Phase I research into Phase II with slightly more than half of its Phase I projects receiving Phase II funding. (See Table E-18.)

SBIR awards have significantly affected the company's product development. According to Mr. Chen, ZONA developed all six of the software packages comprising the company's product line based on capabilities developed during SBIR funded projects. At present, only 40 percent of ZONA's revenue stream is derived from SBIR. Of the remainder, 5-10 percent derives from other government and private research contracts, and 50-55 percent of revenues are generated by licensing fees from ZONA's product line. In 2010, this amounted to $1.5 million annually; it is now closer to $2.5 million.

Because ZONA now has a steady stream of licensing revenue from its core software products, the company makes a practice of funding its own pre-

TABLE E-17 SBIR/STTR Awards to ZONA Technology, Inc., by Program and Phase

Program/Phase	Number of Awards	Funding
SBIR Phase I	39	3,812,459
SBIR Phase II	20	12,352,746
STTR Phase I	13	1,198,775
STTR Phase II	8	5,438,135
Total	80	22,802,115

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 6, 2015.

TABLE E-18 SBIR/STTR Awards to ZONA Technology, Inc., by Phase and Source

Agency	Number of Phase I Awards	Phase I Funding (Dollars)	Number of Phase II Awards	Phase II Funding (Dollars)	Total Funding By Agency	Agency Funding as Percent of Total	Phase I to Phase II Conversion Rate (Percent)
NASA	28	2,750,918	12	7,428,307	10,179,225	44	43
NSF	2	181,428	0	-	181,428	1	0
DoD	24	2,260,316	16	10,362,574	12,622,890	55	67
Total	52	5,011,234	28	17,790,881	22,802,115	100	54

SOURCE: https://www.sbir.gov/sbirsearch/firm/all. Accessed October 6, 2015.

SBIR preliminary studies in a conscious effort to improve the likelihood that its SBIR applications will be successful. This approach appears to have achieved the desired results, and, according to Mr. Chen, is especially important when the proposed project is highly innovative. For example, ZONA conducted significant proof-of-concept work on the Dry Wind Tunnel before applying for a Phase I SBIR award. This strategy reflects the company's view that competition for SBIR awards is intense and that ZONA needs every advantage to be successful.

SBIR funding allows ZONA to take preliminary ideas and test them to see whether they have traction technically and commercially. There can be a tension between what's asked in the solicitation and what's useful in the market. The ZONA management team believes strongly that it's up to ZONA to make something useful for the market, not just the SBIR sponsor. Oftentimes, the solicitation is asking for basic research. Mr. Chen said, "It's difficult but, it's our responsibility to take the product to market. Of course, the fact is that not every project is commercializable." The senior management team estimated that perhaps only 50 percent of completed SBIR Phase II projects produce something useful.

As an example of the uncertainties involved in the commercialization process, in 2010, ZONA was developing a process for collecting real-time flight time data to predict flutter boundary. Termed a "Dry Wind Tunnel," the company believed that a considerable market existed for such a product. By modeling wind tunnel tests, a project team for a new aircraft might avoid costs on the order of $5 million-10 million.

ZONA developed models of F-18 AAW wings and had a clearly marked deployment and commercialization path for this technology. The company was also in discussion with the Air Force Seek Eagle development program at Eglin Air Force Base as potential beta customers. After demonstration in the military program, ZONA intended to expand into the commercial sector through its ties with companies such as Boeing.

Unfortunately, ZONA was never able to fully validate the Dry Wind Tunnel technology. Although the F-18 models generated some data, it was not sufficient to demonstrate to the commercial sector the validity of the technology. Further SBIR funding was not forthcoming, and ZONA lacked the resources to fully demonstrate the accuracy of the simulated approach. In the end, potential customers lacked proof that the simulation worked. Although ZONA now has patented this technology, it has not been able to license that patent.

As noted above, ZONA uses SBIR funding to enhance incrementally the performance of its software products. For example, the company currently has a Phase II SBIR from NASA which ZONA will use to update the ZONAIR technology. The current ZONAIR approach is accurate but not as efficient as industry would like. Since ZONAIR was designed and launched, solver algorithms and parallel computing algorithms have both improved. ZONA wants to take advantage of these improvements to increase the efficiency of the ZONAIR software package.

ZONA has never received a formal Phase III award from DoD (or any other agency); the company's strategy is to move directly to commercialization after SBIR, although in several cases more than one SBIR award was required to reach the commercialization stage.

STTR

Compared to other SBIR/STTR recipients, ZONA receives an unusually large proportion of STTR funding (29.1 percent). Senior management thought the reason is that aeroelasticity is a topic that still requires a great deal of basic research. Consequently, university partnerships are especially advantageous.

STTR projects allow ZONA engineers to get access to greater expertise in a particular area. It allows for better proposals and better alignment with topics. It enables access to University facilities which can be very important. Duke University has a wind tunnel that STTR funding has enabled ZONA to use.

The challenge of STTR is working with a large bureaucracy. Applications get made by ZONA at the last minute, and university sign-off procedures take time. This is especially a challenge for NASA applications where they website requires a university representative to click on a link to give permission prior to accepting an application. DOD doesn't do this.

The other challenge for STTR is negotiating an IP agreement. Generally, IP is negotiated depending on how much each side contributes or is based on the tasks each side is performing. It's not hard to come to an agreement usually, but it can be time consuming especially if ZONA has not worked with a particular university previously.

ZONA executives thought that in general SBIR seems more flexible because you can work with a broader range of consultants. STTR is only preferred if ZONA happens to need something from a university, either expertise or facilities.

Improving SBIR and STTR

ZONA officials suggested several improvements to SBIR operations during both the 2010 and 2015 interviews. There had been some improvements. Other issues continued unchanged.

- **NASA contracting.** NASA SBIR contracting continues to be handled at the office level. If SBIR recipients have questions, they will be answered by whoever is available at the office. At Air Force, on the other hand, each project is assigned a program officer who is always responsible for questions related to that project.
- **Reporting requirements.** In 2010, ZONA reported that both DoD and NASA sometimes impose unnecessarily stringent reporting requirements.

Since then, NASA has improved, requiring only quarterly reports. Ms. Scherr observed, "This seems like a good balance of doing and telling." DoD, however, has gotten worse. For example, Air Force requires technical and financial reports every month and an end of year report. As Ms. Scherr observed, "On an Air Force grant report writing is all my engineers seem to do."

- **Feedback.** Although it fulfills the reporting requirements, ZONA has struggled to derive value from the reporting process. In particular, the technical monitor on SBIR/STTR awards rarely responds to reports other than to note receipt. Given the amount of money involved and the mission orientation of DoD and NASA, this seems an opportunity missed. ZONA recognizes that the technical monitors are busy and that an SBIR project is additional work for them. However, more consistent feedback would probably result in higher technical success rates for these projects and would ensure that the technology developed meets the sponsors' needs.
- **Integrated Project Management.** NASA has a website that allows a single point of contact for managing SBIR/STTR contracts and deliverables. ZONA can see its timelines, upload reports, and submit invoices. With DOD, everything is fragmented. SBIR recipients have to keep track of the project requirements separately and find the e-mail addresses of the people to whom reports and cost reports are to be sent.
- **Size of awards.** In 2010, ZONA management opposed increasing the award size if fewer awards would result. SBIR awards have grown, and fewer awards are being awarded. By reducing the number of awards, this reduces the likelihood of innovation.
- **Communications.** ZONA still recommends that NASA adopt the DoD "talk time" approach, in which COTRs are available for discussion and feedback for a set time period after release of the solicitation. This feedback could be used to address concerns or even redress errors—at least one NASA solicitation was misidentified with the wrong NASA center, leading ZONA to miscompute travel costs.
- **ITAR and solicitation.** Unlike at DoD, NASA solicitations do not clearly indicate which topics are subject to ITAR regulations. Consequently, companies spend time and resources to gain permissions that they may not require. ZONA is not certain whether this had changed from 2010. They suspect it has not but are uncertain. Either way, they admitted that this problem may not be a pressing issue.
- **University Sign-Off.** The NASA STTR process requires formal sign-off from the university partner, prior to acceptance of the project application by NASA. DoD does not require this. To facilitate the application process, ZONA management thought removal of this requirement would be preferred.

Appendix F

Annex 1 to Chapter 5: Supplemental 2011 Survey Data

This appendix supplements Chapter 5 (Quantitative Outcomes) by providing additional data from the 2011 Survey.

The 2011 Survey asked about other potentially significant aspects of the company. Previous analysis of the SBIR program did not address a potentially important intervening variable: industry sector. It is quite possible that commercialization outcomes may be affected by the average cycle time of product development in different sectors. For example, product cycle time is much shorter in software than in materials or medical devices. Table F-1 shows the distribution of responses by Phase and sector.

This question was designed to provide an approximate map of activities by sector. There is considerable overlap between some categories, and respondents would have substantial leeway to define sectors differently, so these results should be viewed as highly preliminary.

A few key points emerge:

- **Aerospace-orientation.** Seventy-eight percent of respondents indicated that the project was in aerospace.
- **Engineering driven.** More than one-half of respondents indicated that the project was in engineering.
- **Defense**. Twenty-nine percent of respondents indicated that the project was in defense-specific products and services.
- **Other sectors**. Three other sectors each accounted for at least 20 percent of responses:
    - Sensors
    - Materials
    - Scientific instruments and measuring equipment

TABLE F-1 Distribution of Responses by Sector

Industry sector	Percentage of Responses
Aerospace	78
Defense-specific products and services	29
Energy and the environment	18
- Sustainable energy production	5
- Energy storage and distribution	3
- Energy saving	2
- Other energy or environmental products and services	6
Engineering	55
- Engineering services	12
- Scientific instruments and measuring equipment	28
- Robotics	9
- Sensors	26
- Other engineering	5
Information technology	11
- Computers and peripheral equipment	2
- Telecommunications equipment and services	2
- Business and productivity software	1
- Data processing and database software and services	3
- Media products	2
- Other IT	1
Materials (including nanotechnology for materials)	25
Medical Technologies	3
- Pharmaceuticals	0
- Medical devices	7
- Other biotechnology products	3
- Other medical products and services	1
Other (please describe)	6
N = Number of Responses	178

NOTE: Bolded values emphasize major categories. Answers do not sum to 100 percent because more than one response is available.
SOURCE: 2011 Survey, Question 20.

Appendix G

Annex 2 to Chapter 5: Department of Defense Data on NASA SBIR Awards

The Department of Defense (DoD) maintains a database of company outcomes, the Company Commercialization Record (CCR). In principle, awardees are required to report on their previous awards on a regular basis. In practice, many companies file reports only when they are preparing a new application for DoD, because updating the CCR is an application requirement.

There is some overlap between NASA and DoD because some DoD awardees who report to DoD on previous awards are reporting on SBIR awards received from NASA. Thus, some NASA outcomes are reported in the CCR. A total of 117 records were identified for FY2001-2011 (see Figure G-1). These awards comprise a small portion of all NASA awards and may be uncharacteristic of the larger population. It is possible, for example, that companies with connections to at least two agencies are more commercially oriented or better established. Nonetheless, these data may provide some cross check against the 2011 Survey data, and this appendix therefore provides supplemental information to Chapter 5 (Quantitative Outcomes) of this report.

Figure G-2 shows the distribution of total sales by amount. Twenty-two percent of respondents reported zero sales to date, while at the other end of the scale, 16 percent reported sales of at least $1 million, with 2 percent of respondents reporting sales of more than $5 million. The percentage reporting some sales (78 percent) is much higher than the percentage calculated from the 2011 Survey data.

Additional investment in research and development is also regarded as evidence of increased commercialization. Only 12 of the 117 projects did not generate either additional investment or sales, although there are likely to be biases in the subsample of projects found in the CCR. Figure G-3 illustrates the distribution of additional investment, by amount, provided by non-DoD federal agencies, which in this case is very likely to be NASA. Sixty-two

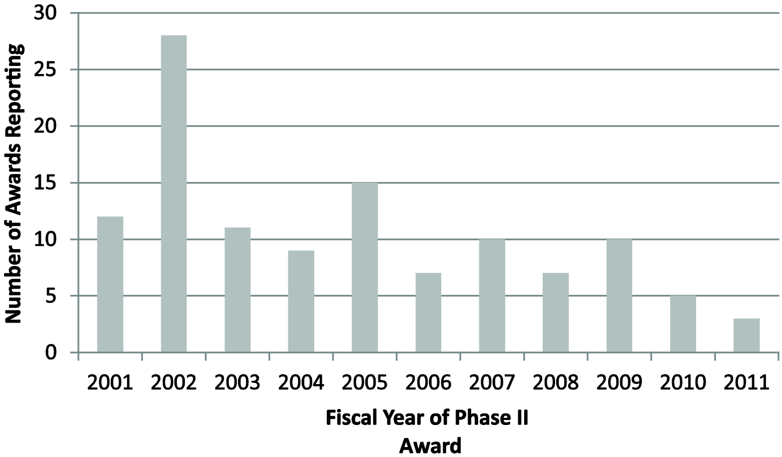

FIGURE G-1 NASA awards reported through Department of Defense Company Commercialization Record (CCR).
SOURCE: Department of Defense Company Commercialization Record database. Provided by the DoD SBIR Program Office, January 28, 2015.

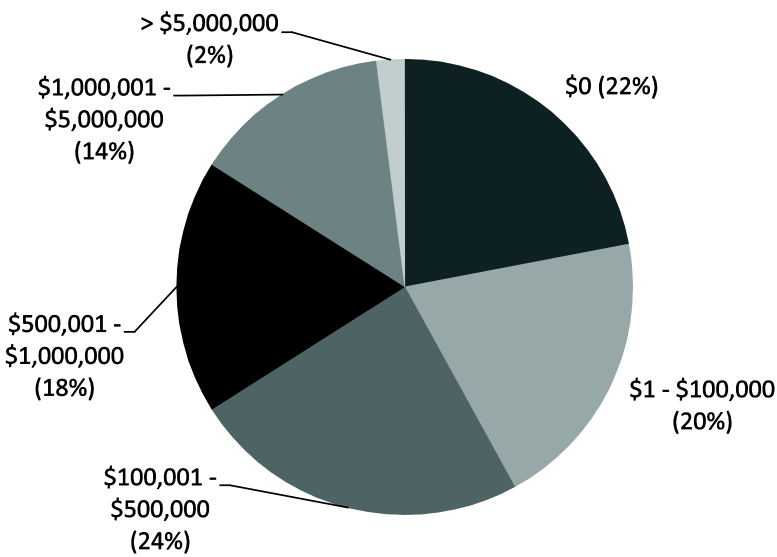

FIGURE G-2 Distribution of sales for NASA projects, by amount, reported through Department of Defense Company Commercialization Record
SOURCE: Department of Defense Company Commercialization Record database.

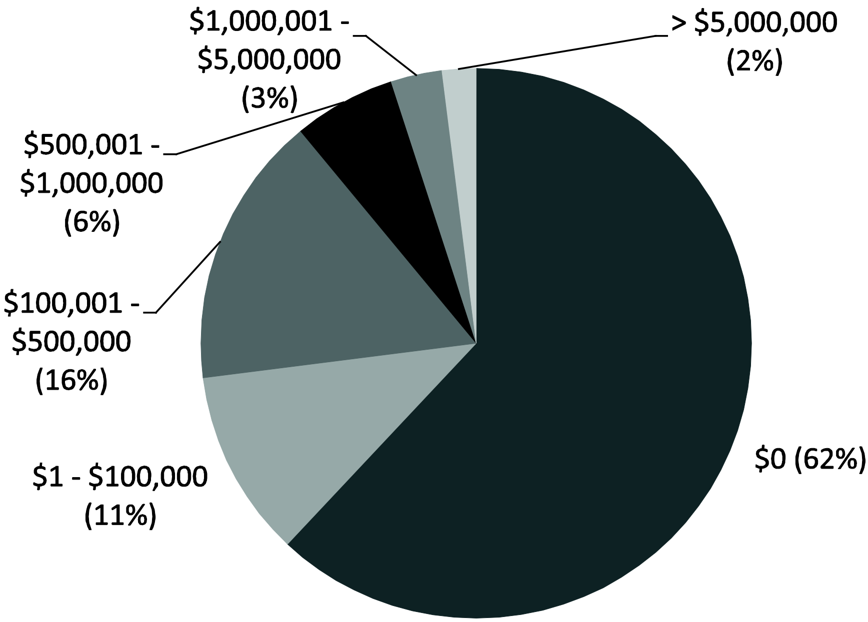

FIGURE G-3 Distribution of additional non-DoD federal investment, by amount, for NASA projects reported through Department of Defense Company Commercialization Record.
SOURCE: Department of Defense Company Commercialization Record database.

percent of respondents reported no additional investment funding, while more than one-third reported some additional investment. Two percent of respondents reported additional investment of more than $5 million, and 3 percent of respondents reported additional investment of $1,000,001 to $5,000,000.

Appendix H

Glossary

ARRA—American Recovery and Reinvestment Act

CCR—Department of Defense Company Commercialization Record

COTR—Contracting Officer Technical Representative

CRP Program—Commercial Readiness Pilot Program

EHB—Electronic Handbook

FAR—Federal Acquisition Regulation

FC—Field Center

FPDS—Federal Procurement Data System

GAO—Government Accountability Office

HBCU—Historically Black Colleges and Universities

JPL—Jet Propulsion Laboratory

JSC—Johnson Space Center

LaRC—Langley Research Center

MD—Mission Directorate

MMOD—Micrometeoroids and Orbital Debris

MOSB—Minority-owned Small Business

MPP—Mentor Protégé Program

MSI—Minority-Serving Institutions

NASBO—NASA Alliance for Small Business Opportunities

NSSC—NASA Shared Services Center

OSBP—Office of Small Business Programs

Phase II-E—Phase II-Enhancement

Phase II-X—Phase II-Expanded

PI—Principal Investigator

SDB—Socially and Economically Disadvantaged Small Businesses

SEDG—Socially and Economically Disadvantaged Groups

SMA—Safety and Mission Assurance

TIM—Technology Infusion Manager

TM—Technical Monitor

TRL—Technology Readiness Level

TWG—Technology Working Group

WOSB—Woman-owned Small Business

Appendix I

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