SBIR at the Department of Defense

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Preface

Today's knowledge economy is driven in large part by the nation's capacity to innovate. One of the defining features of the U.S. economy is a high level of entrepreneurial activity. Entrepreneurs in the United States see opportunities and are willing and able to take on risk to bring new welfare-enhancing, wealth-generating technologies to the market. Yet, 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. 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. The SBIR program was established in 1982 to encourage small businesses to develop new processes and products and to provide quality research in support of the U.S. government's many missions. By involving qualified small businesses in the nation's R&D (research and development) effort, SBIR grants stimulate innovative technologies to help federal agencies meet their specific R&D needs in many areas, including health, the environment, and national defense.

The U.S. Congress tasked the National Research Council 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.[2] Upon completion of the first round of this study, an ad hoc

[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.
[2]See the SBIR Reauthorization Act of 2000 (Public Law 106-554, Appendix I-H.R. 5667, Section 108).

committee prepared a series of reports from 2004 to 2009 on the Small Business Innovation Research Program at the Department of Defense, the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy, and the National Science Foundation (NSF)—the five agencies responsible for 96 percent of the program's operations.[3]

Building on the outcomes from the first round, this second round examines topics of general policy interest that emerged during the first round as well as topics of specific interest to 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 second review of the SBIR program's operations at the Department of Defense.[4]

PROJECT ANTECEDENTS

The current two-phase assessment of the SBIR program follows directly from an earlier analysis of public-private partnerships by the National Research Council's Board on Science, Technology, and Economic Policy (STEP). From 1990 to 2005, the NRC Committee on Government-Industry Partnerships prepared 11 volumes reviewing the drivers of cooperation among industry, universities, and government; operational assessments of current programs; emerging needs at the intersection of biotechnology and information technology; the current experience of foreign government partnerships and opportunities for international cooperation; and the changing roles of government laboratories, universities, and other research organizations in the national innovation system.[5]

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.[6] The report also highlighted the relative paucity of research on the SBIR program.

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[3]For the overview report, see National Research Council, *An Assessment of the SBIR Program*, C. W. Wessner, ed., Washington, DC: The National Academies Press, 2008. See also National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, C. W. Wessner, ed., Washington DC: The National Academies Press, 2009. The committee also prepared reports of the SBIR program at the Department of Energy, NSF, NIH, and NASA.

[4]The formal Statement of Task is presented in Chapter 1 of this report.

[5]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,* op. cit.

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

After release of this initial report, the Department of Defense (DoD) asked the NRC to compare its Fast Track Initiative with 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.[7] The report also 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, the committee expresses its appreciation and recognition for the insights, experiences, and perspectives shared by the conference and meeting participants, as well as by the survey respondents and case study interviewees. The committee also thanks officials from the Department of Defense who provided assistance to this complex study. Special thanks are due to Peter Grunwald of Grunwald Associates LLC for conducting the survey along with the tabulation and initial analysis of quantitative results and to Robin Gaster of Innovation Competitions LLC and to David Dierksheide for assisting the committee in the preparation of this report. We are also grateful to Charles Wessner for directing this study in its early stages.

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' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Eric Adolphe, IPSS Government Solutions, LLC; Richard Bendis, BioHealth Innovation Inc.; Michael Ettenberg, Dole Technologies; David Finifter, The College of William and Mary; Millard Firebaugh, University of Maryland; Heidi Jacobus, Cybernet Systems Corporation; Mahendra Jain, Kentucky Science and Technology Corporation; Gary King, Harvard University;

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

Richard McNamara, RRM&A, LLC; Stephanie Shipp, Virginia Tech; and Todd Watkins, Lehigh University.

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 Irwin Feller, Pennsylvania State University and Edwin Przybylowicz, Eastman Kodak Company (retired). Appointed by the National Academies, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Jacques S. Gansler Sujai J. Shivakumar

Contents

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 a National Research Council (NRC) study of the SBIR program, Congress reauthorized the program in December 2011 for a further 6 years. In addition, Congress called for further studies by the NRC. In turn, the Department of Defense (DoD) Office of Small Business requested the NRC to provide a subsequent round of analysis, focused on operational questions with a view to identifying further improvements in the program.

This study therefore seeks to understand how the DoD SBIR program could work better in addressing the congressional objectives for the SBIR program to stimulate technological innovation, use small businesses to meet federal R&D needs, foster and encourage the participation of socially and economically disadvantaged small businesses, and increase the private sector commercialization of innovations derived from federal R&D. Drawing on the methodology developed in its previous study, an ad hoc NRC committee issued a revised survey of SBIR companies, revisited some case studies and developed new ones, and interviewed agency managers and other stakeholders to provide a second snapshot of the program's progress toward achieving its legislative goals.

It is important to note at the outset that this volume—and 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 our scope. Our work is focused on assessing the extent to which the SBIR program at DoD has met the Congressional objectives set for the program, to determine in particular whether recent initiatives have improved program outcomes, and to provide recommendations for improving the program further.

KEY FINDINGS

The Committee's findings are based on their collective judgment, informed by survey results, case studies of selected firms, discussions with agency managers, and other information complied for this study. Based on this research, the Committee finds that the DoD SBIR program is meeting three of its four legislative and mission-related goals. DoD has failed to meet the important congressional objective of increasing involvement of woman- and minority-owned small businesses in developing and commercializing new technologies through the SBIR program. Key findings with regard to the SBIR program's legislative goals are highlighted and cross referenced below. Chapter 7 lists the committee findings in full.

SBIR projects at DoD commercialize at a substantial rate. (Finding I-A) With regard to commercialization, projects funded by the SBIR program are reaching the market at, what is in the Committee's judgment, an appropriate rate, and are also attracting substantial amounts of follow-on investment, which in many cases is a necessary next step toward commercialization.

- The percentage of Phase II projects reporting sales continues to be greater than 45 percent, based on responses to the NRC Survey.
- Data from the DoD commercialization database suggest that over time about 70 percent of Phase II projects at DoD reach the market.

SBIR projects at DoD are in broad alignment with the agency's mission needs. (Finding II-A)

- There is substantial evidence that outputs from the program are taken up by federal agencies and in particular by DoD and by its primes.

Current participation of women and other under-represented groups in the SBIR program is low and not increasing. (Finding III-A)

- During the study period, approximately 15 percent of awards went to woman-owned small businesses (WOSB) and 7 percent to minority-owned small businesses (MOSB).
- The NRC survey indicated that black- and Hispanic-owned small businesses are themselves a very small share of MOSB overall. Black-owned small businesses accounted for approximately 0.5 percent of all respondents; Hispanic-owned firms, about 1 percent.

- DoD has not made sustained efforts to "foster and encourage" the participation of woman- and minority-owned small businesses.

The SBIR program at DoD supports the development and adoption of technological innovations. (Finding IV-A, B)

- Selection of topics and individual projects for funding maintains a strong focus on developing innovative technologies.
- Data from the survey for linkages with universities, including use of faculty as Principal Investigators (PIs), use of graduate students as researchers, licensing of technology from universities, and use of a university as a subcontractor, all increased from the 2005 survey, suggesting growing university linkages with the DoD SBIR program.

KEY RECOMMENDATIONS

The committee's key recommendations by thematic area are highlighted and cross-referenced below.

Encouraging Commercialization

- **Encourage Prime Contractors:** DoD should consider experimenting with different kinds of incentives to encourage primes to work more effectively—and more often—with SBIR firms to commercialize new technologies. (Recommendations I-A, I-B)
- **Brief PEOs:** DoD should use new administrative funding in part to develop better briefing materials for PEOs and PCOs. DoD should consider developing a briefing program for all PEOs and PCOs, and should in particular focus for new PEOs and PCOs. (Recommendation I-A)
- **Financial Incentives:** DoD should encourage its components to experiment with financial incentives for the adoption of SBIR technologies. Even where financial incentives are not available, DoD should consider encouraging components to add explicit targets to prime contracts, in the same way that targets for the participation of small businesses more generally have been added to some contracts. (Recommendation I-C)

Addressing Under-Represented Populations

- **No Quotas:** DoD should *not* develop quotas for the inclusion of selected populations into the SBIR program. Such an approach is not necessary to meet Congressional intent and is likely to reduce program effectiveness. (Recommendation II-A)

- **Outreach and Education:** DoD should develop an outreach and education program focused on expanding participation of under-represented populations. (Recommendation II-C)
- **Tracking and Metrics:** The DoD Office of Small Business (OSB) should improve tracking and metrics against which to benchmark the activities of components in relation to this Congressional objective. (Recommendation II-C)

Improving Tracking, Data Collection, and Adoption of Best Practices

- **Alignment:** DoD should address the need for better alignment of data collection, agreed metrics, and utilization of effective evaluation and assessment tools to guide program management. (Recommendation III-A)
- **Annual Report:** DoD should provide a single, more comprehensive annual report that could —after appropriate consultations—be used to satisfy the reporting requirements of numerous Congressional sponsors. (Recommendation III-A)
- **Data Accuracy:** DoD should improve the accuracy of data recorded in the Federal Procurement Data System (FPDS). (Recommendation III-B)

Streamlining Program Management and Agency Mission Objectives

- **Streamline Guidance:** DoD should revise guidance at the Small Business Administration (SBA), DoD, or component levels that impose unnecessary rigidity on program operations. (Recommendation IV-A)
- **Maintain TPOC Continuity:** DoD should identify ways to ensure that the knowledge of and enthusiasm of sponsoring Technical Points of Contact (TPOC) is not lost to the project. DoD should consider ways to support ongoing engagement by TPOCs in projects after they have formally handed them on at the end of a rotation. (Recommendation IV-B)
- **Protect Data Rights:** DoD should work with SBA to explore mechanisms that more effectively protect SBIR data rights. (Recommendation IV-C)
- **Disseminating Best Practices:** DoD should develop a process for tracking experimentation within the SBIR program. Furthermore, DoD needs to focus attention on the development of a comprehensive toolset of mechanisms for transferring both formal and informal knowledge about best practices. (Recommendation IV-D)

Improving Contracts and Audits

- **Improve Audits:** DoD should explore the development of less onerous and more effective auditing procedures for small businesses that can be completed in a timelier manner. (Recommendation V-A)
- **Improve Contracting Practices:** DoD should provide opportunities for small business concerns (SBC) to raise concerns about contracting practices at the component level. (Recommendation V-B)

1

Introduction

Small businesses continue to be a major driver of innovation and economic growth,[1] despite 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,

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[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 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 this is often a prototype at the end of Phase II). Contracts are also governed by Federal contracting regulations which are considerably more onerous from the small business perspective. Historically, all DoD and NASA awards have been contracts; all NSF and most NIH awards have been grants, and DoE has used both vehicles.

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

Currently, the program provides funding in 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 2011 reauthorization).[4]
- Phase III reflects commercialization without providing access to any additional SBIR funding, although funding from other federal government accounts is permitted.

Congress mandated four goals for the program: “(1) to stimulate technological innovation; (2) to use small business to meet federal research and development needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and (4) to increase private sector commercialization derived from federal research and development.”

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.

SBIR awards are highly competitive. In recent years, across all Department of Defense (DoD) components, about 13 percent of Phase I applications resulted in an award.[5] Phase II could (before the 2011 reauthorization) be awarded only to projects that had successfully completed Phase I (and at DoD, again before 2011, companies had to be invited to apply for a Phase II award). Across all components, less than 50 percent of Phase II applications were successful. Overall, fewer than 6 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 by fiscal year (FY) 2010, the 11 federal agencies administering the SBIR program were disbursing $2.24 billion dollars a year.[6] Five agencies administer greater than 96 percent of SBIR/Small Business Technology Transfer (STTR) funds: DoD, Department of Health and Human Services (HHS; particularly the National

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[4]All resource and time constraints imposed by the program are somewhat flexible and are addressed by different agencies in different ways. For example, the National Institutes of Health (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]DoD data provided to the National Research Council.

[6]Small Business Association (SBA) SBIR/STTR annual report, <*http://www.sbir.gov/*>, accessed November 1, 2013.

Institutes of Health [NIH]), Department of Energy (DoE), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF) (see Figure 1-1).

In December 2011, Congress reauthorized the program for a further 6 years,[7] with a number of important modifications. Many of these modifications—for example, changes in standard award size—were based on recommendations made in a 2008 National Research Council (NRC) report on the SBIR program, a study mandated as part of the program's 2000 reauthorization.[8] The 2011 reauthorization also called for further studies by the NRC. [9]

In a follow-up to the NRC's first-round assessment, described in more detail below and which resulted in eleven reports[10] including the 2008 report cited above, the DoD Office of Small Business (OSB) requested the NRC to provide a subsequent round of assessment, focused on operational questions with a view to identifying further improvements to the program.

This introduction provides a context for analysis of the program developments and transitions described in the remainder of the report. The first section provides an overview of the program's history 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

[7]Section 5137 of PL 112-81.

[8]National Research Council, *An Assessment of the SBIR Program*, Charles W. Wessner, ed., 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, Public Law 106-554, Appendix I-H.R. 5667, Section 108.

[9]The National Defense Reauthorization Act for Fiscal Year 2012, Public Law 112-81, Section 5137.

[10]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*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2004; National Research Council, *SBIR and the Phase III Challenge of Commercialization: Report of a Symposium*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; National Research Council, *Venture Funding and the NIH SBIR Program*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; and National Research Council, *Revisiting the Department of Defense SBIR Fast Track Initiative*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

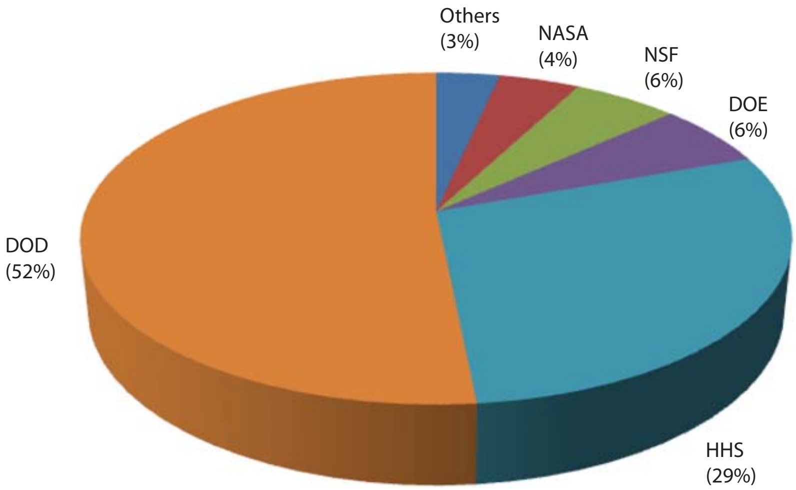

FIGURE 1-1 SBIR/STTR funding, FY2010.
SOURCE: <*http://www.sbir.gov*>, accessed November 1, 2013.

and limitations, in particular the challenges faced by entrepreneurs using (and seeking to use) the program and by agency officials running the program; and a summary of the technical challenges facing the NRC assessment and the committee's solutions to those challenges.

PROGRAM HISTORY AND STRUCTURE[11]

During the 1980s, the perceived challenge of Japanese industrial growth in sectors traditionally dominated by U.S. firms—autos, steel, and semiconductors—led to serious concerns about U.S. competitiveness.[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 this research to the development of innovative products and technologies

[11]Parts of this section are based on the NRC's previous report on the DoD SBIR program, *An Assessment of the SBIR Program at the Department of Defense*, 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 National Research Council, *U.S. Industry in 2000: Studies in Competitive Performance*, D.C. Mowery, ed., 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.

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 offered new 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 is, that federal R&D funding should provide more support for innovative small businesses (which was 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 the National Science Foundation (NSF). In 1976, Mr. Tibbetts advocated for shifting some NSF funding to innovative technology-based small businesses. NSF adopted this initiative first, 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.

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. Program funding totaled $45 million in the program's first year of operation (1983). Over the next 6 years, the set-aside grew to 1.25 percent.[17]

The SBIR Reauthorizations of 1992 and 2000

The SBIR program approached reauthorization in 1992 amidst continued worries about the U.S. economy's capacity to commercialize inventions. Finding that "U.S. technological performance is challenged less in the creation of new technologies than in their commercialization and adoption," the NRC recommended an increase in SBIR funding as a means to improve the economy's ability to adopt and commercialize new technologies.[18]

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[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*>.

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

BOX 1-1

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.

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."

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 assessment of the program's broader impacts, including those on employment, health, national security, and national competitiveness.[20]

[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*, C.W. Wessner, ed., Washington, DC: National Academy Press, 2000, pp. 211-250.

[20]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

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, particularly in biotechnology where proponents argued that the standard path to commercial success includes venture funding at some point.[21] Other issues were also difficult to resolve, but the conflict over participation of venture-backed companies dominated the process[22] following an administrative decision to exclude these firms more systematically.[23]

After a much extended discussion, passage of the National Defense Act of December 2011 reauthorized the SBIR and STTR programs through FY2017. 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.

The eventual compromise on the venture funding issue allowed (but did not require) agencies to set aside 25 percent of SBIR funding (at NIH, DoE, and NSF) or 15 percent (at the other awarding agencies) for participation by firms benefitting from private, venture capital investment. It is too early in the implementation process to gauge the impact of this change.

Several changes to the program made through reauthorization reflected recommendations by the NRC in prior reports.[24] These included the following:

- Increased award size limits
- Expanded program size
- Enhanced agency flexibility—for example to utilize Phase I awards from other agencies 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
- Substantial emphasis on developing a more data-driven culture, which has led to several significant reforms, including the following:

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*>.

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

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

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

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

- adding numerous areas of expanded reporting
- extending the NRC's evaluation
- adding further evaluation from other expert bodies, such as the Comptroller General
- tasking the SBA with creating a unified data platform

- 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 the Commercialization Pilot Program)
- Options for agencies to add flexibility by developing other pilot programs—for example, to skip Phase I or for NIH to support a new Phase 0 pilot program

The reauthorization also made changes that were not recommended in previous NRC reports. These included the following:

- Expansion of the STTR program;
- Limitations on agency flexibility—particularly in the provision of larger awards; and
- Introduction of commercialization benchmarks for companies, which must be met if companies are to remain in the program. these benchmarks are to 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 NRC and 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 Small Business Administration, they have focused on specific aspects or components of the program.[25] Prior to the first round of the NRC assessment, there had been few internal assessments of

[25]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 surveys Phase II awards from 1983 to 1993 among non-DoD agencies.

agency programs. At DoD, assessment work now includes a RAND corporation study in 2004.[26] The academic literature on SBIR is also limited.[27] Writing in the 1990s, Joshua Lerner of the Harvard Business School positively assessed the program, finding "that SBIR awardees grew significantly faster than a matched set of firms over a ten-year period."[28] To help fill this assessment gap, and to learn about a large, relatively under-evaluated program, the National Academies' Committee for Government-Industry Partnerships for the Development of New Technologies prepared the first comprehensive discussion of the SBIR program's history and rationale, reviewed existing research, and identified areas for further research and program improvements.[29] It reported that:

- The SBIR program enjoyed strong support of parts of the federal government, as well as of the country at large.
- The size and significance of the SBIR program underscored the need for more research on its effectiveness.
- The primary emphasis on commercialization within the SBIR program required further clarification.
- Evaluation methodologies required additional work.[30]

In a later, more comprehensive review, the committee found that the SBIR program contributed to mission goals by funding valuable innovative projects. It also concluded that a significant number of these projects would not have been undertaken absent SBIR funding and that Fast Track encouraged the commercialization of new technologies and the entry of new firms into the program.[31]

The committee also found that the SBIR program affected both the development and utilization of human capital and the diffusion of technological knowledge. Case studies showed that the knowledge and human capital generated by the SBIR program have positive economic value, which

[26]B. Held, et al. *Evaluation and Recommendations for Improvement of the Department of Defense Small Business Innovation Research (SBIR) Program*. RAND National Defense Research Institute, Santa Monica, CA, 2006.

[27]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.

[28]See J. Lerner, "The Government as Venture Capitalist: The Long-Run Effects of the SBIR Program," op. cit.

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

[30]National Research Council, *An Assessment of the DoD SBIR Fast Track Initiative*, C.W. Wessner, ed., Washington, DC: National Academy Press, 2000. See Chapter III: Recommendations and Findings, p. 32.

[31]Ibid, p. 33.

spills over into other firms through the movement of people and ideas. Furthermore, by acting as a "certifier" of promising new technologies, SBIR awards encourage further private-sector investment in an award-winning firm's technology.[32]

THE NRC ROUND ONE STUDY OF SBIR

Drawing on these NRC findings and recommendations, the 2000 SBIR reauthorization mandated that the National Research Council complete a comprehensive assessment of the SBIR program. This assessment was conducted in three steps. During the first step, the Committee developed a research methodology,[33] which was approved by an independent National Academies panel of experts. The committee 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.[34]

The research methodology was implemented during the second step. The Committee deployed multiple survey instruments, 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 this report 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 entitled *An Assessment of the SBIR Program*.[35] 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 1-2.)

THE CURRENT, SECOND-ROUND STUDY: CHALLENGES AND OPPORTUNITIES

The first set of NRC reports on the SBIR program established that, overall, the program is "sound in concept and effective in practice."[36] Further, in

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[32]Ibid, p. 33.
[33]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.
[34]Adapted from National Research Council, *SBIR: Program Diversity and Assessment Challenges*, op. cit.
[35]National Research Council, *An Assessment of the SBIR Program*, Charles W. Wessner, ed., Washington, DC: National Academy Press, 2008.
[36]Ibid, p. 54.

its review of the DoD SBIR program, the NRC concluded that "[t]he SBIR program at the Department of Defense is meeting the legislative and mission-related objectives of the program."[37] The current study now seeks to understand how the DoD SBIR program could work *better*.

Along with the current volume, a number of NRC workshops and other publications will fully address this statement of task. The committee convened workshops on the participation of women and minorities in SBIR/STTR (February 2013) and on the evolving role of university participation in the program (February 2014). As a part of the broader task before the committee, future workshops will focus on the role of state programs to encourage participation in SBIR and on agency commercialization programs.

The current volume is focused on updating the committee's 2009 assessment of the DoD SBIR program, by updating data, providing new descriptions of recent program and developments, providing fresh company case studies. This volume, in particular, focuses on the efforts made at DoD in recent years to improve the SBIR program. Guided by this Statement of Task, the committee has sought answers to questions such as the following:

- Are there initiatives and programs within DoD 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?
- Can links with universities be improved?
- Why do some firms simply drop out of the program?
- 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?

[37]National Research Council, *An Assessment of the Small Business Innovation Research Program at the Department of Defense*, p.23, Charles W. Wessner, ed., Washington, DC: National Academy Press, 2007.

BOX 1-2

The National Research Council's 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 SBIR assessment reviewed the SBIR programs at the Department of Defense, National Institutes of Health, NASA, the Department of Energy, and the National Science Foundation. In addition to the release of reports focused on the SBIR program at each of these agencies and a program methodology report that guided the NRC committee's review, the study resulted in a summary of a symposium focused on the diversity of the program and challenge of its assessment, a summary of a symposium focused on the challenges in commercializing SBIR-funded technologies, and two additional reports on special topics in addition to the committee's summary report, *An Assessment of the SBIR Program*. In all, eleven study reports[a] were published:

- *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 Defense* (2009)
- *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 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*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2004; National Research Council, *SBIR and the Phase III Challenge of Commercialization: Report of a Symposium*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2007; National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Charles W. Wessner, ed., Washington, DC: The

National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2008; National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; National Research Council, *Venture Funding and the NIH SBIR Program*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009; and National Research Council, *Revisiting the Department of Defense SBIR Fast Track Initiative*, Charles W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

Study Methodology

It is always useful when assessing government programs to identify comparable programs for appropriate benchmarking. However, comparable programs do not really exist in the United States, and those in other countries operate in such different ways that their relevance is limited. The SBIR/STTR programs are relatively unique in terms of scale and mission focus. Appendix A of this report provides a detailed review of the methods used for this assessment.

Assessing the SBIR program at DoD is challenging for other reasons as well. "The SBIR program" is in fact a multiplicity of agency-specific programs, some of which—especially at DoD—are managed very differently by different components even within the same department. Navy, Air Force, and Army and in some cases smaller components as well have different operational structures, metrics, and support systems, as do some of the other DoD components. In this report the committee is careful to distinguish between aspects of the program that are component specific and those that can be discussed more widely.

Focus on Legislative Objectives

It is important to note at the outset that this volume—and 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 our scope. Our work is focused on assessing the extent to which the SBIR program at DoD has met the Congressional objectives set for the program, to determine in particular whether recent initiatives have improved program outcomes, and to provide recommendations for improving the program further.[38]

[38]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,* op. cit.

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 the 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 partial fulfillment of this Statement of Task, this volume presents the committee's second review of the operation of the SBIR program at the Department of Defense.

[a]The Phase I study refers to the NRC Round One assessments discussed above.

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.[39] "Rather, the NRC Committee conducting 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." 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."[40]

Defining Commercialization

Commercialization offers practical and definitional challenges. As described in Chapter 3, several different definitions of commercialization can be used to discuss the SBIR program. The committee concluded that it is important to use more than one simple definition. For example, a simple measure of the 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 licensing to patenting to acquisition. Even during new product rollout, companies often do not generate immediate profits. In this report the committee uses multiple metrics to address the question of commercialization (see Chapter 3).

Quantitative Assessment Methods

More practically, 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 NRC workshop and published in a 2004 report.[41] Also prepared was a peer-reviewed report on study methodology, which provided the baseline for the initial study and for follow-on studies—such as this one.[42]

[39]National Defense Authorization Act of 2012 (NDAA) HR.1540, Title LI.
[40]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, op. cit.
[41]NRC, The Small Business Innovation Research Program: Program Diversity and Assessment Challenges, National Academies Press, Washington DC, 2004.
[42]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, op. cit.

Survey Development

For the current study, a new survey of SBIR recipients was developed and deployed. The survey[43] was based closely on previous surveys, particularly one deployed by the NRC in 2005, but nonetheless included significant improvements. The survey delved more deeply into the demographics of the program. It addressed in detail the role of agency liaisons who manage the contract operationally and hence link individual projects at companies to DoD. And it provided unique opportunities to collect qualitative views on the program and recommendations for improvement from recipients. The survey generated more than 1,000 responses from DoD award recipients and provided an important pillar to 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. The Committee fully recognizes that there are significant limitations on the conclusions that can be drawn from this assessment, and this recognition is reflected in their findings and recommendations (Chapter 7). However, the Committee also concludes that drawing on quantitative analysis is a crucial component of the overall study, given the need to identify and assess outcomes that are to be found only at the level of individual projects and participating companies.

A Complement of Approaches

Partly because of these limitations, the 2004 methodology report stressed the importance of utilizing a complement of approaches, which has been adopted here. Although quantitative assessment represents the bedrock of the committee's research and provides insights and evidence that could not be generated through any other modality, it is, in and of itself, not sufficient to address the multiple questions posed in this analysis. Consequently, the committee undertook a series of additional activities:

- **Case studies**. The committee conducted in-depth case studies of 20 DoD SBIR recipients. These companies were geographically and demographically diverse, funded by several different components at DoD, and at different stages of the company lifecycle. Lessons from the case studies are described in Chapter 5, and the cases themselves are included as Appendix F.
- **Workshops.** The committee conducted workshops, including workshops to discuss the participation of women and minorities in

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

SBIR and the role of universities in SBIR,[44] to allow stakeholders, agency staff, and academic experts to provide insights into program operations, as well as to identify issues that need to be addressed.

- **Analysis of agency data**. As appropriate, the committee analyzed and included data from DoD or DoD components that cover various aspects of SBIR activities.
- **Open-ended responses from SBIR recipients.** For the first time, the committee collected textual responses in the survey. More than 700 recipients provided narrative comments. These comments are addressed in chapter 5.
- **Agency consultations**. The committee engaged in discussions with agency staff at several of the components about the operation of their program and the challenges they face.
- **Literature review.** Since the start of NRC research in this area, a number of papers have been published addressing various aspects of the SBIR program. In addition, other organizations—such as GAO—have reviewed specific parts of the SBIR program. The committee incorporated references to their work, where useful, into its analysis.

Data Sources and Limitations

Multiple research modalities are especially important because limitations still exist in the data collected for the SBIR program. That said, the DoD SBIR program has been a leader in collecting outcomes data from firms through a pioneering initiative called the Company Commercialization Record (CCR). These data provide important insights. Nonetheless, there are real gaps, especially in relation to the take-up of SBIR-funded technologies by prime contractors ("primes"). The primes account for about one-third to one-half of acquisition spending at DoD, depending on the component and Program Executive Office (PEO). Tracking the primes' use of SBIR technologies is therefore an important element in understanding program impact.

The Federal Procurement Data System (FPDS) provides useful data, but because it relies on individual contract officers to enter the data, not all SBIR technologies are tracked correctly or consistently. In addition, the downstream reach of FPDS is very limited: the system may record the first Phase III contract after a Phase II (i.e., the first commercial contract from the

[44] 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.

technology), but it may not fully track subsequent commercial contracts—some of which are likely to be much larger over time.

Cooperation with DoD Components

The Committee in general received substantial cooperation from DoD and the components. Numerous discussions took place between agency staff and the NRC research team, and DoD provided a considerable amount of data, papers, and presentations. DoD SBIR managers also participated extensively in various SBIR workshops at the Academy. Unfortunately, the Army SBIR office declined to participate in any of these activities, despite repeated invitations.

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

The Committee's analysis and conclusions are organized as follows. Chapter 2 reviews DoD data concerning applications and awards to the program, drawing out differences by component, demographic, geography, industry sector, and previous experience with the program. Chapter 3 describes the study methodology and provides a quantitative assessment of the program, drawing on the NRC survey but also on other sources of quantitative data. Chapter 4 describes and analyzes in some detail the wide range of agency and component initiatives that have been developed and implemented over the past 8 to 10 years, largely aimed at improving program outcomes. Chapter 5 draws on company case studies and on the textual responses from survey respondents to provide a qualitative picture of program operations, issues, and possible solutions. Chapter 6 provides a review of program operations, examining the role of agency liaison offices in some detail, issues related to auditing and contracts, and other issues related to program management, as well as efforts to address the Congressional mandate to foster the participation of women and minorities. Chapter 7 provides the findings and recommendations from the study.

The report's appendices provide additional information. Appendix A sets out 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 lists universities involved in the DoD SBIR awards. Appendix D provides a list of acronyms used. Appendix E reproduces the 2011 survey instrument. Appendix F presents the case study of selected DoD SBIR firms. Appendix G describes the committee's attempts to find a suitable comparison group for the survey data, and, finally, Appendix H provides a list of references.

2

SBIR Awards at the Department of Defense

This chapter addresses the number and distribution of SBIR (Small Business Innovation Research) awards made by the Department of Defense (DoD). It reviews Phase I and Phase II awards separately, and discusses each in terms of the distribution of awards by component, by state, and by company as well as describes the participation of women and minorities.

TIMEFRAME

To focus attention on the most recent data, the timeframe for analysis is the 10 years from fiscal year (FY) 2002 to FY2011 inclusive. This timeframe was selected because DoD reports two financial years for each award—the year in which the award was made and the year in which it was reported, which may be one or more years after the date of award. DoD's published data are based on the financial year reported; therefore, to retain comparability, the committee utilized the financial year reported to determine the date of an award. However, because awards made in FY2012 and FY2013 may not yet appear in the financial year reported data, it seemed prudent to exclude partial data from those years. At the beginning of the timeframe, information about awards made before FY2002 has only limited value to policy assessment, because award procedures have changed substantially since that time (see Chapters 3 and 6).

DATA SOURCES

The analyses in this chapter are based on data provided directly by DoD. These data are not complete, and the quality of the data is, in some cases, uneven, especially as related to women and minority ownership of companies. In several cases, companies are recorded as woman- or minority-owned for one award but not for another, and considerable effort and multiple iterations were required to acquire usable data.[1] Although the quality of the data imposes limits to the committee's analysis, these data are the only available primary source of data about SBIR awards at DoD. We have interpreted this data, accordingly, with the necessary caution.

PHASE I SBIR AWARDS

Number of Phase I SBIR Awards

The numbers of Phase I SBIR awards made by DoD are presented in Figure 2-1. Although declining slightly, award levels have remained largely constant at around 2,000 awards annually. The steady level of awards is also reflected in Phase II funding, which is summarized in Figure 2-2. DoD spent an average of $195 million per year on Phase I awards during the study period.

Phase I SBIR Awards by Component

The generally flat overall numbers do not reflect changes within the program, because different components changed their SBIR profile over time. Table 2-1 summarizes the number of Phase I awards by component over the study period.

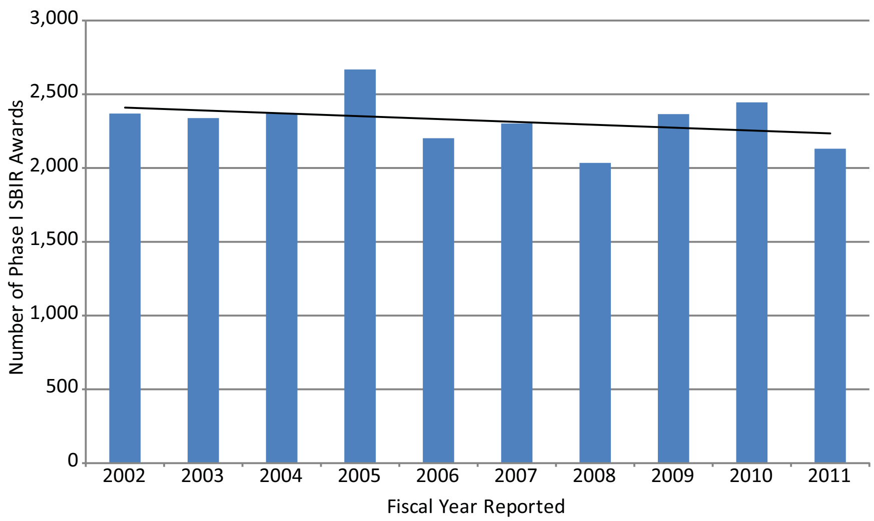

FIGURE 2-1 Phase I SBIR awards at DoD, FY2002-2011.
SOURCE: DoD awards database.

[1]Previous NRC reports have recommended that DoD improve the quality of its data collection. See National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, C. W. Wessner, ed., Washington, DC: The National Academies Press, 2009.

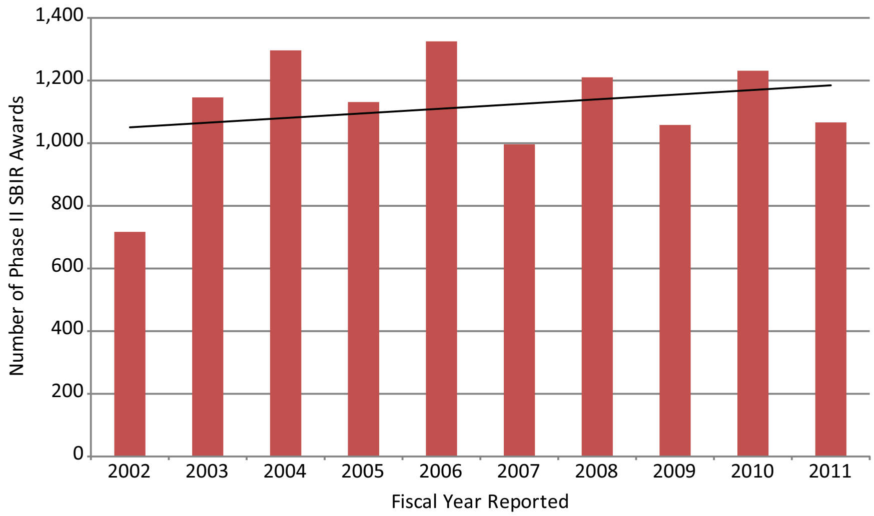

FIGURE 2-2 Phase II SBIR awards at DoD, FY2002-2011.
SOURCE: DoD awards database.

TABLE 2-1 Phase I SBIR Awards by Component, FY2002-2011

	Fiscal Year Reported										
Component	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
AF	427	449	527	608	577	517	485	602	501	480	5,173
ARMY	282	352	356	705	352	312	305	334	434	301	3,733
CBD	34	25	27	21	17	19	14	31	21	16	225
DARPA	120	90	155	74	25	108	108	288	107	68	1,143
DHP	0	0	0	0	0	0	0	0	0	49	49
DLA	0	0	0	0	0	11	0	9	6	7	33
DMEA	0	0	0	0	0	0	5	6	4	0	15
DTRA	23	7	0	40	23	13	13	12	21	17	169
MDA	522	454	315	240	174	165	159	150	126	122	2,427
NAVY	578	550	585	466	446	567	566	414	675	582	5,429
NGA	4	2	2	2	2	0	4	0	0	4	20
OSD	128	156	83	163	197	242	155	161	144	160	1,589
SOCOM	44	28	25	25	49	28	11	14	23	16	263
Total	2,162	2,113	2,075	2,344	1,862	1,982	1,825	2,021	2,062	1,822	20,268

SOURCE: Data provided by DoD, August 2013.

Overall, Air Force (AF) and Navy accounted for more than half of all Phase I awards; together with Army and Missile Defense Agency (MDA), they accounted for more than 80 percent of Phase I awards.[2] Conversely, the Defense Health Program (DHP), Defense Logistics Agency (DLA), Defense Microelectronics Agency (DMEA), and the National Geospatial-Intelligence Agency (NGA) together accounted for 0.6 percent.[3]

There are some year-to-year variations. For example, the number of Navy awards decreased from 566 in FY2008 to 414 in FY2009 before rebounding to 675 in FY2010. The number of AF awards decreased from 517 in FY2007 to 485 in FY2008 before reaching 602 in FY2009. The number of DARPA awards grew sharply from 25 in 2006 to 288 in 2009 before declining again.

Phase I SBIR Proposals and Success Rates

The number of high-quality proposals that DoD can attract depends on many factors, including opportunities for small businesses elsewhere and the state of the business cycle. That being said, the volume of Phase I applications is particularly important, because Phase I is the gateway into the program. Based on available data for 2011, the number of applications declined by 15 percent over the study period, peaking at 16,000 in FY2004 and reaching the lowest point of slightly more than 10,000 in FY2011 (see Figure 2-3).

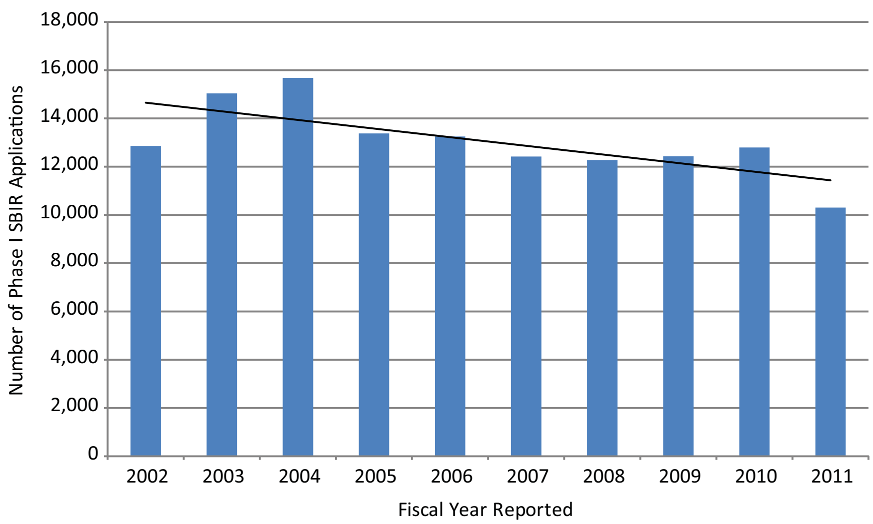

FIGURE 2-3 SBIR Phase I applications received by DoD, FY2002-2011.
SOURCE: DoD awards and applications database.

[2] Unless otherwise noted, all awards and applications data were provided directly by the DoD SBIR Program Manager.
[3] A full list of acronyms used in this report is provided in the Glossary, Appendix D.

As we note below, this overall decline in applications could result from a number of factors (DoD itself has not presented an explanation):

- Companies may be reluctant to compete for Phase I awards if they believe that the effort of applying is too high compared with the chance of entry into the SBIR program.
- Companies may regard the likelihood of long-term success via the Phase I/Phase II/Phase III pathway as being too remote to justify the effort; they may instead focus their efforts elsewhere.
- Efforts by DoD to make sure that topics are tightly linked to acquisitions needed may be reducing the number of more research-oriented applications
- Overly specific topics may exclude some companies from participating.
- Case study reviews of selected companies suggest that small business entrepreneurs increasingly see the need for a full pathway to commercial success before applying for Phase I funding.
- The erosion of award size in real terms may be having an effect (now addressed via reauthorization).

These and other factors at the component level may have affected application decisions. Figure 2-4 shows that the sharp decline from FY2004 to FY2005 was driven by a decline in applications to MDA and that after FY2007 the overall

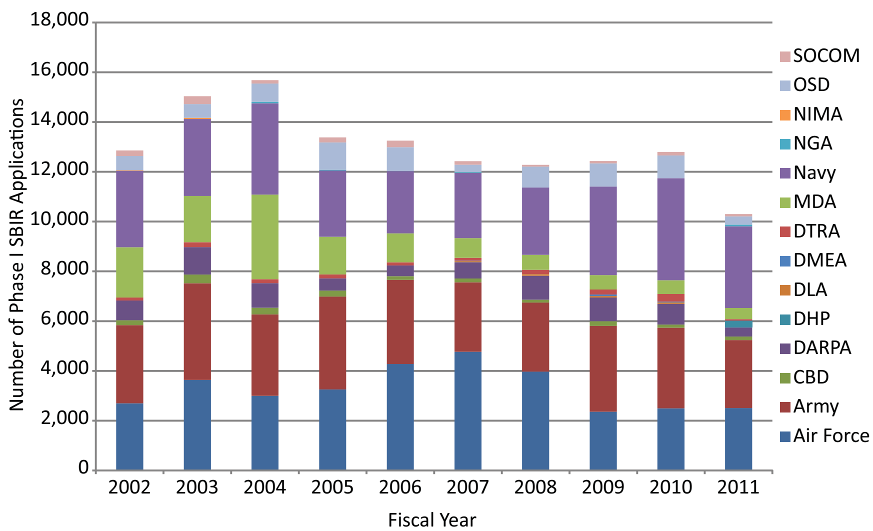

FIGURE 2-4 Phase I SBIR applications by major awarding component, FY2002-2011.
SOURCE: DoD awards and applications database.

decline was driven by a decline in applications to AF from 4,769 in FY2007 to about 2,500 in each of FYs 2009-2011.

The success rate for Phase I applications remained relatively constant during the study period, at 14-16 percent (see Figure 2-5). DoD staff observes that awards to all qualified proposals are often not made due budget constraints.[4] They believe that a 15 percent rate of success suggests that the awarded proposals are of high quality. However, this approach imposes an 85 percent failure rate—and each failed application involves costs for the applicant company. Weighing the costs and potential benefits of applying for SBIR, otherwise promising firms may forgo applying for an award.

Distribution of Phase I SBIR Awards by State

A number of factors affect the shares of SBIR awards by the states, including the overall population of the state, the strength of their science and engineering workforce, and their propensity to apply for SBIR awards. For FY2002-2011, five states collectively received 52 percent of Phase I awards, down slightly from the time period analyzed in the previous National Research Council (NRC) report on the DoD SBIR program.[5] Figure 2-6 shows state

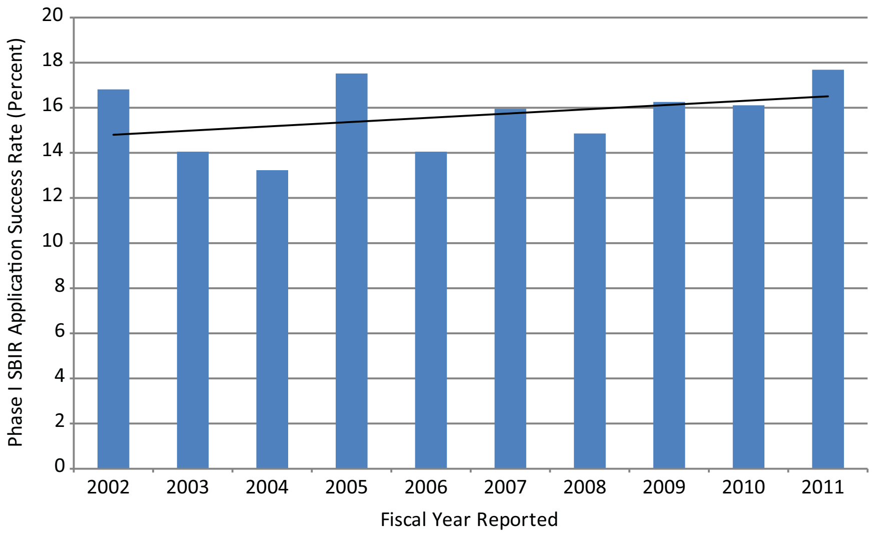

FIGURE 2-5 Success rates for Phase I SBIR applications, FY2002-2011.
SOURCE: DoD awards and applications database.

[4]Other potential reasons could include proposals that did not increase in quality over the years, and that fewer proposals were awarded to keep down management effort and costs.
[5]National Research Council, *An Assessment of the SBIR program at the Department of Defense*, op. cit., p. 56.

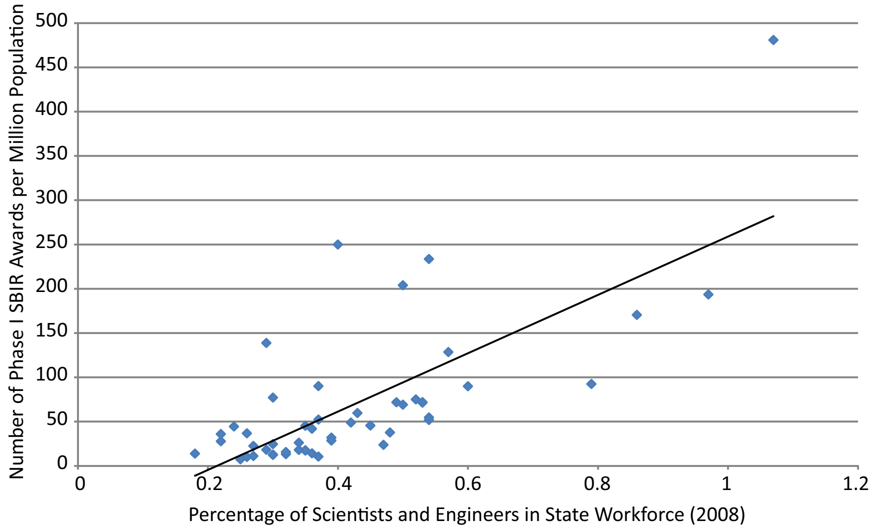

FIGURE 2-6 Phase I SBIR per million population, by percentage of scientists and engineers in the workforce.
SOURCES: DoD SBIR awards applications and awards database, and U.S. Census.

relatively success in receiving awards, normalized for population, charted against population size.[6]

Figure 2-6 shows that some states received more awards than their population would have suggested: Massachusetts more than six times; New Hampshire and Virginia more than three times; and New Mexico, Colorado, and Maryland more than two times. California received almost twice as many awards as its population would have suggested. Overall, 23 states received less than 50 percent of the Phase I awards that would have been proportionate to their population; conversely, 13 states received more than 100 percent of their proportionate share.

This suggests that population alone is not a useful predictor of SBIR awards. The Government Accountability Office (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.[7] Several indicators have been used to normalize state populations for these purposes. Figure 2-7 compares the distribution of a state's science and engineering PhDs as a percentage of its

[6]To more clearly illustrate differential award distribution, the Y-axis reflects not the share of awards, but the share of awards as a percentage of the state's share of the U.S. population.
[7]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.

workforce with the state's percentage of Phase I awards. We would expect the existence of higher numbers of PhDs to broadly correlate with a higher share of awards. The trend line in Figure 2-7 to some extent supports this hypothesis, but the substantial variation suggests that many other factors play a role.

Given the pictures presented in these charts, it is not surprising that the success rates of applications from different states varied substantially (Table 2-2). DoD data indicate that for FY2007-2008, success rates varied from 26 percent in New Hampshire to zero percent in Puerto Rico, with eight states showing rates of less than 10 percent. The reasons for the variability are not clear, and are likely rooted in the complex differences in state industry focus, the locations of key firms, as well as other potential variables.

Phase I SBIR Awards by Company

Table 2-3 summarizes Phase I awards for the top 20 awardees during the study period. The top awardee, Physical Optics, received an average of 45 Phase I awards per year, 50 percent more than the next largest. Combined, the

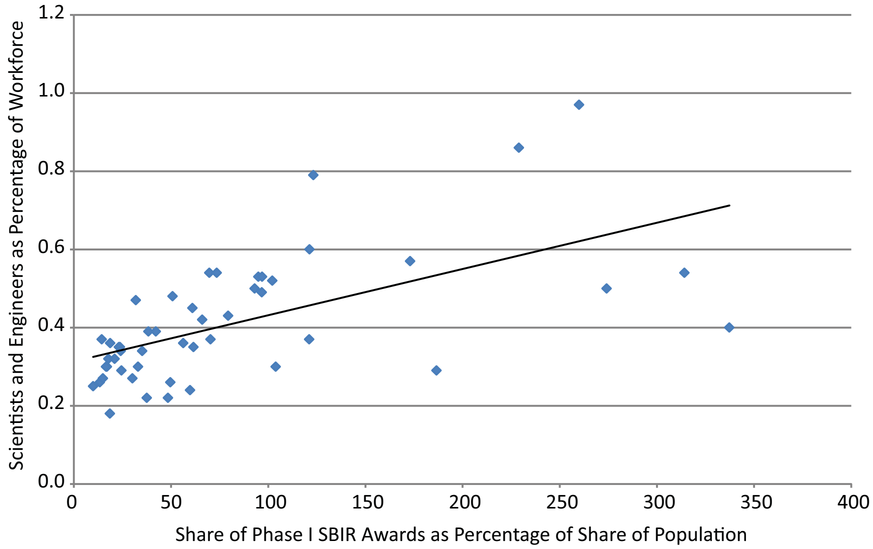

FIGURE 2-7 SBIR Phase I awards by state and by state share of PhD scientists and engineers as a percentage of population.
NOTE: Two outliers have been excluded from this chart—Massachusetts, which has a far higher share of awards per population that other states, and Washington, DC, which has far more PhD scientists and engineers per capita than other jurisdictions. All states and DC are included in the reference table at the end of this chapter.
SOURCE: DoD data; National Science Foundation (NSF) Science and Engineering Indicators 2012, Table 8-34; U.S. Census.

top 20 awardees accounted for about 14 percent of Phase I awards and funding at DoD.[8] Some of these companies, such as Foster-Miller, have been acquired or have reached the SBIR size limit and consequently no longer apply for awards. This table shows that the top 20 companies received about 14 percent of both Phase I awards and funding indicating a concentration of awards in fewer companies.

Phase I SBIR Award Demographics

Woman-owned Small Businesses (WOSB)

Congress mandated that the participation of women in the SBIR program be fostered and encouraged (Chapter 3 discusses additional evidence about female participation in the context of outcomes). The number of applications received from WOSBs remained largely flat over the study period (see Figure 2-8), even though the number of applications received from all companies declined. Overall, the number of awards to WOSBs remained constant, although with year-to-year variation, while the percentage of awards to WOSBs increased, especially after FY2008 (see Figure 2-9). Although overall numbers were relatively flat, there was considerable variation in the awards to WOSBs made by individual components (see Figure 2-10).

In reading this data, it is important to keep in mind the very large role played by three WOSBs: Physical Optics, Intelligent Automation, and CFD Research. All were wholly or in part founded by their female owners, who continue to play a major role at each, so they clearly meet the Small Business Administration (SBA) standard for WOSBs. Combined, they accounted for about 34 percent of all Phase I awards to WOSBs during the study period; in some years, they accounted for much more than 40 percent, as illustrated in Figure 2-11 (numbers dropped sharply in FY2011 for reasons not yet understood). The figure also shows that the number of Phase I awards made to the remaining companies remained largely flat (until FY2011, for which only partial data are likely yet available). More generally, the top 20 WOSB awardees accounted for about 5.4 percent of all Phase I awards and about 42 percent of awards to WOSBs (see Table 2-4).

[8]DoD did not provide unique identifying information for companies, so these data were developed by normalizing company names. This process may not have been completely successful in avoiding duplicate entries, given the very large numbers of awards involved. It also does not account for mergers and acquisitions among these companies. Any errors would have the effect of reducing the degree of apparent concentration of awards.

TABLE 2-2 Phase I SBIR Awards and Applications by State, 2002-2011

State	Applications Total	Awards Total	Proposal-to-Award Percentage
AK	38	3	7.89
AL	1,769	275	15.55
AR	135	25	18.52
AZ	1,426	203	14.24
CA	12,504	2,031	16.24
CO	2,210	411	18.60
CT	891	143	16.05
DC	94	13	13.83
DE	290	38	13.10
FL	2,246	326	14.51
GA	780	89	11.41
HI	414	56	13.53
IA	70	15	21.43
ID	162	19	11.73
IL	887	166	18.71
IN	542	79	14.58
KS	101	9	8.91
KY	158	13	8.23
LA	155	15	9.68
MA	6,791	1,261	18.57
MD	3,238	449	13.87
ME	110	14	12.73
MI	1,660	216	13.01
MN	675	92	13.63
MO	278	38	13.67
MS	95	11	11.58
MT	157	18	11.46
NC	784	101	12.88
ND	51	3	5.88
NE	156	23	14.74
NH	623	164	26.32
NJ	1,650	240	14.55
NM	809	135	16.69
NV	225	30	13.33
NY	2,323	434	18.68
OH	2,550	432	16.94
OK	192	16	8.33
OR	355	58	16.34
PA	2,111	389	18.43
PR	5	0	0.00
RI	201	36	17.91
SC	177	21	11.86
SD	47	3	6.38
TN	347	54	15.56

	Applications	Awards	
State	Total	Total	Proposal-to-Award Percentage
TX	3,031	418	13.79
UT	329	43	13.07
VA	4,893	820	16.76
VT	133	21	15.79
WA	848	151	17.81
WI	316	48	15.19
WV	149	15	10.07
WY	60	10	16.67

SOURCE: DoD awards and applications database.

TABLE 2-3 Top 20 DoD Phase I SBIR/STTR Award Recipients, FY2002-2011

Company Name	Number of Awards	Amount (Dollars)
Physical Optics	451	42,652,863
Intelligent Automation	297	27,904,077
Luna Innovations	232	21,917,054
Physical Sciences	227	21,364,799
Charles River Analytics	210	21,005,630
Creare	193	18,935,632
CFD Research	165	15,730,878
Aptima	163	16,007,675
Triton Systems	153	14,407,979
Toyon Research	124	12,153,649
Agiltron	124	11,743,975
Lynntech	117	11,061,313
Impact Technologies	115	11,483,998
Infoscitex	115	10,984,018
Foster-Miller	107	9,424,013
Texas Research Institute Austin	106	9,558,590
Progeny Systems	96	8,278,168
Nanosonic	90	8,739,854
Materials & Electrochemical Research	90	8,235,150
TDA Research	89	8,256,214
KaZak Composites	87	7,397,216
Total (20 top companies)	3,351	317,242,745
All Phase I awards	23,224	2,222,884,156
Top 20 companies (percent of total)	14.4%	14.3%

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

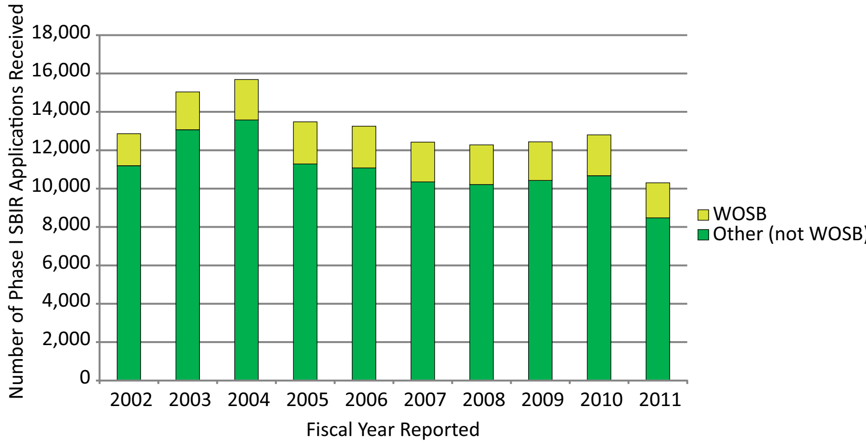

FIGURE 2-8 Phase I SBIR applications from woman-owned small businesses (WOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

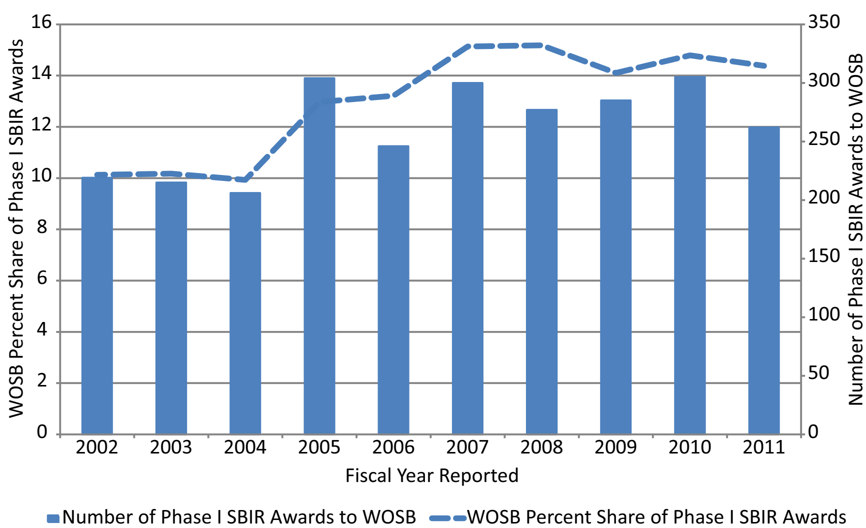

FIGURE 2-9 Phase I SBIR awards and award share for woman-owned small businesses (WOSB), FY2002-2011.
SOURCE: Data from DoD awards and applications database.

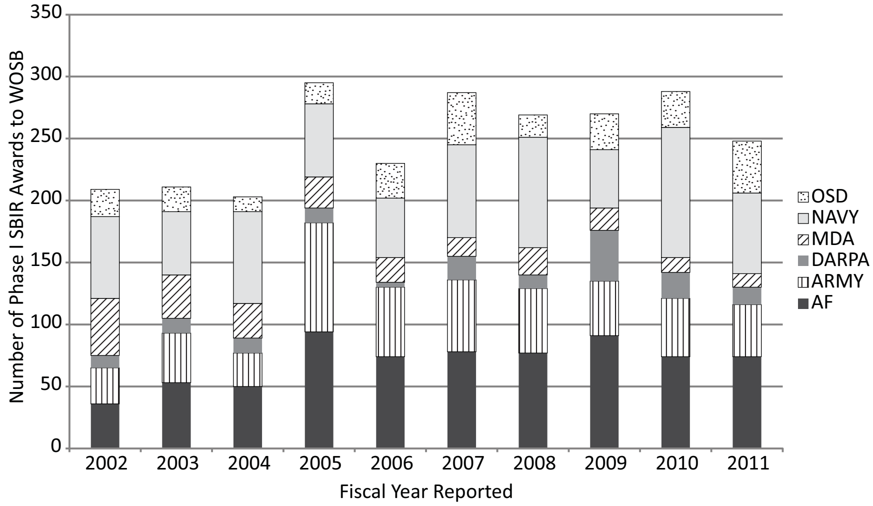

FIGURE 2-10 Phase I SBIR awards to woman-owned small businesses (WOSB) by component, FY2002-2011.
SOURCE: DoD awards and applications database.

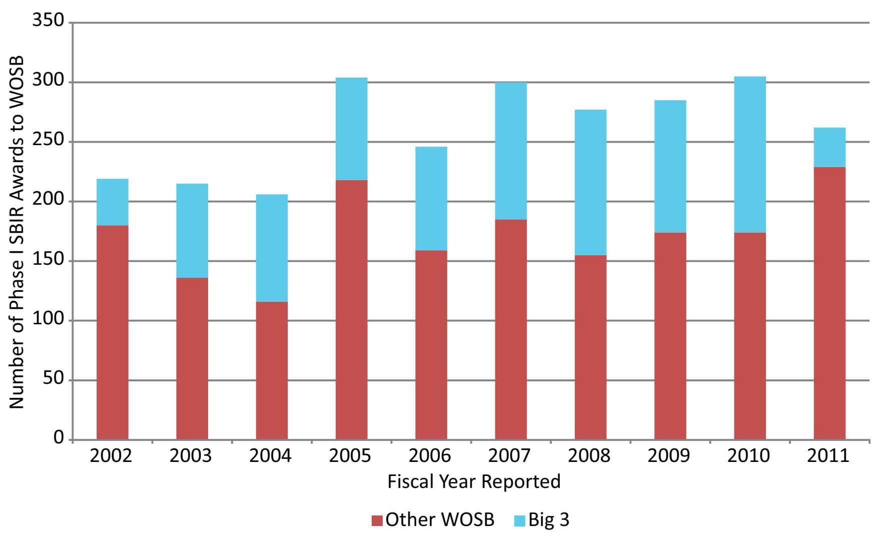

FIGURE 2-11 Distribution of Phase I SBIR awards among woman-owned small businesses (WOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

TABLE 2-4 Top 20 WOSB SBIR/STTR Awardees, FY2002-2011

Company Name	Number of Awards	Total Amount Awarded (Dollars)
Physical Optics	325	30,767,174
Intelligent Automation	269	25,067,179
CFD Research	107	10,219,627
Cybernet Systems	63	6,107,428
First RF	52	5,209,574
21st Century Technologies	43	4,201,388
Navsys	38	3,663,344
Technology Assessment & Transfer	37	3,402,382
Composite Technology Development	35	3,145,330
UES Technologies	35	3,361,153
21st Century Systems	32	3,033,488
Touchstone Research Laboratory Ltd.	32	2,698,160
Williams-Pyro	31	2,718,785
Ridgetop Group	26	2,601,288
Polaris Sensor Technologies	25	2,452,270
Pikewerks	23	2,283,363
New Span Opto-Technology	22	1,945,801
MP Technologies	21	2,004,461
Nu-Trek	21	2,038,348
Management Sciences	21	2,019,714
Top 20 WOSBs—total	1,258	118,940,257
All WOSBs—total	2,963	282,087,120
All Phase I awards FY2002-2011	23,224	2,222,884,156
Top 20 WOSBs (percent of total)	5.4%	5.4%
All WOSBs (percent of total)	12.8%	12.7%

SOURCE: Data provided by DoD.

Minority-owned Small Businesses

The number of Phase I applications by MOSBs declined steadily from a peak of more than 2,300 in FY2004 to a little more than 1,000 in FY2011 (see Figure 2-12). This decline mirrors the overall decline in applications experienced at DoD during the study period (see Figure 2-13).

Figure 2-14 summarizes awards to MOSBs by the different components (excluding components that provided less than 100 awards total to MOSBs). There was substantial variation over time, in particular at Army, as well as a long-term decline at MDA.

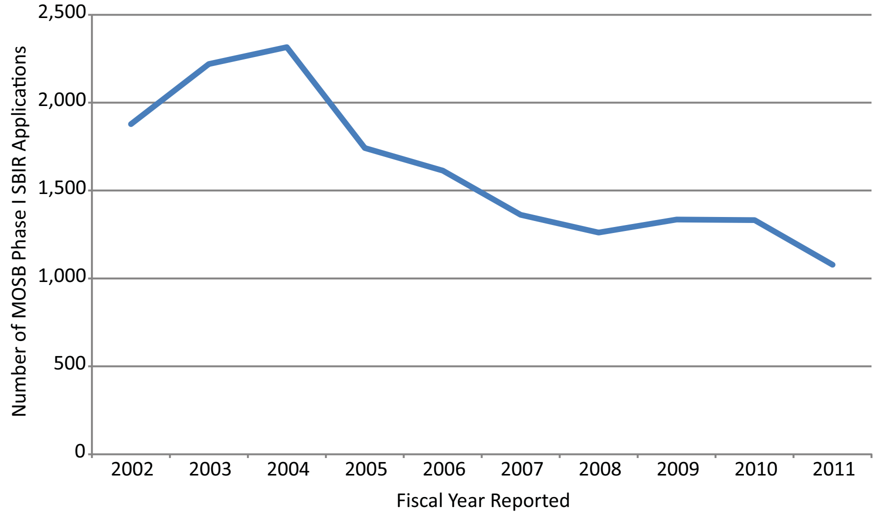

FIGURE 2-12 Phase I SBIR applications from minority-owned small businesses (MOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

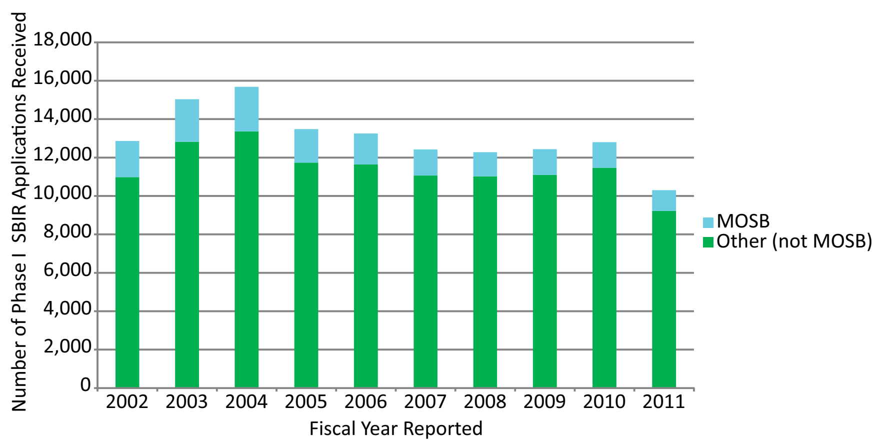

FIGURE 2-13 Phase I SBIR applications by minority-owned small businesses (MOSB) and Other Companies, FY2002-2011.
SOURCE: DoD awards and applications database.

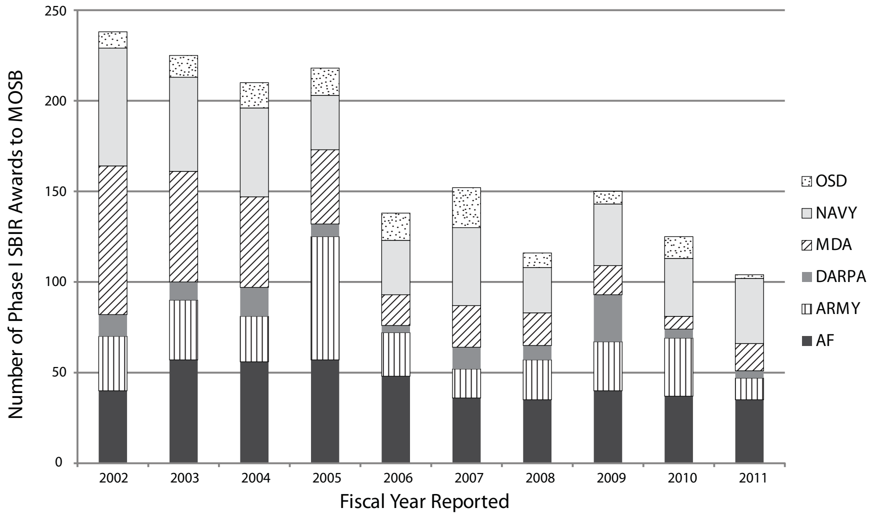

FIGURE 2-14 Phase I SBIR awards to minority-owned small businesses (MOSB) by component, FY2002-2011.
NOTE: DoD data for WOSB and MOSB are intrinsically inaccurate. Each record reports which boxes the company checked when applying, and agency staff acknowledge that companies sometimes fail to check an appropriate box. In addition, companies do move in and out of WOSB and MOSB status as they grow.
SOURCE: DoD awards and applications database.

As with WOSBs (and indeed all awards), awards were concentrated in specific companies. Table 2-5 shows that the top 20 MOSB awardees accounted for about 2.4 percent of all awards and 28 percent of MOSB awards.

PHASE II SBIR AWARDS

To a considerable extent, the pattern of Phase II awards closely follows that for Phase I, which is not surprising because receipt of a Phase I award is a prerequisite for receipt of a Phase II award.

Number and Size of Phase II SBIR Awards

The overall number of Phase II awards exhibits no substantial long-term trend over the study period at about 1,000 awards annually (see Figure 2-15). Although the number of awards was flat, overall spending on Phase II declined fairly steadily from a peak of about $1.1 billion in FY2004 to about $720 million in FY2011 (see Figure 2-16).

TABLE 2-5 Phase I SBIR/STTR Awards to MOSBs, FY2002-2011

Company Name	Number of Awards	Total SBIR Phase I Funding (Dollars)
Scientific Systems	56	5,422,967
Agiltron	46	4,431,760
Cybernet Systems	44	4,267,507
Nextgen Aeronautics	38	3,769,054
Scientific Systems	38	3,365,891
Aerius Photonics	36	3,547,566
Agave Biosystems	35	3,297,911
Intelligent Systems Technology	29	2,867,371
American GNC	27	2,474,936
Edaptive Computing	25	2,438,248
Materials Modification	23	1,887,015
SVT Electronics	23	1,944,899
Hypercomp	22	2,407,524
Acellent Technologies	21	2,006,690
Datasoft	19	1,609,881
Wright Materials Research	18	1,649,791
Ceramatec	17	1,585,321
Composite Technology Development	17	1,486,037
Genex Technologies	16	1,497,975
Applied Technology	15	1,362,104
Top 20 MOSBs	565	53,320,448
All MOSBs	2,003	187,202,401
All Phase I awards	23,224	2,222,884,156
Top 20 MOSBs (percent of total awards)	2.4%	2.4%
Top 20 MOSBs (percent of MOSB awards)	28.2%	28.5%

SOURCE: DoD awards and applications database.

As with all agencies, SBA policy guidance does provide DoD with some flexibility to fund Phase II awards beyond the standard amounts. Table 2-6 shows, however, that this flexibility has been rarely used: about 10 percent of awards were $2 million or more, and about 1 percent were $4 million or more. AF and Navy together accounted for more than two-thirds of the larger awards (see Table 2-7).

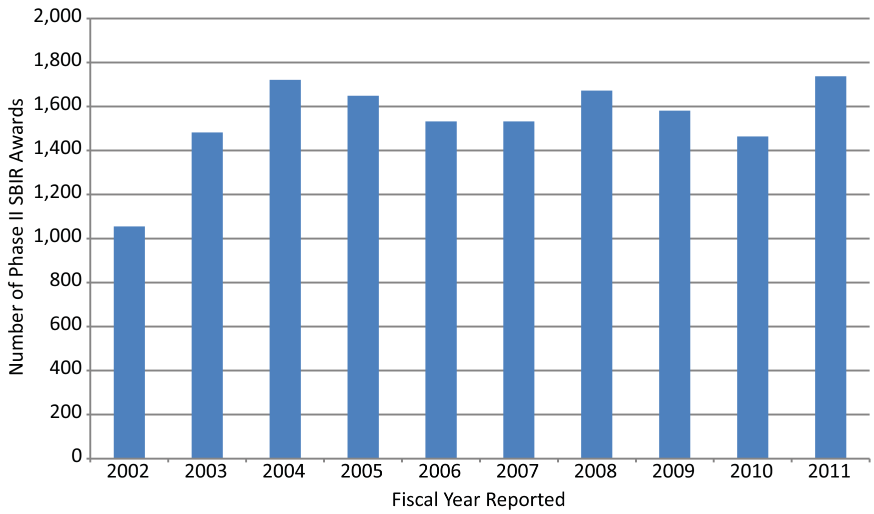

FIGURE 2-15 Number of Phase II SBIR awards, FY2002-2011.
SOURCE: DoD awards and applications database.

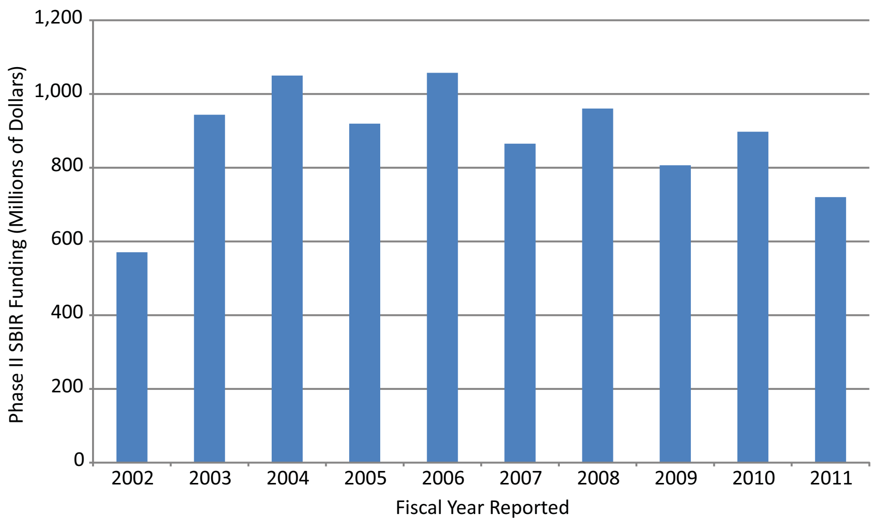

FIGURE 2-16 Phase II SBIR funding, FY2002-2011.
SOURCE: DoD awards and applications database.

TABLE 2-6 Size of Phase II SBIR Awards, 2002-2011

	Number of Awards	Percentage of Total
>$750,000 and <$1M	1,153	41.6
>$1M-$2M	1,346	48.6
>$2M-$3M	179	6.5
>$3M-$4M	61	2.2
>$4M-$5M	19	0.7
>$5M	13	0.5
	2,771	100.0

SOURCE: DoD awards and applications database. Phase II.5 awards are not included in this dataset.

Phase II SBIR Awards by Component

As with Phase I, overall awards were dominated by the Services, each of which averaged more than 200 awards per year during the study period, far more than other components. Of the other components, only MDA averaged more than 100 (but experienced a steady decline to 67 in FY2011) (see Figure 2-17). Among the Services, the number of Air Force awards declined somewhat after FY2008, while those for Navy increased after FY2009.

Phase II SBIR Applications and Success Rates

Until fairly recently, Phase II applications required an invitation from DoD, so only projects deemed appropriate for Phase II by the Technical Point of Contact (TPOC) and the decision-making officers at the various components were eligible for Phase II funding. Reauthorization legislation now instructs all agencies to permit all Phase I participants to apply for Phase II funding.

TABLE 2-7 Distribution of Phase II SBIR Larger Than $2 Million, by Component

Component	Number of Awards >$2M	Percentage of Awards >$2M
AF	103	38.0
ARMY	40	14.8
DARPA	14	5.2
MDA	25	9.2
NAVY	80	29.5
OSD	5	1.8
SOCOM	4	1.5
	271	100.0

SOURCE: DoD awards database.

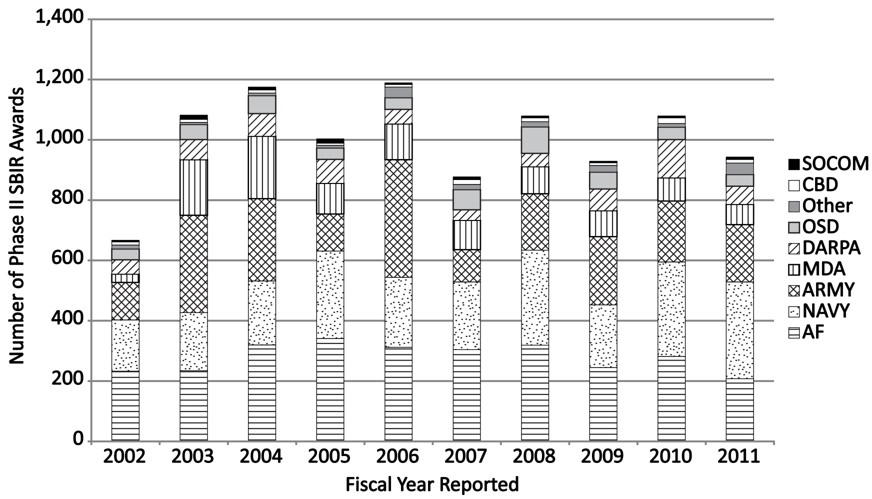

FIGURE 2-17 Phase II SBIR awards, by component, FY2002-2011.
SOURCE: DoD awards and applications database.

Overall, the number of Phase II applications reflects the general distribution of funding and awards by component (see Figure 2-18), remaining fairly stable after the downturn in FY2002. Success rates in being awarded a Phase II contract varied substantially by year, from a peak of about 77 percent in 2006 to a low of about 54 percent in 2011 (see Figure 2-19).

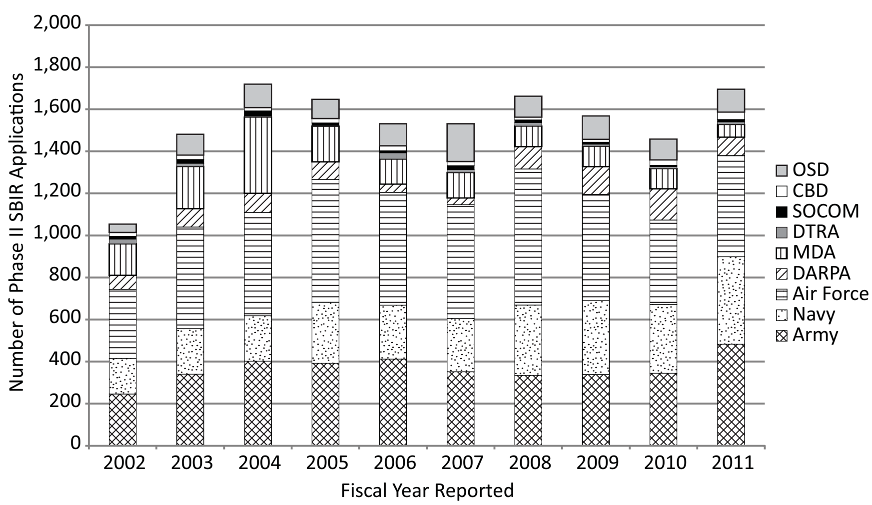

FIGURE 2-18 Phase II SBIR applications by component, FY2002-2011.
SOURCE: DoD awards and applications database.

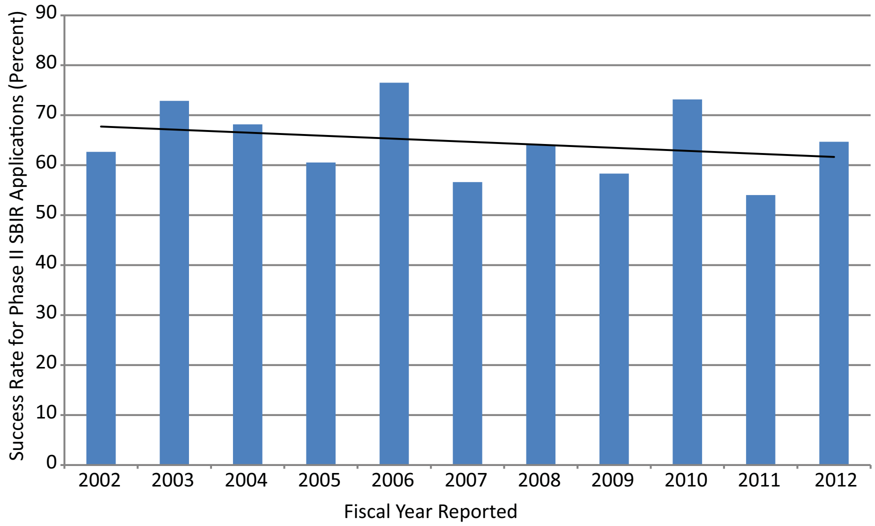

FIGURE 2-19 Success rate for Phase II SBIR applications, FY2002-2011.
SOURCE: DoD awards and applications database.

Distribution of Phase II SBIR Awards by State

As with Phase I awards, companies in some states have a consistently stronger record in receiving Phase II awards. Again, however, the success rates should be normalized against both the size of the state population and the availability of scientific and engineering talent in the state workforce. The scatter chart in Figure 2-20 shows a positive correlation between scientific talent and award shares, when the success rate is normalized for the population.

As states have recognized the benefits of receiving SBIR awards, many have started Phase 0 programs to encourage applications.[9] Some even provide matching funds for Phase I and pay for application preparation.

Evidence suggests that the average quality of applications varies widely: success rates for Phase I differ by state, as does the percentage of Phase I awards that are successfully converted to Phase II awards. Table 2-8 shows the top five and bottom five states as measured by conversion success.[10]

Phase II SBIR 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

[9]E.g. New York State, <http://www.nydirectedenergy.org/programs/sbir.cfm>; Florida <*http://*www.enterpriseflorida.com/small-business/sbirsttr-phase-0-pilot-program/>, South Carolina <*http://www.scepscoridea.org/Funding/Phase-0.html*>.
[10]The complete table is provided at the end of this chapter.

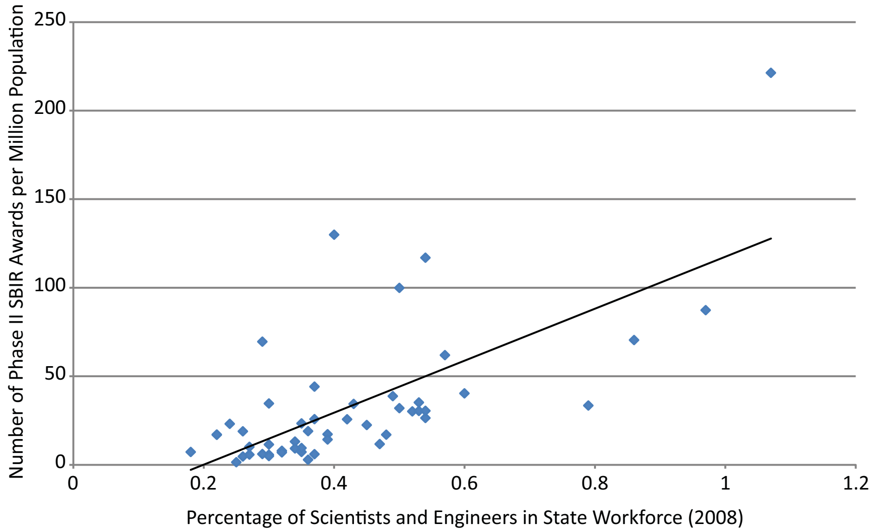

FIGURE 2-20 Phase II SBIR awards by state population and percentage of scientists and engineers in state workforce.
NOTE: Two outliers have been excluded from this chart—Massachusetts, which has a far higher share of awards per population and Washington, DC, which has far more PhD scientists and engineers per capita than other jurisdictions. The exclusion was to permit readers to view the distribution of the remaining states more clearly. All states and DC are included in the reference table at the end of this chapter.
SOURCE: DoD data; National Science Board, *Science and Engineering Indicators 2012*, NSB 12-01, Arlington, VA: National Science Foundation, 2012, Table 8-34; U.S. Census.

the list of top 25 Phase II award recipients at DoD. What is, however, quite striking is the extent to which these companies rely for Phase II success on the sheer volume of Phase I awards that they win: the conversion rate from Phase I to Phase II is lower than the average for all awards for every one of the top 25 awardees except Trident Systems. This is a somewhat troubling finding, because it suggests that the most prolific award recipients at DoD are on average generating Phase I results that are less worthy of further funding than the average Phase II proposal. Both Physical Optics and Intelligent Automation—the top two awardees—show conversion rates that are far below the average.

Phase II SBIR Award Demographics

Woman-owned Small Businesses

As with SBIR Phase I, the number of Phase II applications received from WOSBs remained largely flat across the study period, averaging 12.5

TABLE 2-8 Phase I to Phase II Conversion Success Rate Top and Bottom 5 States 2002-2011

State	Phase 1-Phase 2 Conversion Success Rate (Percent)
Maine	205.0
Nevada	202.8
Arkansas	185.1
Louisiana	185.1
Tennessee	158.7
Kansas	38.5
Delaware	36.1
North Dakota	35.3
South Dakota	26.4
Kentucky	14.4

NOTE: Conversion success rate is the percentage Phase I awards that convert to Phase II, as a percentage of the average of all states.
SOURCE: DoD awards and applications database.

percent of applications annually (compared to 15.9 percent of Phase I applications) (see Figure 2-21). This stable level of applications is largely matched by a stable level of Phase II awards to WOSBs. The share of Phase II awards to WOSBs remained flat at about 14 percent after FY2005 (see Figure 2-22).

Minority-owned Small Businesses

The basic data for SBIR Phase II awards to MOSBs reveal very low levels of awards throughout the study period, with a sharp decline in more recent years (see Figure 2-23). On average, MOSBs accounted for 7.8 percent of Phase II SBIR awards, with a peak of 11.5 percent in 2008 to a known low of 6 percent in 2010. According to DoD's data contractor, some inconsistencies remain in the recording of WOSB and MOSB awards at DoD, and the data for 2011 in particular are currently being revised. In part, this decline reflects a decline in the number of Phase II applications by MOSBs (see Figure 2-24).

Figure 2-25 compares Phase II application and award rates for MOSBs. Overall, rates are closely aligned: across the entire study period, MOSBs submitted 7.8 percent of the applications and received 7.9 percent of the awards.[11] These results suggest that efforts to expand the number of Phase II awards to MOSBs should focus on encouraging more applications.

[11]DoD awards and applications databases.

TABLE 2-9 Top 25 Phase II SBIR/STTR Awardees FY2002-2011

Company Name	Number of Awards	Phase I-Phase II Conversion (Percent)
Physical Optics	166	36.8
Intelligent Automation	104	35.0
Physical Sciences	103	45.4
Creare	95	49.2
Luna Innovations	93	40.1
Charles River Analytics	92	43.8
Aptima	89	54.6
Triton Systems	80	52.3
CFD Research	75	45.5
Impact Technologies	74	64.3
Toyon Research	50	40.3
Progeny Systems	50	52.1
Technology Service	47	61.0
Lynntech	46	39.3
Agiltron	45	36.3
Infoscitex	43	37.4
Nanosonic	41	45.6
Trident Systems	39	88.6
Spectral Sciences	39	60.9
Texas Research Institute Austin	39	36.8
Knowledge Based Systems	39	60.9
AlphaTech	38	55.9
TDA Research	38	42.7
Foster-Miller	35	32.7
Metrolaser	32	62.7
KaZak Composites	32	36.8
Median (top 26)		45.4
Average (all awards)		64.7

NOTE: For the purpose of analyzing company involvement, SBIR and STTR data have been combined in this table. 26 companies are included, as 2 companies were awarded 32 Phase II awards.
SOURCE: DoD awards database.

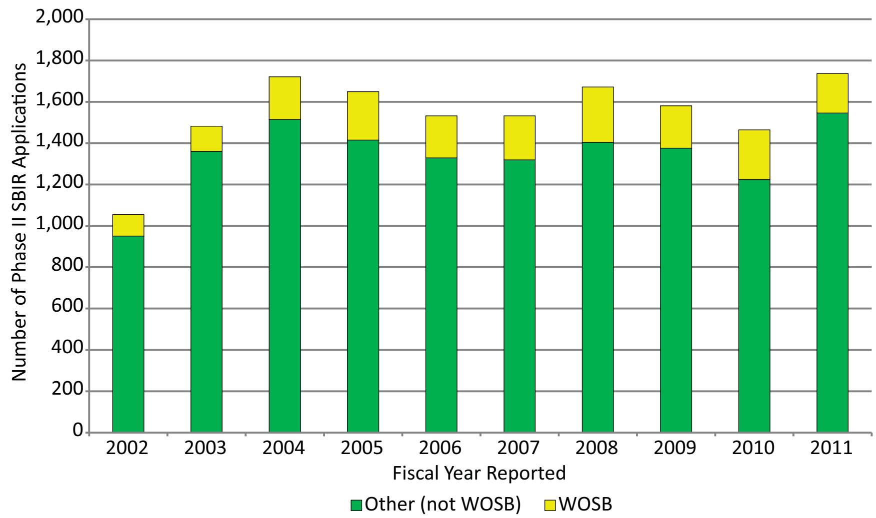

FIGURE 2-21 Phase II SBIR applications by woman-owned small businesses (WOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

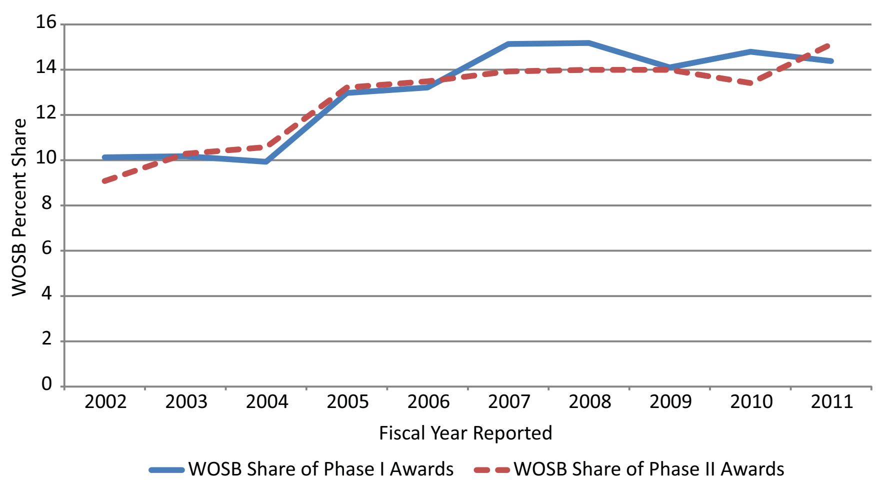

FIGURE 2-22 Woman-owned small business (WOSB) shares of Phase I and Phase II SBIR awards, FY2002-2011.
SOURCE: DoD awards database; DoD SBIR website, accessed August 15, 2013. <*http:*//www.acq.osd.mil/osbp/sbir/>.

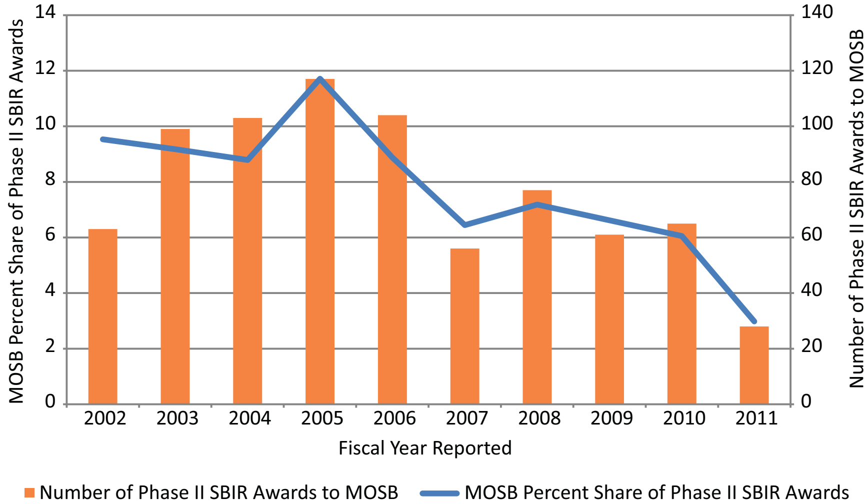

FIGURE 2-23 Phase II SBIR awards to minority-owned small businesses (MOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

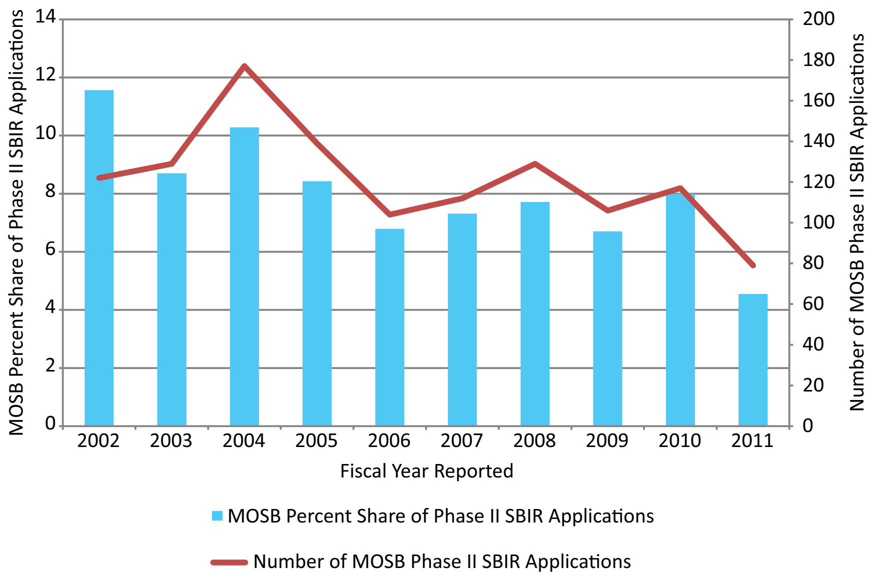

FIGURE 2-24 Phase II SBIR applications by minority-owned small businesses (MOSB), FY2002-2011.
SOURCE: DoD awards and applications database.

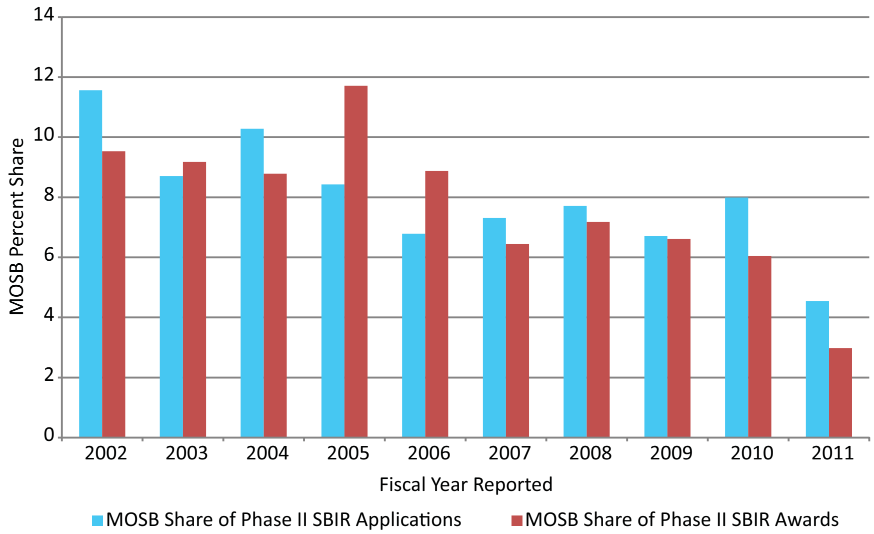

FIGURE 2-25 Phase II SBIR minority-owned small businesses (MOSB) share of awards and applications, FY2002-2011.
SOURCE: DoD awards and applications database.

NEW PARTICIPANTS IN THE DOD SBIR PROGRAM

DoD provided a count of companies receiving their first award in any given year. Tables 2-10 and 2-11 show the numbers of companies entering each phase for the first time, for SBIR and STTR combined,[12] as well as their representation of all companies receiving an award that year.

It is not surprising that both tables show a decline over time in the number of new companies in the program. This may be explained by changes in the national rate of small company formation, which has declined over the period.[13] In addition, the number of companies with program experience continues to grow, and the pool of qualified companies that have not received an award may not be increasing, at least not at a rate sufficient to maintain the percentage.

It is worth noting that new companies receive a higher percentage of Phase II awards than Phase I, which suggests that the quality of proposals from new companies is higher. This in turn suggests that selection criteria for Phase I might be overly weighted to companies with previous experience, although the

[12]DoD provided combined records for new SBIR and STTR entrants.
[13]Kaufmann Foundation, BDS Brief "Number of New Firms Continues to Slide, According to New Census Bureau Data," 5/2/2012, <*http://www.kauffman.org/newsroom/2012/05/number-of-new-firms-continues-to-slide-according-to-new-census-bureau-data*>.

TABLE 2-10 Companies Receiving Phase I SBIR Award for First Time, by Fiscal Year

Fiscal Year Reported	Number of 1st Phase I SBIR/STTR	Percentage of All Companies
2002	495	34.5
2003	404	25.7
2004	436	26.8
2005	475	26.9
2006	317	19.4
2007	320	22.1
2008	277	19.3
2009	299	20.0
2010	315	20.4
2011	277	20.6

SOURCE: DoD special tabulation.

absence of application data about new entrants means that whether the lower Phase I percentage reflects fewer applications or fewer awards cannot be determined. It is worth noting that the companies winning the most Phase I awards almost uniformly had below average Phase II conversion rates, as discussed above.

TABLE 2-11 Companies Receiving Phase II SBIR Award for First Time, by Fiscal Year

Fiscal Year Reported	Number of 1st Phase II SBIR/STTR	Percentage of All Companies
2002	170	36.0
2003	304	40.3
2004	299	36.1
2005	260	33.7
2006	310	35.7
2007	175	26.8
2008	223	29.8
2009	183	27.0
2010	202	26.5
2011	158	25.2

SOURCE: DoD special tabulation

ANNEX

STATE TABLES

The state tables in this annex show relationships between awards, state populations, and the incidence in scientists and engineers in the workforce. There is a positive correlation between the latter and the number of awards, normalized for state population.

TABLE ANNEX 2-1 Phase I SBIR/STTR Awards by State, State Population, and Scientists and Engineers in State Workforce

State	State Population in Millions (2012)	Percentage of Scientists and Engineers in State Workforce (2008)	Number of Phase I SBIR Awards (2002-2011)	Number of Phase I Awards per Million in Population
AK	0.7	0.36	10	14.1
AL	4.8	0.29	663	138.7
AR	2.9	0.18	40	13.7
AZ	6.4	0.30	492	77.0
CA	37.3	0.57	4,786	128.5
CO	5.0	0.50	1,025	203.8
CT	3.6	0.60	321	89.8
DE	18.8	0.79	83	92.4
FL	9.7	0.22	676	36.0
GA	1.4	0.30	238	24.6
HI	3.0	0.52	102	75.0
IA	1.6	0.32	40	13.1
ID	12.8	0.39	50	31.9
IL	6.5	0.39	365	28.4
IN	2.9	0.34	169	26.1
KS	4.3	0.30	36	12.6
KY	4.5	0.25	32	7.4
LA	6.5	0.26	45	9.9
MA	5.8	1.07	3,148	480.8
MD	1.3	0.97	1,117	193.5
ME	9.9	0.35	60	45.2
MI	5.3	0.37	516	52.2
MN	6.0	0.45	241	45.4
MO	3.0	0.35	103	17.2
MS	1.0	0.27	33	11.1
MT	9.5	0.43	59	59.6

continued

TABLE ANNEX 2-1 *continued*

State	State Population in Millions (2012)	Percentage of Scientists and Engineers in State Workforce (2008)	Number of Phase I SBIR Awards (2002-2011)	Number of Phase I Awards per Million in Population
NC	0.7	0.47	226	23.7
ND	1.8	0.37	7	10.4
NE	1.3	0.29	33	18.1
NH	8.8	0.40	329	249.9
NJ	2.1	0.50	607	69.0
NM	2.7	0.86	351	170.5
NV	19.4	0.22	75	27.8
NY	11.5	0.54	1,002	51.7
OH	3.8	0.37	1,038	90.0
OK	3.8	0.27	84	22.4
OR	12.7	0.48	144	37.6
PA	3.7	0.49	912	71.8
RI	1.1	0.53	75	71.3
SC	4.6	0.32	72	15.6
SD	0.8	0.30	10	12.3
TN	6.3	0.35	112	17.6
TX	25.1	0.36	1,051	41.8
UT	2.8	0.42	135	48.8
VA	8.0	0.54	1,868	233.5
VT	0.6	0.53	45	71.9
WA	6.7	0.54	367	54.6
WI	5.7	0.34	102	17.9
WV	1.9	0.26	68	36.7
WY	0.6	0.24	25	44.4

NOTE: For purposes of analyzing state participation in the program, SBIR and STTR awards data were combined.

SOURCE: DoD awards database; NSF Science and Engineering Indicators 2012, table 8-34; U.S. Census.

TABLE ANNEX 2-2 Phase I-Phase II Conversion Success Rate, by State (1999-2012)

State	Phase I-Phase II Conversion Success Rate (Percent)
ME	205.0
NV	202.8
AR	185.1
LA	185.1
TN	158.7
MN	143.1
ID	142.8
NH	141.3
PA	126.3
WA	126.1
VT	125.6
CA	115.0
DC	114.6
MT	112.4
NY	111.7
CO	110.6
MI	110.1
OH	109.5
HI	108.4
AL	108.4
OR	107.5
FL	106.5
NJ	103.2
VA	103.0
WV	102.9
MD	95.2
MA	90.8
MS	89.9
TX	89.9
CT	86.6
UT	85.4
OK	83.8
IN	83.3
RI	81.6
AZ	75.9
NC	75.3
NM	72.4

continued

TABLE ANNEX A-2 *continued*

State	Phase I-Phase II Conversion Success Rate (Percent)
WI	68.8
IA	63.5
IL	61.3
SC	60.5
MO	59.9
GA	58.7
WY	57.3
NE	48.5
KS	38.5
DE	36.1
ND	35.3
SD	26.4
KY	14.4
AK	n/a

NOTE: For purposes of analyzing state participation in the program, SBIR and STTR awards data were combined.
SOURCE: DoD awards database.

3

Program Outcomes—Quantitative Assessment

This chapter utilizes available data from DoD and from the NRC Award Recipient Survey of DoD SBIR winners to analyze outcomes related to the Congressional mandate described in Chapter 1, as well as counterfactuals based on responses to the survey. It also provides insights into program operations drawing in particular on company comments provided through the survey.

THE FOCUS ON COMMERCIALIZATION OUTCOMES

Although the statutory goals of the SBIR program are fourfold, subsequent legislation passed by Congress, as well as administrative policies pursued by DoD and the agencies, focus mainly on the commercialization of SBIR technologies.[1] Moreover, given that commercialization is among the more measurable outcomes of the SBIR program, it has become the benchmark for program performance. The focus on commercialization, however, should not be allowed to obscure the fact that the program is designed to meet all four Congressionally mandated objectives. This chapter provides an update of the commercial outcomes of the DoD SBIR program, as well as outcome measures related to meeting agency mission, expanding the US science and engineering base, and increasing the participation of women and minorities.

SOURCES OF DATA

To develop an effective quantitative analysis of the outputs of the DoD SBIR program, we have drawn on data from the Department of Defense (DoD). We have also drawn from responses to a large-scale survey of SBIR recipients at DoD. This 2011 survey is based on the 2005 survey deployed by the National

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[1]SBA Section 1.(c) SBIR Policy Directive, October 18, 2012, p. 3.

Research Council (NRC), with some additions and modifications.[2] This 2011 survey was sent to two distinct populations: all principal investigators who received DoD Phase II SBIR awards between fiscal year (FY) 1999 and FY2008 inclusive; and all principal investigators who received a Phase I SBIR award and whose company did not receive a Phase II award during the same period. Results from this survey provide the quantitative foundation for much of the analysis in this chapter. Appendix A provides a detailed description of the survey methodology, including discussion of the response rate and discussions of potential survey bias. The 2011 Survey questionnaire is reproduced in Appendix E.

COMPARISON ANALYSIS

We sought to develop a useful comparison group for the data collected through the 2011 NRC Survey, but encountered substantial difficulties in finding matching firms—similar in their demographics, market orientation, industry sector, age, size etc.—that have not received SBIR funding. We then 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, the National Science Foundation, and NASA) during the award period covered by the survey (1999-2008). After considerable review, we concluded that the Phase I-only group was also not appropriate for use as a statistical comparison group. In the interests of providing researchers with a full view of the data collected, Appendix G of this report includes tables showing both the Phase I only and Phase II survey responses for questions where both groups were surveyed.

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. For example:

- Should commercialization include just sales or other kinds of revenue, such as licensing fees and funding for further development?
- Should commercialization include only sales to DoD or other kinds of sales as well?
- 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

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[2]See National Research Council, *An Assessment of the SBIR Program*, C.W. Wessner, ed., Washington, DC: The National Academies Press, 2008, Appendix A.

success and viability? The latter at least would likely be different for each project in each company.
- Should commercialization include sales by licensees, which may be many multiples of the revenues provided to, but are largely reported by, the licensors?
- Should commercialization metrics focus only on formally recognized Phase III contracts,[3] or should they more widely cover follow on sales and development activities across the entire defense sector even where not formally recognized as Phase III?

In practice, these issues resolve in a variety of ways, depending on the DoD component involved.

For the purposes of this study, the committee deployed a broad net to capture a range of potentially useful data. Once acquired, these data can be analyzed in a variety of ways to provide multiple insights into this complex topic.[4]

Revenues

Perhaps the single most used metric for assessing SBIR-type programs is revenue from sales and licensing fees. In its previous SBIR assessments, the NRC warned extensively against overuse of this metric. Although the committee heeded these warnings by adopting a wide range of metrics for this assessment revenues remain an important consideration.

The 2011 survey excluded data that have been collected about licensee activities in the past. Although these activities can be important, SBIR companies have little information regarding the activities of their licensees, other than those that generated revenue for the companies themselves, which are included in baseline sales and revenue data. Descriptions of licensee activities are also in many cases subject to nondisclosure provisions. Hence, given the limitations of the data provided, it did not seem appropriate to include questions about licensee activities in the updated survey.

Reaching the Market

As summarized in Table 3-1, 46 percent of Phase II projects reported some sales or licensing revenues. In and of itself, this is an important finding, because it shows that a substantial number of projects have been sufficiently successful to the point of generating sales revenues. A further 26 percent of Phase II respondents expected to generate sales in the future—a percentage that

[3]"Phase III" is in the context of DoD a technical term for contracts that are officially recognized as following from an SBIR or STTR Phase II award. Not all follow-on contracts are so recorded.
[4]For an overview of the commercialization metrics and survey used in this study, see Appendix A.

TABLE 3-1 Sales (Percent of respondents)

	DoD SBIR Phase II (Percent)
No sales to date, no sales expected	28.1
No sales to date, but sales expected	26.4
Any sales to date	45.5
	100.0
N=	765

NOTE: Data collected 2011. Data covers awards 1998-2007 inclusive.
SOURCE: 2011 NRC Survey, Question 35.

in part reflects the relatively recent date of some awards in the sample and the potentially extended timelines needed to reach required Technology Readiness Levels (TRLs) at DoD. These percentages are substantially in line with results from the 2005 NRC survey and from previous analyses of DoD commercialization datasets.[5]

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 important to also understand the distribution of sales. The survey asked respondents who reported sales to also report the amount of sales, grouped into tiers that reflect different levels of revenue. About 30 percent of Phase II respondents with some sales reported sales of $1M or more; and 8 percent respondents reported sales of $5 million or more (see Table 3-2).

TABLE 3-2 Distribution of Total Sales (Includes only companies with at least some sales)

	DoD SBIR Phase II (Percent)
Under $100,000	23.4
$100,000-$499,999	33.2
$500,000-$999,999	13.2
$1,000,000 or more	30.2
	100.0
N (companies with sales)=	325

SOURCE: 2011 NRC Survey, Question 36, B1.

[5]National Research Council, *Assessment of the SBIR Program at the Department of Defense*, C. W. Wessner, ed., Washington, DC: The National Academies Press, 2009, pp. 89-91.

Markets by Sector

The survey asked respondents about the market sectors in which sales were made. Overall, about 59 percent of sales were made directly to DoD or DoD primes (see Table 3-3).

The low percentage for export sales is also not surprising because DoD work is usually subject to International Traffic in Arms Regulations (ITAR), which restricts the export of defense-related articles and services.

The fact that on average nearly 60 percent of Phase II projects with sales reported sales to DoD or DoD primes suggests that the program is meeting agency needs, particularly because this percentage does not capture sales to other (non-prime) businesses in the defense sector.

Use by Federal Systems or Acquisition Programs

As with previous surveys, respondents were asked whether the funded project was currently in use by a Federal System or Acquisition Program. More than one-fifth of all Phase II respondents report projects whose technology has

TABLE 3-3 Markets for DoD SBIR Products and Services (Percentage of total sales) (Includes only companies with at least some sales)

	Phase II (Percent)
DoD	37.3
Domestic private sector	21.4
Primes for DoD	21.6
Export markets	4.5
Other federal agencies	4.1
NASA	2.4
State or local governments	1.6
Prime contractor for NASA	1.3
Agency that awarded the Phase II (if not NASA or DoD)	0.9
Other (specify)	5.0
	100.0
N=	348

NOTE: For this question, each respondent reported a percentage distribution. Values above were calculated by deriving the mean value for all the responses received for each category.
SOURCE: 2011 NRC Survey, Question 37.

been adopted for federal use. [6]This is a positive outcome, again underscoring ways in which the SBIR program meets agency needs. These data also reveal a substantial increase from 2007, when respondents reported that 12 percent of Phase II projects were in use in federal systems. This increase may be due to enhanced efforts to connect the SBIR program and acquisitions programs (see Chapter 5).[7]

Employment

The SBIR program is often cited as a source of direct employment creation, particularly in high-value Science, Technology, Engineering and Mathematics (STEM) occupations. This firm and job growth in turn can support other economic activity, creating a multiplier effect. As with prior surveys, respondents were asked about the size of the company at the time of the award and at the time of the survey, in terms of number of employees.

The data in Table 3-4 show that among Phase II respondents, the most common company size reported was 20 to 49 employees, although awards were made to a wide range of companies by size, reflected in the distribution shown in Table 3-4. The substantial difference between the mean and median is due to outliers, that is, a few companies with large numbers of employees.

Respondents also provided the current number of employees. Although the results may be affected by selection bias toward surviving companies, the comparisons may be useful. The median size for Phase II companies grew from

TABLE 3-4 Employment at Time of Award

Number of Employees	DoD SBIR Phase II (Percent)
Under 5	19.0
5 to 9	17.6
10 to 19	16.8
20 to 49	23.7
50 to 99	11.4
100 or more	11.5
	100.0
Mean	41
Median	17
N=	727

SOURCE: 2011 NRC Survey, Question 18A.

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[6]2011 NRC Survey, Question 57.
[7]National Research Council, *Assessment of the SBIR Program at the Department of Defense*, op. cit., p. 217.

17 to 24 (see Table 3-5). These data are broadly in line with the median employment numbers reported in 2009.[8]

The percentage of Phase II respondents reporting 100 or more employees also increased—from 11.5 percent of Phase II respondents at the time of award to 15.8 percent at the time of reporting.

The committee concludes that, although they revealed some job growth at many companies, overall the evidence indicates that receiving Phase II awards is not associated with high levels of job growth. It should be noted that employment effects are likely to grow over time and that this analysis does not adjust for the differing elapsed periods between the start of Phase II and the time of the survey.

Further Investment

The ability of SBIR projects and companies to attract further investment has traditionally been an important defining metric for SBIR outcomes.[9] According to the survey results, 61 percent of Phase II projects received additional funding (compared to 54 percent in 2009[10]), which again indicates that SBIR funded projects generate sufficient value to persuade non-SBIR sources to invest funds in them (see Table 3-6).

As with prior surveys, the amount of additional funding received from non-SBIR federal sources is considerably skewed (see Table 3-7). Thirty-six percent of Phase II respondents reported receipt of non-SBIR funding of $1 million or more, while about 18 percent reported funding of less than $100,000.

TABLE 3-5 Employment at Time of Reporting

Number of Employees	DoD SBIR Phase II (Percent)
Under 5	16.0
5 to 9	14.5
10 to 19	15.2
20 to 49	25.1
50 to 99	13.4
100 or more	15.8
Mean	66
Median	24
N=	739

SOURCE: 2011 NRC Survey, Question 18B.

[8]Ibid, pp. 260-261.
[9]National Research Council, *An Assessment of the SBIR Program*, op. cit.
[10]Ibid, p. 262.

TABLE 3-6 Additional Investment after SBIR Award

	DoD SBIR Phase II (Percent)
Yes	61.0
No	39.0
	100.0
N=	765

SOURCE: 2011 NRC Survey, Question 33.

Phase II respondents, more than half reported funding from their own company and from federal non-SBIR. This is especially important in the DoD context, where further funding from acquisition-related sources is a key metric for a technology-related project's progress. Other companies were the next most important source, which also has significant meaning in the DoD context, where links to primes may be captured to some degree in this metric. Personal funds accounted for 10.7 percent of responses, and no other sources were mentioned by more than 7 percent of all respondents. Venture funding accounted for only 2.8 percent of all responses (see Table 3-8).

It is worth highlighting a shift in funding sources since 2009, when only 20 percent reported using non-SBIR federal funding, , because it strongly suggests that connections between SBIR projects and other parts of DoD are becoming closer.[11]

TABLE 3-7 Additional Investments by Non-SBIR Federal Sources by Phase and Amount

	DoD SBIR Phase II (Percent)
Under $100,000	17.8
$100,000-$499,999	31.2
$500,000-$999,999	15.0
$1,000,000 or more	36.0
	100.0
N=	253

NOTE: N=Those reporting additional funds >$0. Table excludes companies with no additional investments.
SOURCE: 2011 NRC Survey, Question 34.1.

[11]Ibid, p. 263.

TABLE 3-8 Sources of Additional Funding

	Phase II (Percent)
Own company	54.6
Federal non-SBIR funding	54.2
Other companies	16.3
Personal funds	10.7
State/local government	6.4
Private equity/angels	3.6
Venture capital	2.8
Foreign private	3.0
Universities/colleges	2.4
N=	467

NOTE: Table excludes companies with no additional investments. Responses do not sum to 100 percent because respondents could select more than one response.
SOURCE: 2011 NRC Survey, Question 34.

Company-Level Development

SBIR companies often commercialize their technology through mergers or other company-level activities. However, evidence from the survey suggests that this was not an especially important outcome for respondents. More than 80 percent of Phase II respondents reported none of the company-level changes listed in Table 3-9: large majority of respondents indicated that their companies had not been acquired, implemented or planned an Initial Public Offering (IPO), or established a spin-off.

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 half of all Phase II respondents reported completion of at least one R&D agreement with U.S.-based companies or investors; slightly more than one-quarter reported customer alliances, and slightly less than one-quarter reported licensing agreements; 19 percent reported manufacturing agreements and 17 percent reported marketing and distribution agreements.

Commercialization Training and Marketing

Federal agencies have in recent years increased the amount of commercialization training for SBIR awardees. In some cases, this training has been mandatory. At DoD, commercialization training is the separate responsibility of each component and is typically delivered through third-party

TABLE 3-9 Company-Level Changes as a Result of the SBIR Funding

	Phase II (Percent)
Established one or more spin-off companies	16.1
Been acquired by/merged with another company	3.5
Made an IPO	1.4
Planning to make an IPO in 2011-2012	0.9
None of the above	80.1
N (unique companies) =	386
N (unique respondents) =	659

NOTE: Responses do not sum to 100 percent because respondents could select more than one answer. Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 10.

contractors such as Dawnbreaker, which provides these services to Navy SBIR awardees. Questions focused on this area were added to the 2011 Survey (see Table 3-11), and responses indicate that about 30 percent of companies had participated. Agency efforts in this area focus heavily on Phase II awardees (see Chapter 6).

TABLE 3-10 Market-Oriented Activities—Finalized Agreements with U.S. Companies and Investors

	Phase II (Percent)
R&D agreement(s)	49.2
Customer alliance(s)	27.0
Licensing agreement(s)	24.2
Manufacturing agreement(s)	18.9
Marketing/distribution agreement(s)	16.8
Joint venture agreement	7.4
Sale of technology rights	6.6
Sale of company	2.9
Company merger	3.3
Partial sale of company	2.9
Other	4.9
N (those reporting at least one such activity) =	244

NOTE: Responses do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 NRC Survey, Question 38.1.

TABLE 3-11 Participation in Commercialization Training

	DoD SBIR Phase II (Percent)
Yes	30.2
No	69.8
	100.0
N=	761

SOURCE: 2011 NRC Survey, Question 17.

A new question to the survey asked whether companies had at least one full-time staff member for marketing; about 40 percent of Phase II respondents indicated that they had at least one full time marketing staffer (see Table 3-12). The relatively small size of the median company may help to explain the limited resources devoted to marketing.

ADDITIONAL EVIDENCE FROM THE CCR DATABASE

As part of its research for this study, the committee reviewed Company Commercialization Register (CCR) data provided by DoD on 18,450 awards. Of these, about half of the awardees had commercialized by generating either sales or additional funding.

Basic Commercialization Metrics

The CCR and the NRC survey provide useful cross-checks on basic commercialization outcomes. They are collected using entirely different mechanisms, and, given the current focus in the NRC survey on responses from principal investigators (PIs), they even draw from a different pool of respondents at SBIR companies.

The most basic metric of SBIR commercialization is whether the project generated sales or additional investment. CCR data as of July 2013 on this core metric (see Figure 3-2) show that for all components just over 50 percent reported some sales, which is consistent with the NRC survey results presented earlier in this chapter which showed that 45 percent of survey respondents had already generated sales. The delays involved in SBIR commercialization (see section on Delays below) illustrates further congruence between NRC and CCR data, as shown in figure 3-2. Similarly, a review of commercialization by component shows that projects at different components largely reach the market at similar rates (Figure 3-2). These comparisons indicate that the results generated from the NRC survey can he viewed with a higher degree of confidence in light of the similar results form the different methodology employed for collecting the CCR data set.

TABLE 3-12 Full-Time Marketing Staff (One or more)

	Phase II (Percent)
Yes	39.0
No	61.0
Total	100.0
N (unique respondents) =	670

SOURCE: 2011 NRC Survey, Question 12.

Although reaching the market is an important milestone of commercialization, it is not sufficient to describe commercial outcomes. For that we also need some sense of scale—how large was the commercialization outcome? Therefore, the second core commercialization metric is "What is the level of commercialization?"

Much work within DoD focuses on the total amount of commercialization, especially the amount reported through FPDS and to a lesser

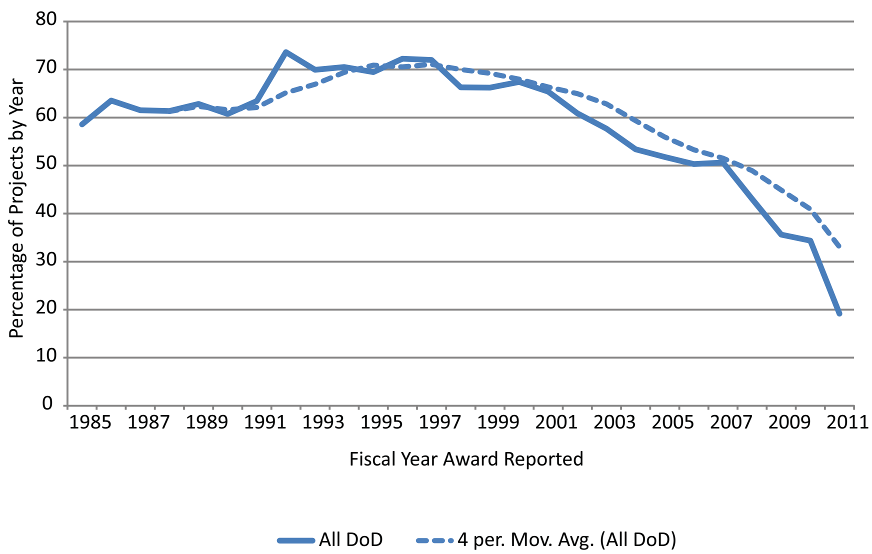

FIGURE 3-1 Cumulative commercialization[12] of DoD Phase II projects over time (projects with returns >$0).
SOURCE: DoD Company Commercialization Record database, August 2013.

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[12]DoD CCR database contains self-reported data from SBIR recipients. All SBIR applicants with previous awards at DoD must update the record for each prior project before they can be awarded a contract. The CCR reports both sales and additional investment as commercialization.

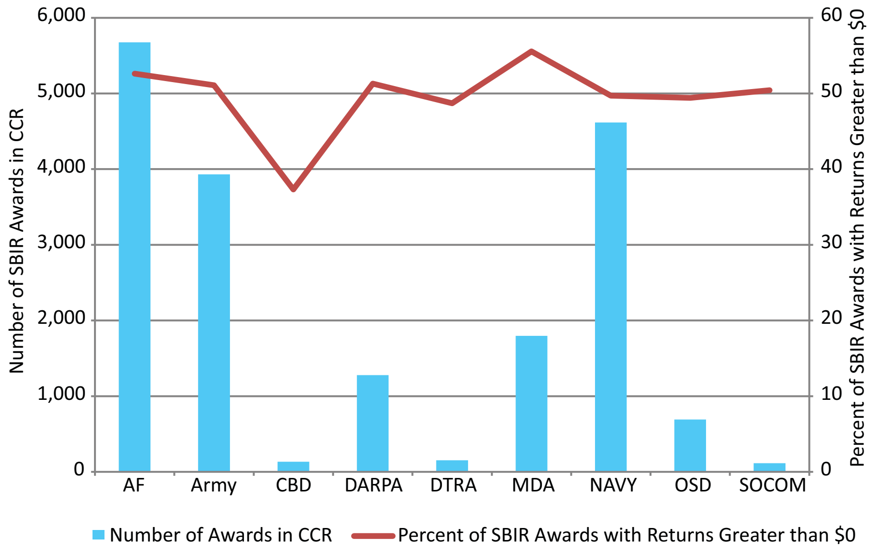

FIGURE 3-2 Commercialization by number and percentage of awards at DoD by component.
SOURCE: DoD CCR database, August 2013.

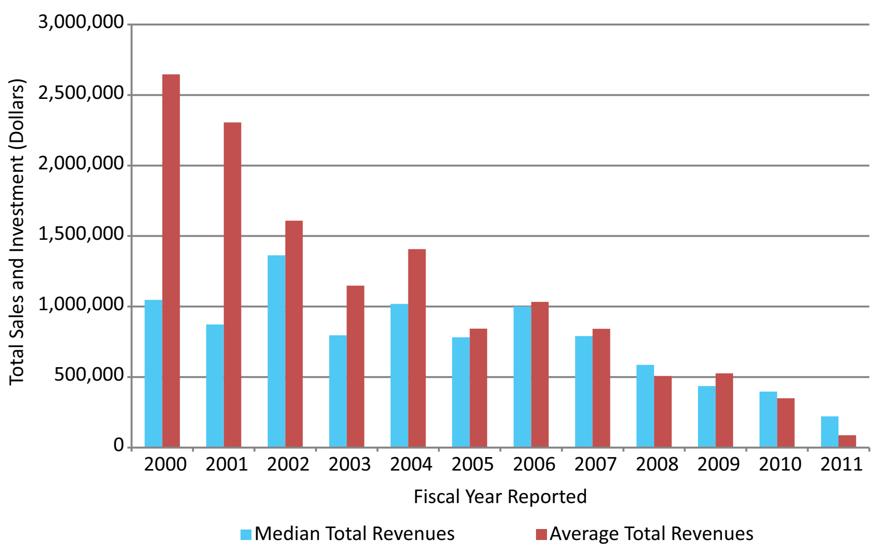

FIGURE 3-3 Average and median total revenues by fiscal year reported.
SOURCE: DoD CCR database, August 2013.

degree CCR. However, this focus—with attendant emphasis on average return on investment (ROI) per project—can be skewed by outliers. For example, a single massive success awarded in 1993 led to mean revenues more than seven times median revenues. Figure 3-3 shows both the median reported revenues and the average reported revenues by fiscal year reported.

The median return once products completed their cycles was about $1 million, for all projects entered into the CCR database, which includes projects returning zero dollars.[13] This median holds when year-by-year fluctuations are disregarded, even if earlier years are reviewed, for example dating back to 1994.

These data provide some evidence about the life cycle of SBIR projects, which appears to end approximately 8 years after the date of award. As a result, aggregate revenue for a project on average continues to increase until 8 years after the award. It should be expected, therefore, that projects awarded in 2013, will—at the median—complete their commercialization cycle by approximately 2021.

The data also suggest that we have not yet seen conclusive quantitative results of policy changes made late in the 2000s, or systematic results from the more recent commercialization initiatives described in Chapter 4.

This finding has important implications for policy analysis. Most notably, efforts to assess commercialization on a shorter time scale—for example, 2 to 4 years after the end of projects—will likely overlook the steady increase in commercialization that occurs over time. Furthermore, when making policy adjustments to the SBIR program, focusing exclusively on short-term outcomes, or, conversely, overlooking longer-term outcomes, is a mistake. While it is possible to develop intermediate metrics, policymakers should understand that commercialization is, in the end, a long-term process that must be addressed through analysis covering a considerable span of years.

However, if reliance on short-run data would be a mistake, and products take many years to move through their life cycles, then it will be important for DoD to develop systematically measurable quantitative milestones *prior to commercialization*.

Commercialization by Component

The summary numbers for commercialization published by DoD and its components have focused to a considerable degree on total commercialization, usually expressed by year. Although DoD itself in most cases relies on utilizes the FPDS database, the data from the CCR database provide similar insights. Figure 3-4 aggregates all revenues generated by all projects in the CCR database.

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[13]According to Office of Small Business (OSB) staff, the database contains all DoD SBIR projects awarded since FY2002, and a large preponderance of awards from before that date. So the median figure above is for all projects, including those with zero returns.

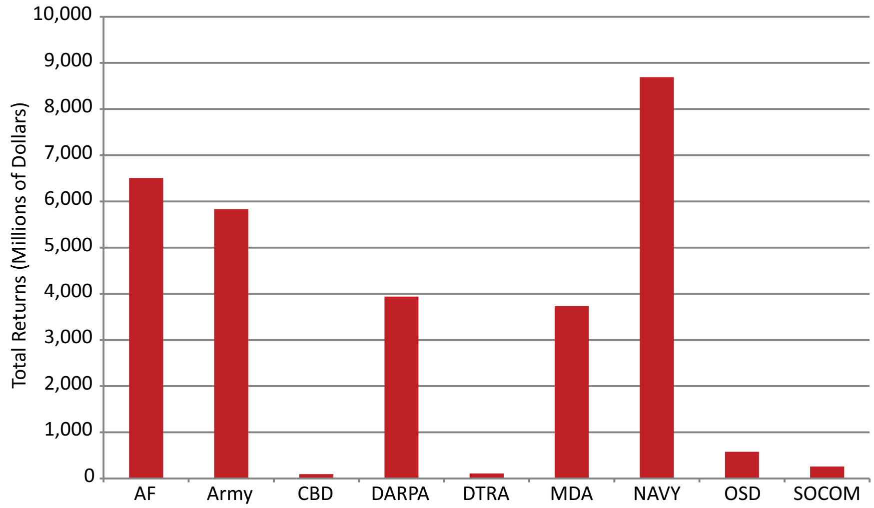

FIGURE 3-4 Aggregated additional revenues and investments for SBIR projects, by component, for Phase II awards, 1992-2013.
SOURCE: DoD CCR database, August 2013.

However, this simple approach is misleading. Figure 3-5 shows that median returns by component were quite similar, unlike average returns, and

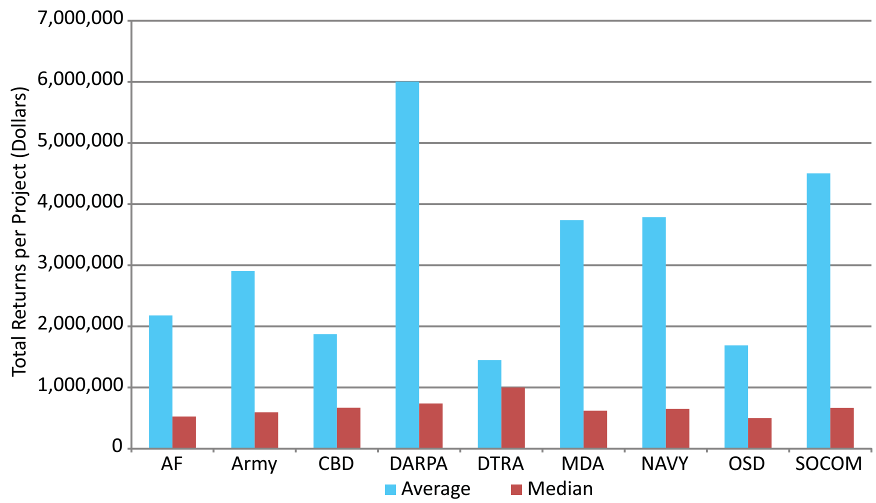

FIGURE 3-5 Average and median total returns for awards by component, FY 1992-2013.
SOURCE: DoD CCR database, August 2013.

that returns at DARPA in particular were positively affected by a single very large project in a portfolio containing a relatively small number of projects.

CONCLUSIONS: COMMERCIALIZATION

Evidence from the NRC survey provides useful insight into the commercialization record of SBIR companies at DoD, on a number of dimensions. Most importantly, the data confirm that a substantial percentage of projects do indeed commercialize through sales of products or services and/or through the receipt of additional development funding.

Forty-five percent of Phase II respondents indicated that their company had already recorded sales of products or services derived from the awarded project. A further 25 percent were expecting sales in the future. Given the relatively short time between the award date and the survey date, these expectations are not unreasonable. The NRC survey and the CCR database reported similar levels of market reach for Phase II awards.

SBIR commercialization is also associated with take-up by DoD. About 60 percent of Phase II projects with some revenues recorded sales to DoD or DoD primes. Further 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 DoD, where careful technology readiness assessment must occur before interest emerges from acquisitions groups. Slightly more than 60 percent of Phase II respondents reported that the project acquired additional funding, and about 9 percent reported receiving $5 million or more.

Of the subset of Phase II projects that received additional funding, more than one-half received it from federal non-SBIR sources, which reflects linkages between the SBIR program and federal acquisition programs, while 16 percent received funding from other private companies, which may include DoD primes. This figure may reflect difficulties in dealing with the primes—see Chapter 6.

Finally, the source of additional investment has shifted. In the current survey, almost three times as many Phase II respondents reported that their company acquired non-SBIR federal funding as did those reporting in the previous survey. This shift may reflect the substantial efforts within DoD to more closely link the SBIR program with the acquisition programs that are the primary source of additional development funding.

Clearly, Phase II SBIR funding is strongly correlated with positive market outcomes, and with links into the DoD acquisition programs either directly or through subcontracts with the DoD primes.

KNOWLEDGE EFFECTS

One of the four congressionally mandated objectives for the SBIR program is to “stimulate technological innovation,” which is often equated to patenting activity. However, in the context of small business, this standard metric of innovation does not capture the entire story: patenting is important, but it is also expensive, and there is some uncertainty across DoD components and services whether SBIR funds can be legally be used for this purpose.[14] In addition, many companies interviewed for this report 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.

However, standard metrics provide at least a starting point for quantitative analysis. Consequently, the survey addressed several metrics related to intellectual property (IP): patents, trademarks, copyrights, and peer-reviewed papers.[15]

Patents

Because patents at small companies often result from multiple contracts in multiple projects, it is important to capture patents related to the surveyed project surveyed and as well as patents more generally attributable to SBIR-funded research.

Overall, about 60 percent of Phase II respondents who answered questions about patents claimed to have been awarded at least one patent related to any SBIR-funded technology, and 10 percent reported at least 10 SBIR-related patents (see Table 3-13), results that are almost identical to those from NRC's Company Survey in 2009.[16] We note however that a considerable number of respondents (approximately 343 out of 765—or more than 50 percent) did not answer this question. It seems plausible that respondents with no patents to report may have been more likely to have skipped this section, so these results should be viewed with an appropriate degree of caution.

So far as the specific project being surveyed is concerned, about 30 percent of respondents reported that their company had received at least one patent related to the surveyed project (see Table 3-14). Again, this finding is very close to that reported in 2009.[17]

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[14]DCAA does sometimes allow patent costs in the General and Administrative rates (G&A) for SBIR companies. An active discussion, whether patents should be direct or indirect costs, is now taking place between small businesses and DCAA on allowing patent costs that arise from an SBIR invention.

[15]It is important to note that the value of these representations of intellectual property varies. Any unique item painting, photo, music score, can be copy-written for a modest fee. Trademarks include a bit more process, 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 not as valued outside of academia as inside. There is no tenure track requirement to publish such articles. The university professors who participate in SBIR may be responsible for production of the number of such articles.

[16]National Research Council, *Assessment of the SBIR Program at the Department of Defense*, op. cit., p. 270.

[17]Ibid, p. 148.

TABLE 3-13 Number of Patents Related to All Company SBIR Awards

	Phase II (Percent)
0	42.0
1 or 2	24.7
3 or 4	12.1
5 to 9	11.3
10 or more	10.0
Total	100.0
At least 1	58.0
N (unique companies) =	374
N (unique respondents) =	643

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 11.

There was limited interest among companies in either trademarks or copyrights, the two other primary forms of legal protection for intellectual property.

TABLE 3-14 Number of Patents Related to Surveyed Project

	Phase II (Percent)
0	68.2
1	17.3
2	9.2
3	2.6
More than 3	2.6
Total	100.0
At least 1	31.8
N=	422

NOTE: The number of respondents for this question is considerably lower than for many other questions. It is perhaps likely that respondents with no project related patents or related peer reviewed articles may have skipped this section, so responses should be analyzed bearing in mind this possibility.
SOURCE: 2011 NRC Survey, Question 39.1.2.

Peer-Reviewed Publications

Knowledge from publicly funded research is not primarily transmitted through patents. Peer-reviewed publications have become a standard metric for knowledge transfer. As the evidence below indicates, there are many incentives for small companies to publish their research. However, there are significant difficulties in applying these standards to small businesses whose technical knowledge is in many cases their only source of competitive advantage. For this reason, there are also significant disincentives to participate in peer-reviewed publication.

Data from the survey suggest that companies and their staff do widely participate in this knowledge transmission process. Almost 75 percent of the Phase II respondents who answered this question indicated that an author at the surveyed company had published at least one scientific paper related to the surveyed project, and more than a quarter reported publishing 3 or more (see Table 3-15).

Links to Universities

An additional metric for knowledge transfer is the development of linkages with universities, in both directions. Data from the survey indicate that SBIR projects often develop close university ties. For example, in response to questions about the use of university staff and facilities on the surveyed project, Just over one-third of respondents reported a university connection of some kind. This represents an increase from the 2007 survey, when one-quarter of respondents reported a university linkage.[18] The most reported types of linkage were a faculty member working on the project but not as a PI; graduate students employed on the project; and a university or college as a subcontractor on the project. (see Table 3-16).

Respondents were also asked to identify the universities with which they worked in various capacities on this project. Overall, 211 different universities and colleges were identified. Those mentioned by 10 or more respondents are listed in Table 3-17 (see Appendix C for the complete list of universities).

Many of the universities are large state universities, a number of which have in recent years focused on technology transition as well as basic research. The University of California system had 56 mentions and the University of Texas system had 22. (See Appendix C.) Although far from a perfect metric, these data provide an initial picture of the connections between specific universities, university systems, and the DoD SBIR program.

Finally, 60 percent of the companies in the sample had at least one

[18]Ibid, p. 265.

TABLE 3-15 Number of Scientific Publications Related to the Surveyed Project

	DoD SBIR Phase II (Percent)
0	25.6
1	18.0
2	17.8
3	12.7
More than 3	25.8
Total	100.0
At least 1	74.4
N=	488

NOTE: The number of respondents for this question is considerably lower than for many other questions. It is perhaps likely that respondents with no project related patents or related peer reviewed articles may have skipped this section, so responses should be analyzed bearing in mind this possibility.
SOURCE: 2011 NRC Survey, Question 39.4.2.

founder with an academic background[19] and about 25 percent had at least one founder who was most recently employed at a college or university.[20]

TABLE 3-16 Links to Universities

	Phase II (Percent)
Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI	18.8
A university or college was a subcontractor on this project	19.7
Graduate students worked on this project	17.7
The technology for this project was originally developed at a university or college by one of the participants in this project	7.7
The PI for this project was an adjunct faculty member	3.3
The technology for this project was licensed from a university or college	3.1
The PI for this project was a faculty member	1.7
Any of the above	34.8
N=	750

SOURCE: 2011 NRC Survey, Question 59.

[19]The definition of "academic background" is left to the recipient, following previous GAO and NRC survey practices.
[20]2011 NRC Survey, Question 4D.

TABLE 3-17 University Participants Mentioned by 10 or More Respondents

	Number of Mentions
University of Colorado	28
MIT	24
Georgia Institute of Technology	23
University of Florida	22
Pennsylvania State University	21
Purdue University	19
University of Maryland	17
University of Michigan	17
Stanford University	14
UC Berkeley	14
University of Minnesota	14
University of Illinois	13
Dartmouth College	11
Ohio State University	11
University of Alabama	11
University of Arizona	10
University of Central Florida	10
University of Massachusetts	10
University of Texas at Austin	10

SOURCE: 2011 NRC Survey, Question 60.

Conclusions: Knowledge Effects

The data reveals that small companies are key drivers of technological knowledge and innovation, a considerable amount of which is protected through the patent system. About 60 percent of Phase II respondents who answered the question about patents reported that their company had received at least one patent based on its work under SBIR contracts, while about one-third reported at least one patent related to the surveyed project alone.

SBIR companies participate at a high level in the standard form of technical knowledge dissemination: publishing in peer-reviewed journals. About 75 percent of Phase II respondents who answered questions about peer reviewed articles reported that their company published at least one article based on the SBIR-funded work, and 25 percent reported publication of at least three such papers.

BOX 3-1

Workshop on Improving University-SBIR Linkages

On February 5 2014, the committee convened a workshop at the National Academies on Universities and the SBIR/STTR.[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]*<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 NAS report on the STTR program.

Finally, some SBIR companies are closely connected to the universities. About one-third of Phase II respondents reported a university connection on the surveyed project, and 19 universities were specifically mentioned as playing a role in at least 10 reported projects. This suggests that SBIR plays a potentially important role in supporting the practical implementation of university research.

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 determining whether a specific factor was a *necessary* condition for success is challenging. Furthermore, the large number of factors and the multiple paths to success and failure lessen the ability to state with confidence that a particular intervention—in this case an SBIR award—constitutes a *sufficient* condition for a project's success.

One approach has been to ask recipients for their own views on the program's impact on their project or company. What would have happened to the project absent the SBIR award? Would it have proceeded anyway, and, if so, in what form? This section addresses these questions.

Project Go-Ahead Absent SBIR Funding

The survey asked whether the project would have been undertaken absent SBIR funding, and, if so, whether the scope and timing would have been affected. The results strongly support the view that SBIR funding affected the decision to move or not move forward (see Table 3-18). Slightly less than 8 percent of the Phase II respondents indicated that there was even a probability that the project would have proceeded without SBIR funding. In contrast, more than 80 percent thought the project would most likely not have proceeded absent SBIR funding: 38 percent were definite that the project would not have proceeded, and 43 percent thought it unlikely. Responses in 2007 were similar, although fewer respondents believed the project would not have proceeded (70 percent).[21] These data highlight interesting wider implications for the debate about early-stage funding: they suggest a weakness in the "crowding out" hypothesis, because it would appear that awardees—presumably those with the closest knowledge of funding prospects for the project—overwhelmingly believed it unlikely that funding alternatives to SBIR could be found.[22]

Project Scope Absent SBIR Funding

SBIR funding may also have affected project scope: additional funding through the SBIR program may have led to an expansion of project scope. However, because DoD awards SBIR funding to proposals that closely meet agency criteria for a specific topic (which can be very tightly drawn), tailoring a project to the demands of a particular solicitation could also potentially reduce its scope.[23]

The committee's analysis focused only on the responses indicating that the project would have definitely proceeded absent program funding. Most respondents indicated that the absence of SBIR funding would have limited the project scope. Interestingly, however, about 13 percent indicated that SBIR funding would have limited the project's scope, most likely because of the need to meet the specific SBIR award criteria (see Table 3-19).

Project Delays Absent SBIR Funding

As with project scope, the immediate supposition is that, absent SBIR funding, projects would have been delayed while other funding was identified

[21]National Research Council, *Assessment of the SBIR Program at the Department of Defense*, p. 259.
[22]See discussion of crowding out in Dirk Czarnitzki and Andreas Fier, *Do Innovation Subsidies Crowd out Private Investment? Evidence from the German Service Sector*, ZEW Discussion Papers, No.02-04, 2002.
[23]SBIR topics posted by DoD vary substantially, and there is no requirement or standard that each topic should contain a certain amount of specificity. Over the past 15 years, the character of topics in the DoD solicitation has perceptibly changed, becoming more specific, according to companies interviewed for this project as well as interviews with agency staff.

TABLE 3-18 Project Undertaken in the Absence of SBIR Funding

	Phase II (Percent)
Yes	7.8
Definitely yes	1.2
Probably yes	6.7
Uncertain	11.5
Probably not	42.9
Definitely not	37.8
Total	100.0
N=	765

SOURCE: 2011 NRC Survey, Question 24.

and acquired. However, as we shall see when considering program operations later in this report, SBIR awards involve delays of their own, which can in some cases be substantial. This question addresses the balance between delays imposed by the need to seek alternative funding and delays inherent in the SBIR program.

A majority of respondents who were certain that the project would have proceeded absent SBIR funding agreed that the absence of SBIR funding would have delayed the project (see Table 3-20). Seventy-five percent reported that the project would have been delayed by at least 12 months—up from the 50 percent reported in 2009.[24] Given that gaps and delays can significantly impact the viability of small companies with limited resources to retain technical teams, this would seem to be an important consideration.

TABLE 3-19 Project Scope in the Absence of SBIR Funding

	Phase II (Percent)
Broader	13.3
Similar	26.7
Narrower	60.0
Total	100.0
N=	60

NOTE: Based on responses from 60 companies who were certain that the project would have proceeded even without the SBIR award.
SOURCE: 2011 NRC Survey, Question 25.

[24]National Research Council, *Assessment of the SBIR Program at the Department of Defense*, op. cit. p. 260.

TABLE 3-20 Likely Project Delay in the Absence of SBIR Funding

	Phase II (Percent)
< 12 months	25.0
12-23 months	50.0
24 to 35 months	14.3
≥36 months longer	10.7
Total	100.0
N=	56

NOTE: Based on responses from 60 companies who were certain that the project would have proceeded even without the SBIR award.
SOURCE: 2011 NRC Survey, Question 26B.

SBIR Funding and Project Duration

The survey also asked respondents to determine how the absence of SBIR funding would have affected the project duration. More than 80 percent reported that the project would have taken longer (see Table 3-21). This is also a potentially important finding, in that delays in bringing projects to conclusion, and hence to the point of potential market entry, can have a negative effect on company prospects, because the window for market entry can be a narrow one.

Long-Term Impacts on the Recipient Company

Although SBIR awards have direct effects on specific projects, they can also have a powerful 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 issue directly. The results are striking: they demonstrate a clear positive long-term impact on recipient companies (see Table 3-22). Overall, 20 percent of Phase II respondents

TABLE 3-21 Project Longevity in the Absence of SBIR Funding

	Phase II (Percent)
Longer	83.3
The same	15.0
Shorter	1.7
Total	100.0
N=	60

NOTE: Based on responses from 60 companies who were certain that the project would have proceeded even without the SBIR award.
SOURCE: 2011 NRC Survey, Question 26B.

TABLE 3-22 Long-Term Impacts of SBIR Funding on Recipient Companies

	DoD SBIR Phase II (Percent)
Had a transformative effect	20.2
Had a substantial positive long-term effect	56.8
Had a small positive effect	17.2
Had no long-term effect	3.8
Had a negative long-term effect	1.9
Total	100.0
N (unique companies) =	416
N (unique respondents) =	762

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 45.

indicated that SBIR funding had a transformative effect on their company, and a further 56 percent reported a substantial positive effect. Only 2 percent reported negative effects.

Key Aspects of SBIR-Driven Transformation

It is not easy to summarize the numerous ways in which DoD SBIR awards helped to transform recipient companies. The key aspects of SBIR-driven transformation are explored in more detail in Chapter 5, which draws extensively on the numerous open-ended comments received in response to this question. What follows, therefore, is a limited list of impacts:

- provided first dollars;
- funded areas that did not interest venture capital and other funders;
- created connections to acquisition programs;
- opened doors to many potential stakeholders in specific technologies, including agencies, primes, investors, suppliers, subcontractors, and universities;
- assisted entry into niche markets too small for major players/funders;
- funded technology development;
- enabled projects with high levels of technical risk;
- supported adaptation of technologies to new uses, markets, and industry sectors;
- diversified expertise and allowed hiring of specialists;
- replaced private capital funding during downturns;
- attracted and developed young researchers;

- redirected company activities to new opportunities;
- developed connections to primes;
- reduced costs;
- helped address needs that require high technology at low volume and relatively low cost;
- moved technology up to technology readiness level (TRL) 7-9 (at which point acquisition funding becomes more possible);
- provided new companies with immediate credibility;
- funded researchers to enter business full time;
- helped university researchers manage IP and ITAR problems;
- transformed company culture to become more market driven;
- drove researchers to focus on technology transition;
- created new companies and kept companies in business (that would not exist without SBIR funding); and
- supported feasibility testing for high-risk, high-payoff projects (Phase I).

Overall, the strongest conclusion drawn from these responses is that small innovative companies are highly sensitive to the impact of exogenous variables. The sudden withdrawal of a sponsor can crush a company; a single contract can provide funding for 2 or 3 years of growth. And above all, these small companies are highly path dependent: what happens to them at a given moment can have long lasting effects.

In the end, SBIR was in many cases a profoundly positive exogenous variable: one that provides funding, validation, and market access that are otherwise not available. Although it is difficult to link one SBIR award to the eventual success of a large corporation, in fact, SBIR awards played a key role in enabling some very small companies to grow into larger ones.

COMPANY AND PROJECT CHARACTERISTICS: INDEPENDENT VARIABLES

The outcomes section above strongly suggests that, overall, Phase II SBIR funding at DoD correlates with commercial success. However, a variety of other factors may play a role, which the survey sought to identify.

Founders and Company Foundation

Venture investors focus heavily on the composition of the company team when deciding whether to make an investment. Accordingly, it seemed appropriate to explore the characteristics of company founders.

About 41 percent of Phase II respondents indicated that the company had one founder, 31 percent reported two founders, 28 percent reported more than two founders. (see Table 3-23).

TABLE 3-23 Number of Founders

	DoD SBIR Phase II (Percent)
1	41.8
2	30.8
3	16.1
4	7.7
5 or more	3.5
	100.0
N (unique companies) =	382
N (unique respondents) =	660

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 4A.

Venture investors also consider previous experience in founding companies, on the theory that some mistakes will have been made and lessons learned. Pursuing this line of questioning enabled the committee to estimate the use of SBIR by serial company founders. about 60 percent of Phase II respondents indicated that their companies did not have a founder who had previously founded a company. About 7 percent of Phase II respondents reported founders of three or more companies (see Table 3-24).

TABLE 3-24 Number of Previous Companies Started by Founders

	DoD SBIR Phase II (Percent)
0	62.0
1	17.8
2	12.9
3	4.2
4	1.3
5 or more	1.8
	100.0 percent
N (unique companies) =	382
N (unique respondents) =	660

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 4B.

Slightly less than one-half of Phase II respondents reported at least one founder with a business background (see Table 3-25), and just over 60 percent of all respondents reported at least one founder with an academic background (see Table 3-26). Although almost three-quarters of founders were previously employed at other private companies, more than a one-quarter of respondents reported at least one founder previously employed at a college of university.

Previous studies from the NRC have asserted that for at least some companies, SBIR funding provided opportunities that led directly to company formation. Here, more than one-third of respondents indicated that the surveyed award contributed to some degree to the formation of the company (see Table 3-28).

Industry Sector

Previous analyses of SBIR 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 3-29 shows the distribution of responses by sector and phase.

TABLE 3-25 Number of Founders with Business Backgrounds

	DoD SBIR Phase II (Percent)
None	51.7
1	32.2
2	11.0
3	2.9
4	1.4
5 or more	0.7
Total	100.0
At least 1	48.2
N (unique companies) =	382
N (unique respondents) =	660

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 4C.

TABLE 3-26 Number of Founders with Academic Backgrounds

	DoD SBIR Phase II (Percent)
None	38.8
1	39.9
2	12.2
3	4.2
4	3.6
5 or more	1.4
Total	100.0
At least 1	61.3
N (unique companies) =	382
N (unique respondents) =	660

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 4D.

This question was designed to provide an approximate map of activities by sector. There is considerable overlap between some categories, and respondents had substantial leeway to define sectors, so these data should be viewed as highly preliminary. However, several key points emerged from the data:

- **Defense-orientation.** About 70 percent of Phase II respondents indicated that their project was in defense-specific products and services.

TABLE 3-27 Prior Employment of Founders

	DoD SBIR Phase II (Percent)
Other private company	73.1
College or university	27.6
Government	9.2
Other	4.8
N (unique companies) =	391
N (unique respondents) =	671

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 5.

TABLE 3-28 Company Founded Because of SBIR Program

	DoD SBIR Phase II (Percent)
Yes	17.9
In part	17.5
No	64.7
Total	100.0
N=	673

SOURCE: 2011 NRC Survey, Question 6.

- **Dominant sectors.** Engineering and aerospace were the two dominant sectors (at 52 percent and 46 percent of Phase II responses respectively), followed by materials (23 percent) and IT (18 percent).

Project Status and Review of Discontinued Projects

Because the survey covers 10 years of Phase II awards, projects were at different stages of completion at the time of the survey. As noted in previous NRC analyses, this implies that project outcomes were in aggregate substantially under-reported, because of the number of projects whose entire life cycle was not yet complete. Table 3-30 shows the current status of the projects surveyed.

For Phase II respondents, 28 percent reported products or processes in use, while about 30 percent reported projects had been discontinued and 27 percent reported projects still in development.[25]

About one-fifth of the Phase II projects with outputs in use recorded sales to customers not expected at the time of the award. This reflects the flexible path often necessary for technology-based commercialization in this sector.

The survey sought explanations as to why company efforts had been discontinued (see Table 3-31). For Phase II respondents, no single explanation dominated—none of the options was selected by at least one-quarter of respondents. Market-related categories together totaled about 25 percent, which was only slightly higher than the “other” category, and lack of funding accounted for about the same percentage of responses. However, the percentage of market-related failures suggests that many Phase II projects do not advance far enough on the production curve to reach a market in which they might succeed or fail.

[25]Sometimes SBIR-funded research is picked up later at another company. This survey focused on the original recipient.

TABLE 3-29 Distribution of Responses by Sector

Technology Sector	DoD SBIR Phase II (Percent)
Aerospace	46.3
Defense-specific products and services	71.6
Energy and the environment	10.7
- Sustainable energy production (solar, wind, geothermal, bio-energy, wave)	2.2
- Energy storage and distribution	2.0
- Energy saving	2.5
- Other energy or environmental products and services	3.0
Engineering	51.9
- Engineering services	14.3
- Scientific instruments and measuring equipment	12.6
- Robotics	5.5
- Sensors	24.0
- Other engineering	10.6
Information technology (IT)	18.2
- Computers and peripheral equipment	4.2
- Telecommunications equipment and services	3.8
- Business and productivity software	3.3
- Data processing and database software and services	5.9
- Media products (including web-, print- and wireless-delivered content)	1.3
- Other IT	5.4
Materials (including nanotechnology for materials)	23.1
- Medical technologies	2.1
- Pharmaceuticals	0.7
- Medical devices	5.9
- Other biotechnology products	2.2
- Other medical products and services	1.6
Other (please describe)	12.6
N=	765
T (total responses)=	2,650

NOTE: Answers do not sum to 100 percent because respondents could select more than one response.
SOURCE: 2011 NRC Survey, Question 20.

TABLE 3-30 Current Status of Surveyed Projects

	DoD SBIR Phase II (Percent)
Project has not yet completed [SBIR] funded research	2.4
Efforts at this company have been discontinued	30.7
Discontinued because no sales or additional funding resulted from this project	20.8
Discontinued—The project did result in sales, licensing of technology, or additional funding	9.9
Project is continuing post-award technology development	26.9
Commercialization is under way	12.4
Products/Processes/Services are in use	27.6
In use by target customers	21.7 percent
In use by customers not anticipated at the time of the award	5.9 percent
Total (primary categories)	100.0
N=	765

SOURCE: 2011 NRC Survey, Question 30.

TABLE 3-31 Primary Reason for Project Discontinuation

	DoD SBIR Phase II (Percent)
Not enough funding	24.8
Project goal was achieved (e.g. prototype delivered for federal agency use)	16.5
Market demand too small	13.0
Company shifted priorities	2.6
Level of technical risk too high	2.6
Other reason mentioned:	40.4
	100.0
N=	230

NOTE: N= Respondents with awards no longer active.
SOURCE: 2011 NRC Survey, Question 32.

Company Size by Revenue

SBIR is aimed at supporting small companies. As employment data show, most awardee companies are much smaller than the Small Business Administration (SBA) maximum size for small companies (500 employees in most sectors).[26]

At the time of the survey, about 24 percent of awardee companies responding to the 2011 survey had revenues of $5 million or more, and 1.4 percent had revenues of $100 million or more. Further, about 24 percent of Phase II respondents reported that their companies had less than $500,000 in revenues. (see Table 3-32).[27]

Company Activities and SBIR

The case studies conducted for this assessment reveal that in many cases the role of SBIR's in the development of the small firm diminished over

TABLE 3-32 Company Annual Revenues by Phase (Most recent fiscal year)

	DoD SBIR Phase II (Percent)
Less than $100,000	10.0
$100,000-$499,999	13.9
$500,000-$999,999	12.2
$1,000,000-$4,999,999	37.6
$5,000,000-$19,999,999	18.3
$20,000,000-$99,999,999	6.7
$100,000,000 or more	1.4
	100.0
N (unique companies) =	385
N (unique respondents) =	659

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 8.

[26]See SBA, Table of Small Business Size Standards Matched to North American Industry Classification System Codes, <*http://www.naics.com/naicsfiles/Size_Standards_Table.pdf*>. Accessed 10/20/13.
[27]The issue of potential non-respondent bias is addressed in Appendix A.

time as the company became less dependent on SBIR, that is, commercial products reached the market. The following section reviews survey data related to this issue.[28]

SBIR Share of R&D Effort

The survey asked respondents to estimate 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.

Approximately two thirds of all Phase II companies were described by respondents as devoting 25 percent or less of their R&D effort to SBIR projects, while about 15 percent devoted more than 75 percent. (See Table 3-33).

These results correspond fairly closely to those from Question 9, which asked what percentage of company revenues during the current year were derived from SBIR projects (see Table 3-34).

TABLE 3-33 Percentage of R&D Effort Expended on SBIR Projects (Most recent fiscal year)

	DoD SBIR Phase II (Percent)
0%	17.3
1%-10%	14.5
11%-25%	15.9
26%-50%	19.5
51%-75%	17.6
76%-100%	15.2
	100.0
N (unique companies) =	387
N (unique respondents) =	660

NOTE: Because multiple responses were received from some companies (those with more than one PI or with PIs who provide more than one responses, multiple responses from a single company were averaged to generate data by company. The table includes this averaged data.
SOURCE: 2011 NRC Survey, Question 7.

[28]The contention that that there are a large number of companies that live off a stream of SBIR contracts with few if any commercialized products has been dispelled in previous NRC reports. See National Research Council, *An Assessment of the SBIR Program*, op. cit., p. 86. In addition, our review of agency practices shows that DoD program managers seek to exclude companies that seek additional awards but have a poor commercialization record.

Prior Use of the SBIR Program

The linear model of innovation implies that ideas are tested in Phase I, prototyped in Phase II, and commercialized in Phase III,[29] but there is considerable evidence to suggest that this model over-simplifies the process. Often, multiple iterations are required, or projects must restart with an earlier phase, or multiple efforts are needed to meet specific problems.

The survey asked respondents to indicate how many prior SBIR or STTR Phase I awards had been received by the company that were related to the project being surveyed. Nearly 80 percent of respondents overall reported receipt or one or more prior awards related to the same product/problem the surveyed award was intended to address. (See Table 3-34). This suggests that the norm is for companies to need several rounds of funding and research in the course of product development.

Prior Investment

One question surrounding the SBIR program is its role in the *sequence* of funding that leads from an idea to a product. As shown in Table 3-35, about two-thirds of respondents indicated that the company received investment funding for the surveyed technology *prior* to receiving the surveyed award.

TABLE 3-34 Number of Prior SBIR or STTR Phase I Awards Related to the Surveyed Project

	DoD SBIR Phase II (Percent)
0	20.0
1	34.4
2	17.3
3	11.5
4	6.5
5 or more	10.2 percent
Total	100.0
1 or more	80.0
N=	704

SOURCE: 2011 NRC Survey, Question 40.1.1.

[29]For a review of the model and its intellectual history, see B. Godin, "The Linear Model of Innovation: The Historical Construction of an Analytical Framework," Project on the History and Sociology of S&T Statistics Working Paper No. 30, 2005. Godin indicates that an important source for the model was Vannevar Bush's famous paper, Science: The Endless Frontier, published in 1945.

TABLE 3-35 Sources of Funding, Prior to SBIR Award, for Related Technology

	DoD SBIR Phase II (Percent)
Internal company investment (including borrowed money)	52.7
Prior [SBIR] (excluding the Phase I that preceded this Phase II) (a)	53.3
Prior non-[SBIR] federal R&D	30.0
Other private company	14.0
Private investor (including angel funding)	9.5
State or local government	7.7
Venture capital	5.7
College or university	3.7
Other (please specify)	6.1
N=	493

SOURCE: 2011 NRC Survey, Question 21.

Overall, about two-thirds of respondents reported at least one source of additional funds. The largest source of prior funding was internal company funds, closely followed by previous SBIR awards.

Overall, 7.5 percent of Phase II respondents indicated that they had previously received venture capital (VC) funding.

CONCLUSIONS

Evidence reported in this chapter provides supports the conclusion that DoD is meeting Congressionally mandated objectives for the SBIR program with regard to commercialization and knowledge production. With regard to commercialization, projects funded by the SBIR program are reaching the market at - in the Committee's judgment - an appropriate rate, and are also attracting substantial amounts of follow-on investment, which is in many cases a necessary next step toward commercialization. The data also show that knowledge effects from the SBIR program are positive, as funded projects generate a large number of patents and peer-reviewed articles.

There is only limited evidence from the 2011 NRC Survey and CCR database to indicate that projects are being taken up for use in DoD directly or indirectly through DoD primes in considerable numbers. We follow up on this point with a more detailed review of agency use of SBIR funded technologies in Chapter 4. Evidence from the 2011 NRC Survey about the fourth objective—support for women and minorities—is discussed in Chapter 6.

4

Commercialization Initiatives in the DoD SBIR Program

Over the past 20 years, the Department of Defense (DoD) has greatly increased its efforts to accelerate transition and to make the Small Business Innovation Research (SBIR) program a much more integral part of weapons acquisition and procurement more generally. This chapter reviews the many initiatives and programs developed primarily to achieve these goals.[1]

Although DoD is by no means a monolithic entity, it is convenient (and necessary sometimes) to talk about the "DoD SBIR program." However, the reality is that no such program actually exists—there are quite different programs at each of the Services, and many of the larger components have differentiated programs as well.

So the discussion of commercialization initiatives in this chapter reflects the fact that while initiatives—and especially policy guidance—come from DoD or even Congress, many come from efforts at the Services or even Systems Command (SYSCOM) or Program Executive Office (PEO) level to make the program work better. Initiatives are not by any means always adopted by other components even if they prove successful. And adoption of initiatives may be uneven even within a Service. Data for this chapter have been gathered primarily from DoD documents and other public records, as well as agency interviews. In some cases, private material has been shared by DoD (these are referenced internally). These sources are discussed in more detail in Appendix A.

This chapter provides a framework for understanding the broad thrust of developments within DoD by identifying and explaining specific efforts and initiatives. It should not be read as a definitive description of activities on the

[1]Material for this chapter was sourced primarily from a range of DoD documents provided to the NRC, and interviews with SBIR and acquisitions officers at Navy. Air Force, SOCOM, and DARPA, as well as the DoD SBIR office, conducted in May and June 20 2013. Efforts to interview Army staff were unsuccessful.

ground. The chapter begins, however, with a key question: What does commercialization mean at DoD?

WHAT IS PHASE III?

"Phase III" is usually taken to refer to the period of commercialization after the end of Phase II. However, in the specific context of DoD, "Phase III" has two distinct meanings that are often conflated or confused when discussing commercialization at DoD.

In terms of the SBIR legislation, "Phase III" simply means further commercialization of an SBIR-funded product or service *without the use of SBIR funding.* It is, simply put, an unfunded Phase into which projects are expected to move after completing Phase II. Thus, at non-procurement agencies such as the National Institutes of Health (NIH) and the National Science Foundation (NSF), Phase III is typically taken to mean the commercial take-up of SBIR-funded technologies. The Small Business Administration (SBA) officially defines commercialization as:

> [t]he process of developing marketable products or services and producing and delivering products or services for sale (whether by the originating party or by others) to Government or commercial markets.[2]

At DoD, however, "Phase III" also has additional and separate meanings; in general, it means not that a project has reached the market, but that it has transitioned into use within DoD as

> the *transition* of technologies, products, and services developed under the SBIR Program to Phase III including the acquisition process.[3]

More specifically, Phase III in DoD means that a further contract exists from DoD or a DoD supplier *which is certified as a Phase III contract by the contracting officer*—i.e., it is certified as following on from an SBIR or Small Business Technology Transfer (STTR) award.

This certification carries potentially valuable contracting rights: companies seeking funds (either sales or further investment) for Phase III are exempt from normal regulations governing the need to compete for federal contracts, because the competition is deemed to have taken place at Phase I and Phase II. Hence, certified Phase III projects can be sole sourced, a designation that could provide a faster route to commercialization. Confusion between these two uses of "Phase III" is widely found even within DoD.

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[2] Small Business Administration, *SBIR Policy Directive,* September 2002, §3(f), p. 6.
[3] FY2006 National Defense Authorization Act, P.L. 109-163, §252 (a)(y)(1).

For the purposes of this analysis, the committee proposes to use the following terminology, drawn from the discussion of commercialization in Chapter 3:

- "Transition" means the commercialization of any SBIR-funded technology within DoD. It is a broad term that includes but is not limited to Phase III contracts.
- "Phase III" means only certified Phase III contracts between a small business and either a defense contractor or a DoD component.
- "Commercialization" means all kinds of commercial activity, including both DoD and the private sector.

SETTING THE STAGE: 1992-2002

Issues related to the commercialization of SBIR-funded technologies are long-standing. More than 20 years ago, the Government Accountability Office (GAO) found that "issues that affect Phase III activity include the extent of the Department of Defense's (DoD) commitment to the goal of increasing private-sector commercialization, inconsistent procurement practices in requiring competition for SBIR projects entering phase III, and whether the company or the agency that funded the work should perform additional work after phase II if the agency wishes to continue work on the technology."[4]

The GAO report was soon followed by legislation that mandated a strategy for technology transition out of SBIR: "[T]he Secretary of Defense (SECDEF) [. . .] shall develop and issue a strategy for effectuating the transition of successful projects under the SBIR Program."[5] More importantly, perhaps, in 1992 commercialization was formally incorporated into SBIR program objectives[6]:

- "emphasize the program's goal of increasing private sector commercialization of technology "
- "the innovative products and services developed by small business concerns participating in the small business innovation research program have been important to the national defense, as well as to the missions of the other participating Federal agencies [. . .] the small business innovation research program has effectively stimulated the commercialization of technology developed through Federal research and development, benefiting both the public and private sectors of the Nation "

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[4]Government Accountability Office (GAO), *Small Business Innovation Research Shows Success but Can Be Strengthened*, RCED-92-37, March 30, 1992.
[5]FY1993 National Defense Authorization Act, P.L. 102-484, §4237(c), October 1992.
[6]Small Business R&D Enhancement Act, P.L. 102-564, October 28, 1992, §102 and §103.

- "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 or the subject of the research "

Starting even before the new legislation was enacted, and continuing for several years thereafter, DoD and the major SBIR-funding components moved to address the need for improved commercialization.

- **November 1991—**The Secretary of the Navy (SECNAV) and the Chief of Naval Research issued general guidance to use the SBIR program to support current or planned Navy R&D and acquisition programs.
- **April 1992—**The Under Secretary of Defense for Acquisition & Technology (USD [A&T]) formed a Process Action Team (PAT) with Component and Office of the Secretary of Defense (OSD) participation to assess GAO findings and recommendations.[7]
- **February 1993—**DoD components began collecting commercialization information from Phase I proposing firms as a selection discriminator.
- **1995—**The Director of Defense Research & Evaluation assessed SBIR commercialization, found that DoD Phase IIs (1984-1992) yielded a Phase III average commercialization (revenues plus additional investment) of $760,000—but the Process Action Team (PAT) found that the top 1.5 percent of Phase IIs accounted for more than 50 percent of Phase III results.[8]
- **January 1997—**Using recommendations from PAT, DoD established the SBIR Fast Track Program to accelerate SBIR projects that were able to attract third-party investment and required that all Phase II proposals have detailed commercialization plans.
- **February 1998—**DoD extended Fast Track, requested that all relevant DoD entities develop an SBIR plan that included performance-based Phase III metrics, stressed Phase III results as a criterion for proposal evaluation, and initiated a policy to pull acquisition programs closer to the SBIR program.
- **January-November 1999**—Navy implemented a Rapid Commercial Off-the-Shelf (COTS) Insertion (A-RCI) pilot using the SBIR

[7]GAO, *Small Business Innovation Research Shows Success but Can Be Strengthened*, RCED-92-37, March 30, 1992.
[8]National Research Council, *SBIR Challenges and Opportunities,* Washington, DC: National Academy Press, 1999, pp. 97-98.

competition model to create a revolutionary, affordable "open architecture" process that addressed a perceived gap in acoustic technology.[9]

During this period, Congress consistently encouraged the components—and in particular the Services that accounted for the vast majority of SBIR awards—to promote commercialization. In December 1998, the FY1999 Defense Authorization Act directed DoD and SBA to develop a plan to "provide for favorable consideration, in the acquisition planning process, for funding projects under the SBIR program" and facilitate their "rapid transition into DoD acquisition programs."[10]

The pressure from Congress and the directives from DoD underscored the need for change, and the three Services responded with separate initiatives for formal plans to commercialize SBIR technologies:

- **The Army Research Office** issued a plan to establish SBIR liaisons with ACAT[11] I and II programs, require that more than 20 percent of SBIR topics have ACAT approval, and that SBIR use be discussed in the context of ACAT 1 milestone reviews (October 1999).
- **The Air Force Assistant Secretary for Acquisition** directed ACAT I and II program managers (PMs) to "give favorable consideration to" SBIR technologies and to discuss SBIR use in ACAT 1 milestone reviews (December 1999).
- **The Navy Assistant Secretary for RDA** reiterated May 1998 guidance to all PEOs and acquisition managers regarding increased SBIR program participation, inclusion of SBIR in acquisition program planning, and discussion of SBIR use in milestone reviews (December 1999).
- **USD (A&T)** submitted a Report to Congress on DoD SBIR program improvements in six acquisition areas.[12] This reflected Congressional concerns raised in the FY2000 Defense Appropriation Act, for example, "unless program managers budget for Phase III SBIR participation in their acquisition programs [. . .]the increased utilization of small business will not occur" (March 2000).
- **OSD Office of Small Business Programs** launched the Commercialization Achievement Index (CAI) from the SBIR Company Commercialization Register (CCR). CAI became an informal selection discriminator, starting in 2000. This was a first effort to address

[9]William Johnson, Delivering combat power to the fleet*, Naval Engineers Journal,* Fall 2004, pp. 3-5.
[10]P.L. 105-261, §818(a), December 1998.
[11]ACAT I programs are Major Defense Acquisition Programs (MDAPs). ACAT II are small but still significant acquisition programs. See Acquisition Category article at ACQipedia for more details. *<https://dap.dau.mil/acquipedia/Pages/ArticleDetails.aspx?aid=a896cb8a-92ad-41f1-b85a-dd1cb4abdc82>*. Accessed on October 7, 2013.
[12]House Report 106-244, January 2000, p. 49.

concerns about the development and implementation of reliable metrics for commercialization.

These steps culminated in 2002 with an important DoD acquisition management text on increased and open competition that specifically referenced the enhanced use of SBIR by ACAT program managers. This marked SBIR's first documented step into DoD acquisition: "The Program Manager shall develop an acquisition strategy that plans for the use of technologies developed under the SBIR program, and gives favorable consideration of funding to successful SBIR technologies. At milestone and appropriate program reviews for ACAT I programs, the PM shall address the program's plans for funding the further development and insertion into the program of SBIR-developed technologies."[13]

Also in 2002, Congress funded the Defense Acquisition Challenge (DAC) Program and Quick Reaction Fund[14] and the OSD Technology Transition Initiative[15] at approximately $25 million each, in an effort to address "last mile" problems—getting technology into actual use. Subsequent DAC reports, however, do not show significant, successful small business inclusion in these programs.

However, there is evidence from DoD commercialization data to suggest that despite relatively flat DoD Research, Development, Test and Evaluation (RDT&E) funding through the 1990s, a steadily increasing number of DoD Phase II SBIRs won follow-on sales/investment contracts. This increase is reflected both in the number of projects reaching the market and in the scale of commercial success. These data suggest that, even in the relative absence of "technology pull" from the DoD acquisition community from 1991 to 2001, at least 50 percent of DoD SBIR Phase IIs found sales and/or additional investment—especially private-sector sales, as DoD SBIR was seen as a "dual use" program during virtually all of this decade.[16]

LAYING THE FOUNDATION FOR ENHANCED COMMERCIALIZATION: 2003-2006

By 2003, pressure to improve impacts was increasing. In May 2003, a draft DoD Instruction 5000.2 on "Operation of the Defense Acquisition System" cited SBIR/STTR as a source for three key technology-related functions. But the published instruction omitted this important language.[17]

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[13]Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD (AT&L)), *Interim Defense Acquisition Guidebook*, October 2002, p. 41.
[14]FY2003 National Defense Authorization Act, P.L. 107-314.
[15]FY2003 10 U.S.C. 2359a.
[16]BRTRC Federal Solutions, *DoD SBIR Phase III Data from CCR: Data Threshold Information*, July 2005.
[17]OUSD (AT&L), *DoDI 5000.2,* May 2003, pp. 71-73.

In the same year, the biannual Office of Management and Budget (OMB) federal program review returned negative findings on the DoD SBIR program. The Program Assessment Rating Tool (PART) Review reported "results not demonstrated" for program design, planning, or management.[18] OMB rated the program as "Not Performing" with results "Not Demonstrated."

The report argued that the program had poor controls on unproductive spending, continued to provide funding to companies with track records of poor performance, and overestimated commercial successes resulting from federal support—that is, the program counted additional investment as well as product sales as measures of success. (It should be noted that this metric remains in wide use today, and indeed NRC reports including the current volume continue to utilize this useful metric).

OMB's primary recommendation was to tighten eligibility requirements for companies and individuals that repeatedly fail to sell resulting products in the marketplace, by changing the way companies' past performance is assessed. OMB also suggested that the program add efforts to encourage highly successful awardees to enter the mainstream of Defense contracting.

Congress remained interested in the issue. In May 2004, Congress followed by directing the Under Secretary of Defense Acquisition, Technology and Logistics (USD [AT&L]) to "encourage DoD acquisition program managers and prime contractors (holders of direct government contracts) to make significantly more SBIR Phase III contract awards" and also to present a comprehensive report by March 31, 2005.[19] In July 2004, a House Armed Services Committee (HASC) special hearing on small technology firms' DoD commercialization history generated six recommended improvements from Small Business Technology Coalition members, focused on acquisition incentives, Milestone Review inclusion, and more Phase III funding. And in July 2005, at HASC's Subcommittee on Tactical Air/Land Forces hearing, SBIR awardees with large DoD sales described major acquisition-process barriers that impeded the selection and integration of SBIR/STTR technologies.

At about the same time, the NRC Board on Engineering Design published an influential study recommending proven best practices to speed transition, citing Defense Advanced Research Projects Agency (DARPA) work with small business.[20]

GAO also remained engaged. In June 2005, GAO told Congress that the DoD SBIR Program was not capturing commercialization results and that the Defense Acquisition Challenge, Technology Transition Initiative and Quick Reaction Fund had together generated only four fielded projects (out of 68

[18]Office of Management and Budget Program Assessment: Defense SBIR/STTR, September 27, 2003.
[19]FY2005 Defense Authorization Act Committee Report on P.L. 108-375.
[20]National Research Council, *Accelerating Technology Transition: Bridging the Valley of Death for Materials and Processes in Defense Systems,* Washington, DC: The National Academies Press, June 2004.

total). GAO argued that this was due to inadequate acquisition management and to a lack of ACAT program commitment.[21]

In May 2006, House and Senate Small Business Committee chairs posed seven detailed questions to USD (AT&L) on the implementation of new DoD SBIR commercialization initiatives, directing a fresh DoD-wide review of SBIR commercialization with quadrennial follow-up reports to Congress.[22] The seven questions were as follows:

- How did DoD plan to implement the new requirement in the FY2006 National Defense Authorization Act (NDAA) for research focus of its SBIR and STTR programs?
- How would DoD and its departments involve acquisition PMs and PEOs in topic selection, integration into DoD's mission, and testing and evaluation (T&E)?
- How did these DoD stakeholders propose to plan for post-SBIR funding through the Project Objectives Memorandum (POM) and other vehicles, so as to utilize SBIR/STTR in acquisition processes?
- How did DoD stakeholders plan to implement the Commercialization Pilot Program (CPP)?
- What acquisition incentives and activities would be deployed to accelerate the transition of SBIR/STTR technologies into the acquisitions process?
- What reporting requirements would be imposed on acquisition PMs, PEOs, and prime contractors with regard to CPP reporting?
- How did DoD stakeholders plan to implement Executive Order 3329 on Encouraging Innovation in Manufacturing?

Technology Insertion: Early Navy Initiatives

Activity at the level of DoD and Congress continued throughout this period, providing important context for Service-level initiatives, where important changes were occurring.

Given the very long lead time and complexity of many large DoD programs, increasing the take-up of SBIR-funded technologies through acquisitions at the different Components required considerable planning—and significant shifts in the way that planning was undertaken.

In 2004, the Navy's PEO Ships, which managed about 200 SBIR/STTR projects, supported the first-ever ACAT I Technology Insertion Plan to identify SBIR technologies for system integration. This was an extraordinarily important step. It was the first time that acquisitions programs had deliberately planned to include SBIR technologies in their eventual deployment decisions, as well as the

[21] GAO 05-480, *Defense Technology Development: Management Can Be Strengthened*, June 2005.
[22] Senator Olympia Snowe, Rep. Donald Manzullo, *Letter to Honorable Kenneth Krieg,* May 15, 2006.

first time that acquisitions had made a formal and significant effort to seek out technologies that were SBIR-funded. This initiative appears to have had a significant impact on Navy's eventual leading role in commercializing SBIR-funded technologies through Phase III awards.[23]

It was followed in December 2005 by a formal instruction from the Office of the Secretary of the Navy: "Each PEO shall designate a lead SBIR Technology Manager responsible for advocating transition of SBIR products (to its) platforms." Navy became the first DoD Component to take this step.[24]

And in June 2006, PEO Submarine issued a first-in-DoD instruction to its PMs requiring plans to provide incentives that would encourage prime contractors to include SBIR projects, thus helping to achieve affordability and innovation goals. [25]

2006-2011: CPP AND AFTER

The growing pressure on DoD from Congress and other stakeholders for more effective use of SBIR led in January 2006 to the introduction of four significant reforms in the context of the FY2006 National Defense Authorization Act.[26]

- Quadrennial review of the SBIR topic development process at the Service level, to help ensure alignment between topics and high-priority Service acquisition needs;
- Introduction of the Commercialization Pilot Program (CPP)[27]:
  - SECDEF and each Service were to identify SBIR projects with the greatest potential for accelerated DoD commercialization.
  - One percent of SBIR funds were made available to the Services for administration of CPP through fiscal year (FY)2009, on a pilot basis.
- Executive Order 13329 on manufacturing innovation was formally incorporated into 15 U.S.C. 638; and

[23]The Virginia Class sub program had an ACAT 1 level technology insertion plan and budget since the mid-1990s, but not dedicated to SBIR. By the late 1990s it did include SBIR projects and the Virginia class sub program had SBIRs included in the Program Acquisition Plan for Phase 3 SBIR procurements as a source for technology insertions.

[24]SECNAVINST 4380-7B, *Implementation of the Department of the Navy SBIR Program*, December 23, 2005.

[25]NAVSEA PEO Submarine Executive Director, *Operating Instruction #44: Incentivizing Large Business Contractors to Increase Small Business Participation in Submarine Procurement*, June 29, 2006.

[26]FY2006 National Defense Authorization Act, P.L. 109-163 Sec. 252, which SBIR/STTR authorization is in 15 U.S.C. 638.

[27]As of 2012, CPP ended pilot status and became known as the Commercialization Readiness Program (CRP).

- Testing and evaluation awards could be made to SBIR Phase I-II projects for the first time.

In effect, each Service was encouraged to set up its own pilot to identify ways to commercialize SBIR projects more successfully within DoD; by May 2007, the Office of the Secretary of Defense (OSD) established an internal SBIR CPP Managers' Database for reporting and tracking purposes. And in June 2006, USD (AT&L) directed the Services to implement CPP[28]:

- Each Service was to develop and launch a CPP using the 1 percent funding set aside (to meet additional program management costs only).
- Each Service was to report on CPP action/spending plans, projects, and the use of incentives by September 15, 2006—a short time frame that suggests a high priority for this initiative.
- Each Service was to support an annual "Beyond Phase II" event beginning in 2007, bringing together SBIR projects, defense prime contractors, and DoD system developers as well as acquisitions officers.
- Status reporting was assigned to the OSD Director of Small Business Programs.

In parallel, as required by Congress, DoD reported on its plans to enhance technology transition within the agency. In what became known as the Kubricky Report, the Deputy Under Secretary for Advanced Systems and Concepts reported that successfully transitioning technology from science and technology (S&T) into defense acquisition programs required four actions:

- Expanding resources for maturing technology beyond Technology Readiness Level (TRL) 5;
- Expanding resources and developing strategies for mitigating risk in innovative technologies;
- Reducing barriers to competition and to new suppliers such as small business;
- A formal DoD-wide mechanism for improving technology transition from S&T into defense acquisition programs.[29]

CPP's mission was therefore quite straightforward: "The purpose of the CPP is to accelerate the transition of SBIR-funded technologies to Phase III, especially into systems being developed, acquired and maintained for the warfighter."[30]

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[28]OUSD (AT&L), *Small Business Innovation Research Program*; June 27, 2006.
[29]Office of the Secretary of Defense (OSD), *DoD Report to Congress on Technology Transition,* July 2007.
[30]OUSD (AT&L) Ofc. of Small Business Programs, *Report for Fiscal Year 2009*, January 2010.

Army CPP Program

From an R&D and acquisitions perspective, the Army is a relatively centralized agency.[31] Traditionally, SBIR had been seen as an offshoot of the Army's R&D establishment, and was in particular closely aligned with the Army Research Office. More recently, Army SBIR was aligned with RD&E Command, which was no longer under Army Research Office jurisdiction. It was anticipated that this would enable the SBIR program to establish better linkages with Army PEOs.

The Army CPP program, formally launched in October 2006, solicited projects for accelerated transition of selected Phase II projects with studied dual-use potential and with high Army priority. Of the 548 then-active Army Phase II projects, 76 percent filed Commercialization and Technology Assessment (CTA) applications for Army CPP status. Evaluation was to be based on evidence of "factors typically exhibited by successful firms" and on Army high-priority needs or capability gaps.

The process involved filling out a 120-question application, followed by a two-stage selection process implemented by a contractor. It involved data analysis of the company responses, which reduced the number of applicants to 150, and then an assessment of match between the proposed projects and Army priorities, as well as of PEO interest in these technologies.

Under the program, Technology Assistance Advocates (TAAs) were appointed to five Army (Continental United States [CONUS]) regions. They were to support selected active Army Phase I and II projects with technical advice, aimed at mitigating risk and supporting project integration into Army Programs of Record. TAAs provided different kinds of support for different Phases:

- Phase I assistance focused on technical decision-making, technical problem-solving, and risk avoidance.
- Phase II assistance focused on building linkage with target PEOs to help ensure SBIR technology integration through detailed Phase III planning.

Army's CPP funding was used largely to contract with MILCOM Venture Partners (MILCOM), a defense-focused venture investment firm with consulting capabilities. MILCOM helped identify SBIR projects and companies with high transition potential that met high-priority requirements, provided market research and business plan development, matched SBIR companies to customers and facilitated collaboration, prepared detailed technology transition plans and agreements, and—notably—provided additional funding for select SBIR projects.

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[31]Material in this chapter related to Army activities is derived from secondary sources. The Army SBIR Office declined to cooperate with this NRC assessment.

For FY2009, the Army's process was similar to that of FY2008, except that it used a new electronic Commercialization and Technology Assessment (CTA) questionnaire that contained more than 80 questions, and was used to evaluate 472 active Phase II projects. One hundred and forty companies passed the initial screening. The Army approved a further 25 projects in FY2009. Overall funding was approximately $60 million in SBIR funding (over 3 fiscal years), while matching stakeholder funding was about $180 million.

At the same time, Army continued to expanded outreach, training, and collaboration opportunities for PEOs and acquisition PMs, seeking to strengthen the links between the SBIR program and the acquisition programs.[32]

Army does not appear to publicly provide systematic or aggregate results from CPP: its web site mentions three cases in which CPP projects generated significant sales. However, because these were the most promising of current SBIR projects, this is not a surprise.

Air Force

Air Force CPP Program

The Air Force (AF) SBIR program has long been aligned with the Air Force Research Lab (AFRL) but it also has links to Product Centers, Test Centers, and Air Logistics Centers.

The AF process focused on using CPP to find better ways to connect SBIR projects to possible users within the AF and to prime contractors. To accomplish this, it introduced the idea of Transition Agents (TAs) based in different regions. Originally, the TAs were supposed to facilitate a "Hunter Gatherer Process" that linked Product Center PEOs to AFRL technical experts. These links were expected to support better SBIR topic development and to encourage the creation of lists of SBIR awards in alignment with highest priority Product Center needs. Once this preliminary process was completed, those implementing potential projects were invited to attend face-to-face PEO-Industry Workshops on collaboration potential.

This effort at two Product Centers produced 220 initial face-to-face meetings with 120 follow-up meetings between industry and SBIR firms. However, only nine continuing AF CPP projects resulted from this approach by the end of FY2007. AF SBIR CPP management therefore curtailed the Hunter Gatherer Process.[33]

In FY2009, AF refocused on conducting two types of Technology Interchange Workshop (TIW) as the primary means by which stakeholders (program customers, integrators, SBIR firms, and laboratories) could identify areas of mutual interest and collaborate:

[32]OUSD (AT&L) Ofc. of Small Business Programs, *Report for Fiscal Year 2009*, May 2011, p. 2.
[33]OUSD (AT&L) Ofc. of Small Business Programs, *Report for Fiscal Year 2007*, January 2008.

- PEO workshops to enable the technology community to concentrate on meeting documented systems needs within each AF Product Center; and
- Focused Industry Workshops conducted to facilitate prime contractors' search for SBIR solutions to their own technology-based needs related to AF projects.

The FY2009 annual CPP report emphasizes the way in which the workshop-based approach allowed AF to expand cooperation with other components, conducting seven joint-service industry workshops for 156 small businesses and facilitating nearly 300 one-on-one "technology matching" sessions with the Navy, Army, Missile Defense Agency, and multiple industry partners. The AF CPP report also claimed credit for meetings organized at the 2009 DoD SBIR "Beyond Phase II" Conference.

In transitioning from the pilot CPP to the ongoing CRP, AF states, "The Air Force has implemented a strategically-driven process that directly links Program Executive Officers' representatives to Air Force Research Laboratory Technical Points of Contact (TPOCs) to generate topics that are of high interest to Air Force product centers."[34]

AF approved 30 CPP projects in FY2009, increasing the cumulative number of CPP projects since the inception of the pilot to 148. Cumulatively (over 3 fiscal years), AF invested $46.3 million in SBIR funding to CPP projects, which included funding for accelerated transition. Stakeholders contributed an additional $141.8 million. As of the end of FY2009, AF had 23 acceleration projects expected to improve performance, 19 to provide new capabilities, 14 to reduce costs, and 8 to increase reliability.[35]

Transitioning from CPP to CRP

By FY2013, the transition from CPP to CRP was largely in place. CRP accounted for 8.3 percent of the total AF SBIR budget in FY2013,[36] and the TA's funded by CRP were established at AF research centers across the United States (see Figure 4-1). AF has identified four major goals for CRP:

- Identify and accelerate technology transition to the warfighter;
- Facilitate transition of SBIR/STTR projects;
- Establish the use of SBIR/STTR technologies as a normal course of business; and
- Enhance connectivity among SBIR firms, Major Defense Contractors, and AF Centers.

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[34] Air Force, Commercialization Readiness program (CRP), <*http://www.afsbirsttr.com/CommercializationReadinessProgram/default.aspx*>. Accessed July 23, 2013.
[35] OUSD (AT&L) Ofc. of Small Business Programs, *Report for Fiscal Year 2009*, May 2011, p. 1.
[36] Air Force SBIR Briefing for NRC Staff, June 2013.

FIGURE 4-1 AF SBIR participating organizations and technology agents.
SOURCE: Air Force SBIR Briefing for NRC Staff, June 2013.

AF CRP funding to companies was explicitly designed to support development beyond Phase II, encouraging transition to use by primes or the Air Force directly. By using either CRP funding or the new capacity now available under the 2012 SBIR reauthorization to provide a sequential Phase II, AF was able to provide additional funding of up to $2.25 million per project (see Figure 4-2).

The key levers for enhanced commercialization at AF are SBIR Technology Transition Plans (STTPs) and SBIR Technology Maturation Plans (STMPs). These result from AF efforts to match up primes and their primary supply chains with SBIR companies, through AF/Industry Technology Interchange Workshops (TIWs).

After AF identified possible SBIR sources of technology/solutions that meet expressed industry needs, industry in turn vets the SBIR companies to be invited to a TIW. TAs then re-engage with the product center that initiated the need and also with the SBIR project's Technical Point of Contact (TPOC). If successful, then the link leads to a new STTP, which identifies the specific roles

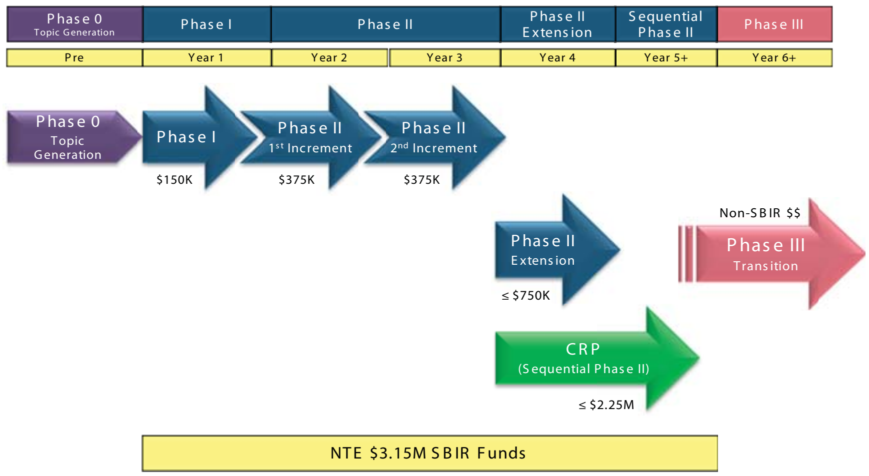

FIGURE 4-2 AF nominal SBIR commercialization funding.
NOTE: CRP=Commercialization Readiness Program.
SOURCE: Air Force SBIR Briefing for NRC Staff, June 2013.

and responsibilities of each of the stakeholders, as well as any required Phase III assistance (including funding).[37] (STMPs are for projects that lack clearly related PEOs [e.g., hypersonics]) or that are not yet ready for transition but are regarded as promising).

TAs start to identify candidate companies for an STTP 10 to 16 months into a Phase II award (although there are no formal rules governing this window). They work with TPOCs to ensure that the technology is maturing fast enough to meet agency needs.

In the end, the STTP is agreed upon by the small company, technology agent, and acquisition office that is interested in the ensuring technology. It must be stressed that *acquisitions offices are not bound by these agreements*. However, they represent an important signal of acquisitions interest, according to Richard Flake, CRP Coordinator.[38] In addition, a primary success metric for the program is in fact to ensure that "20% of previous year awarded Phase IIs (is) in funded SBIR Technology Transition/Maturation Plans (STTP/STMP)."[39] STTPs thus constitute an important effort by AF to ensure that SBIR projects are "tightly tied to critical stakeholders and necessary funding."[40]

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[37]Air Force SBIR Briefing for NRC Staff, June 2013; Air Force agency staff interviews, June 28, 2013.
[38]Richard Flake, Interview, June 28, 2013.
[39]Air Force SBIR Briefing for NRC Staff, June 2013.
[40]Richard Flake, Interview, June 28, 2013.

AF sees this as a way of leveraging SBIR funding. Over the extended FY2007-2012 period, during which CPP and then CRP were implemented, more than 100 AF STTPs and SMTPs used about $92 million in CRP/CPP funding but also attracted almost $340 million in additional funding, including $152 million from AF acquisitions offices and a further $54 million from industry sources (see Figure 4-3).

AF also notes that STTPs allow tighter tracking of eventual outcomes. Although STTPs do not necessarily include formal reporting requirements back to the SBIR office, AF claims that of the 108 STTP/SMTPs signed to date, 10 are inactive while 45 have generated outcomes that are now "in the hands of the customer."[41] The AF target is to reach STTP agreements for 20 percent of prior-year Phase II awards, although this will clearly be challenging, as Figure 4-4 indicates.

AF tracking shows that CRP supports transitions, and these transitions in turn provide significant benefits for AF acquisition programs. AF has developed its own tracking tool, which seeks to identify the kinds of enhancements generated by transitions. In FY2013, STTP/SMTPs supported 22 identified transitions. These generated 33 identified benefits to the AF (see Table 4-1). Of course, it should be noted that this table—and indeed the AF metrics approach more generally—does not attempt to quantify the scale of these impacts or indeed the overall amounts of commercialization in dollar terms. Nonetheless, this represents an effort to capture benefits that are not easily quantifiable (see, for example, Box 4-1 and Box 4-2, which outline two early successes from the STTP process at AF).

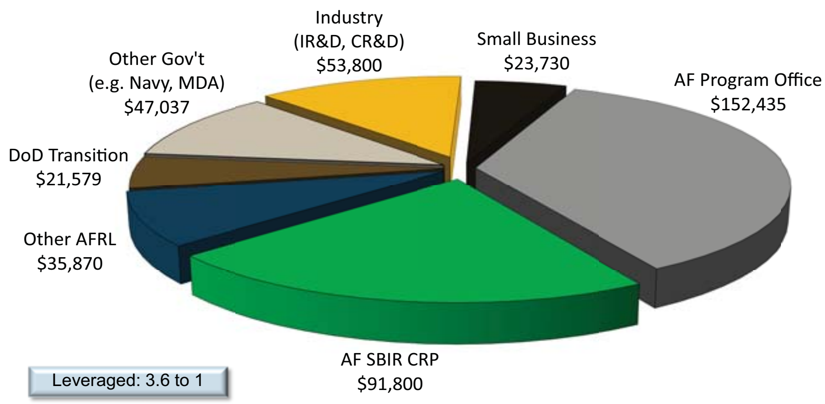

FIGURE 4-3 AF CRP funding FY2007-2011 (thousands of dollars).
SOURCE: Air Force SBIR Briefing for NRC Staff, June 2013.

[41]Richard Flake, Interview, June 28, 2013.

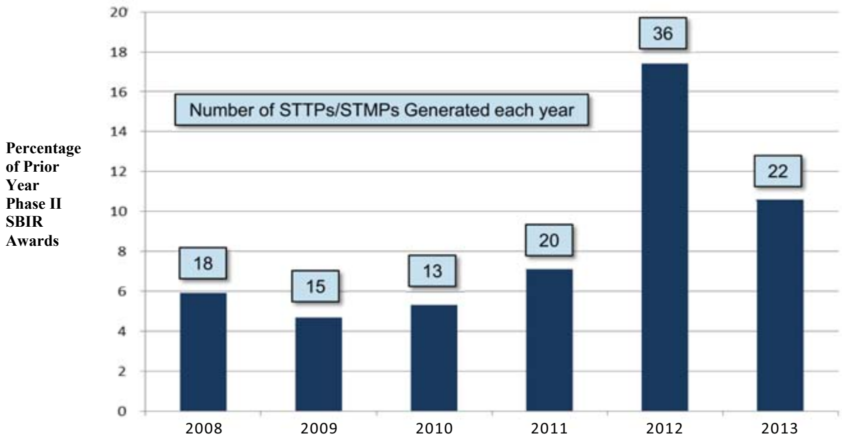

FIGURE 4-4 AF STTP and SMTP agreement by year.
SOURCE: AF SBIR Office.

TABLE 4-1 AF Benefits from FY2013 Transitions

Receiving Command/Organization	New Capability	Improved Performance	Greater Reliability	Cost Savings
ACC (2)		√	√	√√
ACC (JSF) (3)	√		√	√√√
AFGSC (1)	√		√	√
AFMC (AFLCMC) (4)	√	√√	√	√√
AFMC (AFSC) (6)	√√√	√√√√√	√√√√	√√√√√√
AFMC (AFTC) (1)		√		
AFSPC (3)	√	√√	√	√
AFSOC/USSOCOM (7)	√√√√√√	√√√√		√√√
AMC/USTRANSCOM (3)	√√	√√		√
AFCEC (1)		√		√
AFISRA (1)		√		
JEIDDO (1)	√	√		

SOURCE: Air Force SBIR Briefing for NRC Staff, June 2014.

Box 4-1

**An Early STTP Success:
The Avionics Bus Characterization and Integrity Toolset
(BCIT) (STTP 2007)**

Diagnosis and repair of cabling faults is a pressing aircraft maintenance need in today's complex networked systems. On aircraft such as the B-2, network troubleshooting was taking too long because of antiquated test equipment. This jeopardized aircraft availability and fleet readiness, because inability to isolate a complex anomaly could ground an aircraft.

Better fault isolation could help minimize panel removal and hence reduce the time and resources needed to restore performance. To meet this need, SBIR technology and CPP support for transition helped ITCN deliver a rugged, portable, easy-to-use, reliable tool that can reduce aircraft maintenance down time from days to minutes and weeks to hours. Technicians can quickly identify the precise location of isolated faults—including intermittent faults—to a tolerance of 6 inches per 1,000 feet of cable. During periods of high utilization, this technology can effectively add one operational aircraft to the fleet by minimizing maintenance cycle time.

BCIT is now receiving wide acceptance for the B-2 and other customers. Three units are in use at Whiteman Air Force Base (AFB), one at Eglin AFB, and two at Northrop Grumman, Palmdale. BCIT can be applied to all AF aircraft, as well as to other defense and commercial platforms. The 16th Electronic Warfare Squadron has acquired a unit. The Australian Air Force purchased five units for the P-3 Orion. Seven more were purchased by the Navy in 2012.

SOURCE: AF SBIR Success Stories. Provided by AF SBIR Office.

Navy

Navy CPP Program

For CPP purposes, the Department of the Navy includes both the Navy and the Marine Corps. The Navy SBIR program was aligned with the Assistant Secretary of the Navy—Research, Development and Acquisition (ASN RDA) but had links to SYSCOMs down to PEO levels.

Box 4-2

Case Study:
AF project shows impact of cost savings and efficiency gains—GATR Deployable Antenna
(STTP 2008 and 2011)

Drawing on two early DoD SBIR awards,[a] GATR Technologies developed an inflatable 2.44 meter antenna for soldiers, mobile medical units, and emergency response teams, which can be used to receive high-speed Internet and phone communications in remote locations.

Using inflatable technology reduced the size and weight of the antenna by 80 percent and led to deployment by soldiers and relief teams in the Middle East, Haiti, Superstorm Sandy, and elsewhere. The inflatable dish fits into two small cases and can be set up in less than 1 hour.

The GATR Antenna saved SOCOM $41 million in acquisition costs over 5 years, and has reduced operations and maintenance costs by 90 percent. GATR was awarded $26 million and $37 million IDIQ contracts for acquisition, and SOCOM has deployed more than 100 systems. More than 25 organizations are now customers.

GATR continues to evolve the technology. Its new 1.2 meter back-packable SATCOM terminal allows one person to set up and be on satellite within 15 minutes. The design integrates a patented inflatable radome with a precision antenna, allowing all components to fit in a backpack or carry-on that weighs less than 50 lbs. Bandwidth to accommodate video, audio communications, and Internet protocol is available with minimum power, smallest logistical footprint, and significant cost savings for remote battlefield use, including UAV (unmanned aerial vehicle) data distribution.

GATR has received numerous awards for its work, including a Tibbetts Award, the 2007 *Popular Science* invention of the year award, an R&D 100 award, a place in the NASA Technology Hall of Fame, and a place on the Inc. 500 lists of hottest products and fastest growing companies (for 4 years in a row).[b]

[a]Helen Jameson, "GATR: Shaking Up the SATCOM antenna market," *Satellite Evolution Asia*, March/April 2013, p. 34.
[b]Awards based on GATR web site. <*http://www.gatr.com/media-section/awards*>. Accessed July 23, 2013.

SOURCE: Air Force SBIR SBIR Office.

In FY2006, the Navy SBIR CPP strategy included several elements:

- Accelerated transition of SBIR technologies into high-priority systems and formalized linkage to acquisition programs through immediate- and longer-term initiatives in each Navy SYSCOM;
- Increased PEO and acquisition program-level transition support;
- Expanded small business support for technology maturation and manufacturing capability;
- Enhanced database capability to improve project tracking and access by all transition project participants;
- Identified best transition practices and obstacles, by acquisition personnel, small business, and industry;
- In each SYSCOM, formalized SBIR program linkage with PEOs and acquisition programs through Chief Technology Officers from topic development through SBIR project management to SBIR technology insertion. Work included refinement of acquisition program technology roadmaps to ensure SBIR inclusion in product development;
- Developed and implemented new project transition tracking and data management tools at Navy and SYSCOM levels, which enabled PEO-level reporting on transition performance (i.e., "program health monitoring"); and
- Identified operational technology transition innovations in key operations: incentives to leverage non-SBIR investment, project investment via gated technology decision-making, and project tracking databases that accommodate multiple inputs from transition participants.

Of the 51 Phase II projects recommended for CPP status in FY2007, 36 completed Technology Transition Plans, six received Phase III awards, and 12 completed pre-insertion Technology Risk Assessments or Manufacturing Readiness Assessments.

In FY2007, Navy also ran an SBIR Accelerated Transition competition to speed high-priority projects. From this, 35 Phase II projects received $43.9 million in added SBIR funds, matched by $30.4 million in Phase III funds.

By FY2009, the Navy CPP had matured considerably. The annual CPP report indicated that Navy was now setting aside approximately 20 percent of SBIR program funding for selected CPP projects, funding them above the normal Phase II limits. Projects that met a high Navy priority and had a demonstrated potential for rapid transition into an acquisition program of record or fielded system could access these funds to advance their technology.

Documentation and Planning

Access to CPP funds required completion of a Technology Transition Plan/Agreement (TTP/A) and commitment of non-SBIR matching funds. The TTP/A defined the transition requirements, the funding profile, areas of risk, milestones, test and demonstration plans, and management oversight.

Tracking and Monitoring

In FY2009, 17 on-site visits were made to specific CPP companies to confirm transition potential and provide assistance. Navy staff debriefed each company visited. Navy also held one-on-one meetings, scheduled around outreach conferences, with numerous Phase II companies to discuss CPP requirements and transition-potential meetings.

Outreach

Prime contractor outreach generated numerous interactions with SBIR companies and acquisition sponsors. The Navy partnered with AF and other components to attend four TIWs hosted by different major primes during FY2009. These events enabled 41 Navy SBIR companies to present prescreened technologies for potential partnership.

Technical Assistance

CPP participants could leverage other Navy initiatives, such as the Navy Transition Assistance Program (TAP), which culminated with a technology showcase and presentations at the Navy Opportunity Forum. Other technical assistance services included assessments for risk, manufacturing and production, and technology transition, as well as assistance for engineering analysis (problem solving), best practices, transition planning, and testing and evaluation. The Navy also launched an enhanced search capability available to the public at <*http://www.navysbirsearch.com*> to provide access to SBIR/STTR technologies. However, tools for integrated search across all SBIR awards within DoD—or even beyond DoD—were still not available.

Metrics and Standardized Processes

Navy CPP focused on increasing standardized processes and metrics of success in FY2009. A draft set of CPP guidelines was initiated, which established funding and time limits for individual CPP projects, cost-matching requirements, procedures for annual reviews of all ongoing CPP projects, minimum reporting requirements for Commercialization Pilot Program (CPP) firms and government technical managers, and requirements for execution of TTP/As. Metrics for the Navy's CPP were developed to cover actual implementation of the technology, the amount of non-SBIR investment received, and the percentage of projects that met requirements set forth in the TTP/As.

The Navy approved a total of 31 projects in FY2009 (see Appendix C), increasing the cumulative number of Navy CPP projects since inception to 129 projects. Over 3 years, Navy invested $221.2 million in SBIR funding for CPP projects. Stakeholders contributed $408.8 million.[42]

Commercialization Readiness Program (CRP): Phase II.5

Navy CRP Phase II.5 has emerged as a further significant innovation in commercialization programs at DoD. It started as a Navy transition tool, but after 2008 emerged from CPP practice as a method for identifying SBIR projects with greatest ACAT "pull," then leveraging increased levels of SBIR investment with ACAT non-SBIR matching funds, using the GAO-recommended "gated process" of technology approval.

This emergence reflects an important aspect of the Navy SBIR program: its extraordinary degree of decentralization. Implementation of broad policy guidance—such as the mandate to increase transition—is largely left to the SYSCOMs, PEOs, or even different Acquisition Offices within each PEO. Many of these experimented with different CPP/CRP transition support strategies, and there is no standard, formal Navy approach or policy on CRP services and/or implementation.

Thus, any description of the "Navy CRP" or "Navy II.5 Program" is to some degree a simplification of a much more complex set of moving policies and initiatives. And over time, many of the Navy Phase II.5 practices changed substantially in response to testing (the Office of Naval Research [ONR], for example, discontinued Phase II.5, while the Naval Sea Systems Command [NAVSEA] and the Naval Air Systems Command [NAVAIR] increased it but used different funding approaches).

Navy views all efforts to support transition beyond Phase II as part of the Phase II.5 process. It has set aside 20 percent of SBIR program funding to support Phase II.5, with the funding provided through three basic mechanisms[43]:

- **Phase II Enhancements**—require a minimum of 1:1 concurrent matching and are usually limited to $500 thousand;
- **Continued Development (CD)**—requires a signed TTP/TTA (which in turn requires buy-in from a PEO or HQ [Headquarters] Directorate). No matching funds are required and CD is limited to $750 thousand; and

[42]OUSD (AT&L) Ofc. of Small Business Programs, *Report for Fiscal Year 2009*, May 2011, p. 3.
[43]Lee Ann Boyer, "Department of the Navy Commercialization Readiness Program—Phase II.5," Internal SBIR Office memorandum n.d.

- **Accelerated Transition (AT)**—usually requires a signed TTP/TTA. 1:1 matching funds are required, which may be concurrent or out-year. Funding is limited to $1.5 million or the balance from $1.5 million minus prior CD or Phase II Enhancement funding.

Selection for Phase II.5

Aside from formal/legal criteria (e.g., a prior Phase II), there are three functional criteria for inclusion in the program:

- **Firms must be selected by a Navy SYSCOM Transition manager.** Some SYSCOMs review all of their current portfolio for potential candidates; others allow TPOCs to nominate specific projects.
- **The project must address a high-priority Navy need.** Project relevance to a planned or existing Acquisition Program, Future Naval Capability, or documented Technology Gap must be identified in the TTP/TTA.
- **Projects must meet any/all matching funds requirements** and SBIR/STTR funding limits for Phase II.5.

Although these requirements must be met, there was no formal application process for the company to complete: action remains in the hands of Navy staff. It appears now that a more formalized approach might be introduced.

Other Navy Commercialization Efforts

Navy was one of the first agencies (along with NSF) to provide commercialization training for SBIR award winners, aimed at generating an increase in the raw commercialization (percentage of projects with sales and/or additional investment). It has had a long relationship with a commercialization contractor, Dawnbreaker, which provides a year-long course for Phase II award winners. The course culminates in the Navy Opportunity Forum, a showcase at which selected companies can market their technologies, and which is well attended by executives from the prime contractors.

Results from Navy Transition Initiatives

Navy has also pioneered efforts to improve data collection to document transition successes. It has expended considerable effort on more accurate reporting of Phase II contracts through the Federal Procurement Data System (FPDS; see discussion of transition metrics elsewhere), and it consistently tracks Phase III contracts and uses these Phase III numbers as a key metric for success (see Figure 4-5). The figure shows total Phase III contracts reported through FPDS for Navy and for other DoD components (the latter through FY2010

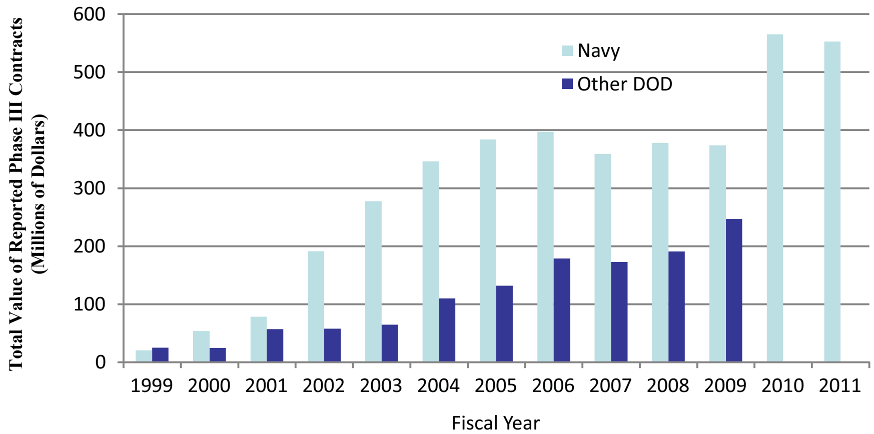

FIGURE 4-5 Phase III contracts reported through the Federal Procurement Data System, by total value, FY1999-2011.
SOURCE: Navy SBIR program office.

only). Given the efforts made by Navy to correct reporting errors, it is not entirely clear that the reporting at other components is equivalent. However, these data indicate that Navy was a leader in encouraging transition from 2002 to2009, and has since 2009 made substantial further gains: currently, the annual FPDS-reported Phase III contracts total for Navy is about $650 million, based on approximately $271 million in Navy SBIR awards for FY2012[44]

Transition Success Stories

Navy has identified 14 SBIR companies that work on the Sikorsky Super-Stallion Helicopter, supporting 13 different functions. Similarly, Navy has identified a number of SBIR companies and technologies utilized on the Virginia class submarine (See Figure 4-6).

As a second example, the Promia success story (see Box 4-3) illustrates three important elements of the SBIR program at Navy. First, the time lag to commercialization can be considerable: the Promia intrusion detection-and-alert system received its last Phase II funding in 2004 (of two Phase II awards total). Only in FY2011-2012 did it start to get commercial traction. Second, timing is affected by Navy and even DoD policy and timelines: it happened that the Promia system was ready when Navy needed a new solution—in response to new demand from new DoD policy. Third, the CRP process clearly helped to

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[44]DoD, *SBIR Annual Report*, <*http://www.acq.osd.mil/osbp/sbir/about/sbirAnnualReport.shtml*>. Accessed October 14, 2013.

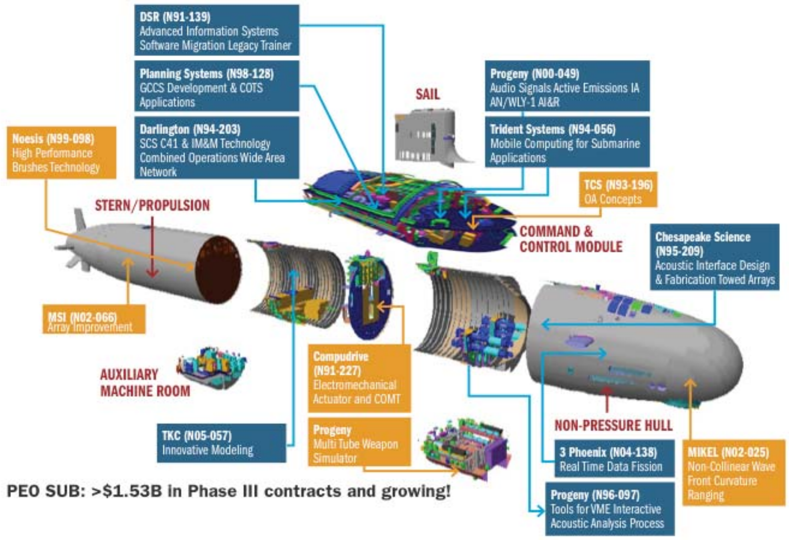

FIGURE 4-6 Navy SBIR firms and the Virginia Class Submarine.
SOURCE: Lee Ann Boyer, U.S. Navy, May 2013.

bring the Promia system on stream and into connection with the appropriate acquisitions officers at the right time.

Limits of Transition Funding—Team Subs

PEO Subs has for more than a decade been a pioneer within Navy in transitioning SBIR technologies, under the previous leadership of PEO Richard McNamara and currently under Dr. Regan Campbell. For recent solicitations, PEO Subs has been tracking Phase III transitions closely (see Figure 4-7). The data show that a substantial number of Phase II awards are attracting Phase III funding, although the figure does not make clear the substantial lags involved—Phase II awards are often ripe for Phase III 4 or more years after the award.

In 2012, PEO Subs transitioned six projects into the Phase II.5 program (see Table 4-2). The table shows the SBIR program funding (under Phase II.5) as well as the matching funds from acquisition programs. However, although these transitions attracted about $4.5 million in Navy transition funding, a larger backlog of projects did not receive Navy support and hence is still in the queue

Box 4-3

Promia's Network Intruder and Alert System (Intelligent Agent Security Module or IASM)

Promia has developed a high-speed, secure distributed messaging infrastructure that allows network analysts to see and integrate information from a wide range of sources, in order to identify and isolate cyber network attacks. Results are translated into simple English for Navy watch standers and centralized analysts to help them monitor the electronic terrain of their global networks.

The system applies various analytic processing techniques such that intrusion patterns can be detected as they occur. Organizations can use the system to detect large-scale intrusions that were previously undetectable, decrease false alarm rates, and perform dynamic drill down of intrusions for analysis and determination.

With the IASM tool, the number of watch standers and network analysts is much reduced, because many current workstations are consolidated into one console. This has resulted in a 75 percent reduction in current tests, a 99 percent reduction in false-positive count of network alert messages, and a 64 percent improvement in accuracy in identifying network attacks.

Navy is now using the commercial application of the IASM system (Promia Raven) to meet new Enterprise Mapping and Leak Detection requirements for all DoD networks, and it plans to upgrade the 23 existing Promia Raven systems now operational within Navy. Thirteen new Raven 2100 Rev B systems have already been ordered for the OCONUS Navy Enterprise Network, along with nine more analytic ENMLDS units. These will support Navy bases in Singapore, Guam, Diego Garcia, and eight other sites around the world.

Promia's success is directly based on two Phase II SBIR awards with Navy in 2000 and 2004, totaling $1.5 million in Phase II funding, along with additional CRP funding focused on transition. Altogether, the Navy investment is $2.9 million, which has resulted in Phase III revenues of $35 million to date, as well as extensive, ongoing, and expanding cost savings and efficiency gains for Navy.

SOURCE: Navy SBIR Success Stories Database; Promia Inc. web site, accessed August 25, 2013.

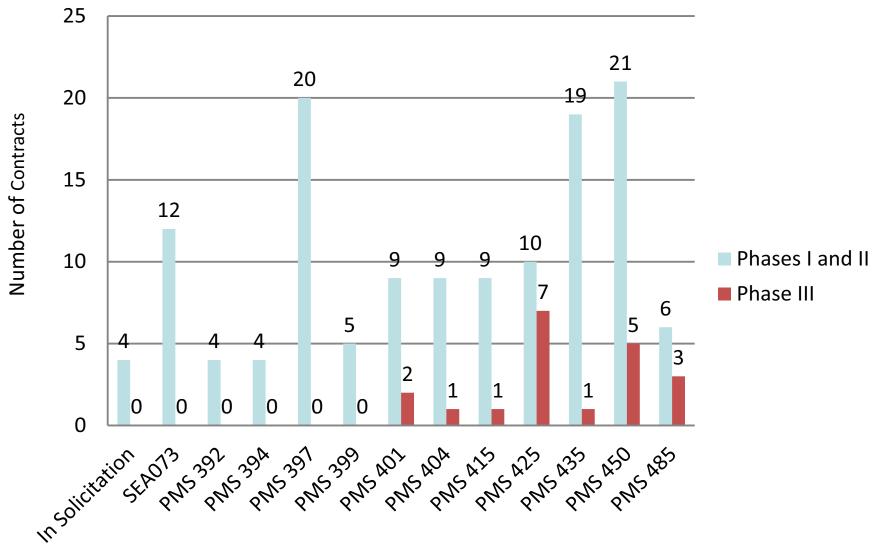

FIGURE 4-7 Team Subs Phase III transitions.
SOURCE: Dr. Regan Campbell, Executive Director, PEO SUB, Department of the Navy, DoD Small Business Transition Program, presentation to NRC, June 25, 2013.

waiting for funding. PEO Subs reports 10 projects in their queue, most with little prospect of funding in subsequent rounds.

For all of these projects, Transition Agreements have been signed and matching funds from the acquisition programs have at least in principle committed. The fact that the projects are stuck suggests that the acquisition programs like these projects but are not prepared to fully fund them, or that the Navy's financial commitment to transition—although large—is not enough to meet Service needs. Both may be true.

New Initiatives in Commercializing SBIR, 2006-2011

The momentum toward new approaches to enhance commercialization of SBIR projects continued between 2008 and 2010, reflected in a number of reports and activities:

- **June 2008—**A RAND study commissioned by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD AT&L) estimated that DoD-wide the SBIR administrative budget level was 6 percent and that this was significantly lower than that of DoD

TABLE 4-2 PEO Subs SBIR Transitions, FY2012

		Fiscal Year 2012	
Topic	Vendor	SBIR Funding	Program Funding
Synthetic Oil	METSS Corp	$66,000	$100,000
Automation of Equipment/System Isolation and Safety Tagout for Maintenance Actions)	Progeny Systems	$450,000	$0
In-Situ Learning for Underwater Object Recognition	3 Phoenix, Inc.	$475,000	$475,000
Spread Spectrum Techniques for Sonar Ping Technology	3 Phoenix, Inc.	$2,500,000	$1,500,000 (funded in FY11)
Light Weight Ready Stow Group Launcher and All Up Round Equipment Composite Canisters	Pacific Engineering, Inc.	$1,080, 696	$1,500,506
Techniques for Automatically Exploiting Passive Acoustic Sonar Data	3 Phoenix, Inc.	$0	$250,000

SOURCE: Dr. Regan Campbell, PEO Subs, Department of the Navy, DoD Small Business Transition Program, presentation to NRC, June 25, 2013.

acquisition programs, which are also responsible for maturing innovative technologies for product development, at 17 percent.[45]

- **January 2009—**The DoD Office of Inspector General reported possible underreporting of SBIR commercialization and recommended better reporting, supplemental administration funding, and SBIR internal champions within acquisition program offices.[46]
- **Between June 2010 and August 2011—**USD AT&L issued five memoranda on transformation of the DoD acquisition system to increase competition and affordability, principally by creating new small business access. The "Better Buying Power" memos were

[45]RAND National Defense Research Institute, *Estimating the Cost of Administering DoD SBIR*, June 2008.
[46]DoD Inspector General, D-2009-048, DoD SBIR Program, January 30, 2009.

supported by an execution memo from the Director of Defense Procurement and Acquisition Policy.[47]

- **September 2011—**The House Armed Services Committee formed its first Defense Business Panel focused on recommending improvements to DoD acquisition favoring increased small business access.[48]
- **December 2011—**The White House signaled to SBA that it planned to hold cabinet-level accountability for the small business mission by elevating the SBA Administrator position to the cabinet of Secretaries.
- **November 2012—**The second Better Buying Power memo reiterated support for improved integration of small business into acquisitions.[49]

During this period, perhaps the most notable development of all was the validation by Congress of the CPP approach. In its FY2010 NDAA,[50] Congress made CPP a permanent component of DoD SBIR/STTR. This marked a significant change in the legal infrastructure supporting SBIR at DoD. The program was renamed the Commercialization Readiness Program (CRP).

Congressional action occurred despite limited public information about CPP outcomes. The FY2010 report on CPP was not published (and with the change in status this requirement has since lapsed). The data reported in previous reports provide detailed information about CPP inputs—what the Services did and how much it cost—but almost nothing (and in particular nothing quantitative) on program outputs.

ADDITIONAL COMMERCIALIZATION MODELS: 2006-2012

At the same time that the Services were starting to experiment with different commercialization mechanisms through CPP, other efforts to enhance commercialization relevant for SBIR were also gaining some traction within DoD.

The period was marked by a flurry of acquisition related memos and guidance for DoD SBIR programs (Table 4-3).

Small Business Technology Insertion Program

In 2008, House appropriators led by Rep. John Murtha funded an annual “Small Business Technology Insertion” program funded at about $50 million. Funding was split between Services’ ACAT programs to test the

[47]Defense Procurement and Acquisition Policy (DPAP), *Increase Dynamic Small Business Role in the Defense Marketplace*, June 27, 2011.
[48]House Armed Services Committee (HASC) Press Release, *HASC Leadership Announces Bipartisan Defense Business Panel*, September 12, 2011.
[49]Office of Under Secretary of Defense (OUSD) memorandum for Acquisition Professionals, *Better Buying Power 2.0: Continuing the Pursuit for Greater Efficiency and Productivity in Defense Spending*, November 12, 2012.
[50]P.L. 111-84.

Box 4-4

Better Buying Power Memorandum #1

Increase dynamic small business role in defense marketplace competition. Small businesses have repeatedly demonstrated their contribution to leading the nation in innovation and driving the economy by their example of hiring over 65 percent of all new jobs and holding more patents than all the nation's universities and large corporations combined.

Our defense industry must leverage that innovation and opportunity into our competitions, as small business representation on programs has demonstrated lower costs to the government. For many small businesses, subcontracting on Department contracts is the first step to becoming a Department prime contractor. Components must understand the small business capabilities within their industry and increase market research and outreach efforts to ensure small business utilization is maximized. In order to remove barriers to small business participation in Department contracts and competition, *I direct the CAEs to institute in all competitive and noncompetitive procurement actions emphasis on small business utilization through weighting factors in past performance and in fee construct*. (emphasis in original)

SOURCE: OUSD memorandum for Acquisition Professionals, Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending, September 14, 2010.

proposition that innovative SBIR technologies could bring efficiencies of cost, schedule, and performance to DoD acquisition if decisions were made within acquisition programs.[51]

The Deputy Under Secretary of Defense (DUSD) formally recognized the program,[52] and in 2008 a Navy report on first-year progress with PEO Submarine's Virginia-class and PEO Integrated Warfare Systems Anti-Submarine Program supported the House appropriators' hypothesis.[53] The same year, a Navy survey of DoD Tier 1 and 2 prime contractors, integrators, and suppliers noted among other findings that technology commercialization

[51]Committee on Appropriations-Report 110-279, *Report on the DoD Appropriations Bill 2008*, July 2007, pp. 13-14.
[52]Deputy Under Secretary of Defense for Acquisition and Technology (DUSD (A&T)), *Small Business Technology Insertion Funding*, December 21, 2007.
[53]NAVSEA, *Report to DUSD on Small Business Technology Insertion Plan*, DAA FY08, March 2008 (distribution restricted).

TABLE 4-3 SBIR Related Acquisitions Memos and Guidance

28-Jun-10	"Better Buying Power-Mandate for Restoring Affordability and Productivity in Defense Spending"—USD AT&L
14-Sep-10	"Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending"—USD AT&L
3-Nov-10	"Implementing Directive for Better Buying Power" - USD AT&L
22-Apr-11	"Implementing Will-Cost/Should-Cost Management"—USD AT&L
27-Apr-11	"Improving Competition in Defense Procurement"—DPAP
19-Jul-11	"Increased Use of Small Business Concerns"—ASN RDA
5-Aug-11	"Maximizing DoN Opportunities for Small Businesses"—USN
24-Aug-11	"Should-Cost and Affordability"—USD AT&L
10-Feb-12	"Advancing Small Business Contracting Goals in FY2012"—Dep SECDEF
13-Mar-12	"Improving Small Business and Competition Opportunities in Services Acquisitions"—USD AT&L
10-Apr-12	"Improving Small Business and Competition Opportunities"—ASN RDA
12-Nov-12	"Better Buying Power 3.0" memo - USD AT&L
16-Nov-2012	"FY2012-2018 Defense Planning Guidance (Transition Planning Information for SBIR and STTR)—USD AT&L
29-Nov 2012	"DoD Small Business Functional Integrated Product Team"—USD AT&L
13-Dec-2012	"Meeting Small Business Goals in FY2013"—ASN RDA

SOURCE: John Williams, Navy SBIR Program Manager.

decisions are most effectively made within acquisition programs and their industry correlate offices—that is, at lower acquisition levels.[54]

Beginning with the FY2008 DoD Appropriations Bill, Congress annually supported this "Small Business Technology Insertion" program in amounts ranging from $100 million in FY2008 to $50 million in FY2012, to ensure funding support for actual technology insertion. Although funding was originally split between the Services for the two highest-priority ACAT programs each, by FY2010 this funding was allocated to Navy ACAT programs only, based on prior results. ACAT PMs selectively applied these funds to SBIR projects that had already successfully competed for awards and were included in ACAT system technology roadmaps.

[54]Navy SBIR/STTR Program Office, *Defense Contractors SBIR/STTR Partnering Manual,* August 2008, pp. 47-49.

DoD Rapid Innovation Program (RIP)
(Later Renamed Rapid Innovation Fund [RIF])

In its May 2010 report on the proposed FY2011 NDAA, HASC cited a December 2009 Defense Science Board finding that DoD "lacks the ability to rapidly field new capabilities to the warfighter" and cited the success of Small Business Technology Insertion to justify a competitive DoD Rapid Innovation Program (RIP),[55] which was established through the FY2011 NDAA (and other related legislation).

The objective of the RIP was "(to) accelerate the fielding of technologies developed pursuant to Phase II SBIR projects [. . .] and others [. . .] to stimulate innovative technologies [. . .] and reduce acquisition costs [. . .] improve T&E outcomes [. . .] and rapidly insert such products [. . .] in primarily military MDAPs."[56]

Funding for the new program was by small business standards quite substantial: not less than $128 million for each Service for Phase III SBIR projects.[57] Formal USD (AT&L) guidance on RIP was issued in August 2011. It reiterated Congressional goals, renamed the initiative the "Rapid Innovation Fund" (RIF), and directed each Service and Office of the Secretary of Defense Office of the Small Business Program (USD OSBP) to establish RIF award procedures. The guidance emphasized SBIR/STTR prioritization for the competition, outlined proposal solicitation and selection processes, and established an RIF timeline.[58]

In response, in October 2011 each Service and OSD published Broad Agency Announcements (BAAs)[59] inviting RIF applications by November submission deadlines and describing the RIF execution and program purpose as in this example from Navy:

"The goals of the Navy Rapid Innovation Fund (RIF) are to enhance and accelerate delivery of military capability, reduce the cost of weapons systems either fielded or under development, or improve the quality of life for service personnel, by meeting urgent operational needs or other critical national security needs."[60]

The new RIF funding attracted a large number of applications, resulting in success rates lower than those for standard Phase I SBIR awards. Drawing from unofficial sources, responses by component are provided in Table 4-4.

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[55]House Report 111-491, *Report of the Committee on Armed Services on H.R. 5136*, May 21, 2010, pp. 356, 370.
[56]FY2011 NDAA, P.L. 111-83, §1073 and "Explanatory Statement," p. 447.
[57]FY2011 CAA, P.L. 112-10, §9436.
[58]OUSD (AT&L), *Defense R&D Rapid Innovation Fund Goals and Implementation Guidelines*, August 12, 2011.
[59]For current DoD BAA links, see <*http://www.defenseinnovationmarketplace.mil/RIF2012.html*>. Accessed on October 10, 2013.
[60]Office of Naval Research BAA #11-032, Department of the Navy Rapid Innovation Fund, September 2011.

TABLE 4-4 Responses to DoD RIF BAAs, by Component

	Number of Applications	Number of Awards	Success Rate (Percent)
Army	950	62	6.5
AF	729	56	7.7
Navy	858	57	6.6
OSD	1034	25	2.4

SOURCE: Unpublished draft of OSD situational summary for HASC leadership, February 8, 2012.

Each of the three Services moved to address the need for better commercialization models during this period. Navy focused on the twin efforts to improve linkages between acquisition offices and SBIR and to support commercialization through adoption of what came to be known as the SBIR Phase II.5 Program. AF instead focused on enhancing connections between SBIR and prime contractors and, through the addition of new TTAs with explicit mandates to work out of selected AF bases, to encourage the transition of SBIR technologies.

Navy Commercialization Training

Navy has supported an extensive Technology Assistance Program (TAP) for a number of years, operated by a contractor (Dawnbreaker, Inc.). The TAP is an 11-month training program that provides scientists and engineers with basic business training, culminating in the Navy Opportunity Forum (see above). Phase II awardees are eligible, and Navy makes a concerted effort to alert potential participants to the benefits of the program.[61]

LINKING SBIR AND ACQUISITIONS

The need to improve linkages between SBIR and acquisitions is well recognized and goes back almost 20 years. It has become well understood that "technology push"—simply funding the development of advanced technologies—is not in and of itself sufficient to lead to the adoption of technologies downstream.

Within DoD this is especially true, because weapons development programs have developed careful technology-development roadmaps that specify sequential improvements and then integration of technologies, a process that can span many years or even decades. Technologies that are not included in

[61]Navy requires that "[a]ll [SBIR] awardees, during the second year of the Phase II, must attend a one-day Transition Assistance Program (TAP) meeting. This meeting is typically held in the summer in the Washington, D.C. area. Awardees will be contacted separately regarding this program. It is recommended that Phase II cost estimates include travel to Washington, D.C. for this event." <*http://www.dawnbreaker.com/defense/navy-tap.php*>. Accessed June 11, 2013.

the roadmap are essentially orphaned and will be picked up for use within DoD only by fortunate chance.

Thus, as pressure has increased from Congress and from DoD senior staff (notably USD AT&L) to improve utilization of SBIR-funded technologies, three broad areas for reform and improvement can be discerned:

- Better coordination of topics between SBIR programs and acquisitions;
- Better connections to primes, who generally control the technology utilized in acquisition programs; and
- Improved communication between technology providers and potential users.

Topics and Planning

In recent years, there has been considerable effort to include more input from acquisition into the topic selection process and to shorten the process to allow more opportunities to use SBIR for rapid insertion.

We have seen that in 2004 Navy's PEO Ships supported the first-ever ACAT I Technology Insertion Plan to identify SBIR technologies for system integration—the first time that acquisitions programs had deliberately planned to include SBIR technologies as a core part of their eventual deployment decisions, and the first time that acquisitions had made a formal and significant effort to seek out SBIR-funded technologies.[62]

Today, a much greater percentage of topics originate with the acquisition programs' informal estimates Agency interviews suggest that these now account for about 50 percent of Army topics, 70 percent of AF topics, and about 65 percent of Navy topics. And even for topics that originate elsewhere, acquisitions input has increased. At Navy, PEO input is now a required "gate" through which topics must pass before approval.

At NAVAIR, concerted attention to topic coordination has grown over the years. NAVAIR uses a web-based Technology Portfolio Evaluation Tool™, which facilitates a collaborative virtual evaluation of more than 100 hundred SBIR topics by NAVAIR technologists, POs, and PEOs distributed throughout NAVAIR's global network.[63] One example of tool use is the review and tracking of Navy topics by different variables (see Table 4-5).

[62]The VA class program started COTS based and Open Systems adoption strategies in the mid-1990s as a direct result of SBIR successes with DSR starting in 1992. The VA Class program paid $34M for a Phase III in 1994 which was the first.

[63]Dawnbreaker, NavAir CPP, <*http://www.dawnbreaker.com/defense/navair-cpp.php*>. Accessed June 11, 2013.

TABLE 4-5 Navy Utilization of Prognostics and Health Management Tool

1.0-S	Topics and Phase I Activity Metrics—Measured by Topic Solicitation	0.9.1	09.2	09.3	2009	10.1	10.2	10.3	2010	11.1	11.2	11.3	2011
A	Number of Navy Topics Published in Solicitation	91	66	67	224	104	87	41	232	86	84	11	181
B	Percentage of "Provider Enterprise" Published Topics (goal 10%)***	61.5	75.8	70.1	68.3	73.1	57.5	82.9	69.0	73.3	33.3	*	50.3
C	Percentage of Topics Allocated to PEOs (goal 90% or more)	63.7	77.3	80.6	72.8	63.5	57.5	85.4	65.1	65.1	66.7	63.6	65.7
D	Percentage of Topics Addressing Affordability** (goal 40% or more)	68.1	63.6	76.1	69.2	60.6	63.2	75.6	64.2	72.1	71.4	63.6	71.3
E	Number of Ph I Contracts Awarded by Navy	271	178	163	612	316	253	128	697	233	222	25	480
F	Average Time in months from Proposal Submission to Ph I Award (goal <4 months)	4.8	4.3	6.0	4.9	4.7	4.3	4.4	4.5	5.1	3.7	4.5	4.4

G	Average number of Ph I Awards per topic	3.0	2.7	2.4	2.7	3.0	2.9	3.1	3.0	2.7	2.6	2.3	2.7

NOTE: Shaded cells denote annual data. *Did/do not collect this data. **Data collected since 07.2 solicitation. ***Data collected since 08.1 solicitation. Table dated Tuesday, April 17, 2012.
SOURCE: Navy SBIR program office.

Integration into the Acquisitions Planning Process

Acquisitions planning is an exceptionally complex and formally constricted process. To increase the inclusion of SBIR technologies in acquisitions, the acquisition process must be engaged directly. Discussions with senior Navy staff suggest that SBIR must be built into core acquisition Milestone documents and into the Milestone assessment process (note that the planning process is different for each Component: the discussion below focuses on Navy, but similar processes will have to be engaged throughout DoD).

This means that the SBIR program must be engaged *before* Milestone A, during the planning phases identified as Analysis of Alternatives (AoA); Acquisition Strategy (AS); and Acquisition Planning, aka Technology Insertion Plan (TIP). This early engagement will help to ensure that planners are aware of SBIR technologies at an early stage, and of the potential uses of SBIR in filling technology gaps, which in turn will help to keep SBIR technologies within the process from the start.

Engagement will be needed beyond Milestone A, through sequential updates to AoA and TIP, completion of a Technology Development Strategy (TDS) and a Test & Evaluation Strategy, as well as a Corrosion Prevention/Control Strategy (CPC) and a Life Cycle Sustainment Plan. For Navy, this planning process also includes the Naval Probability of Program Success (PoPS) assessment process, in which the SBIR program will probably have to be engaged.

Tracking and Enforcement

A core issue for SBIR firms has been the need for better enforcement of goals and agreed-upon processes. Several companies interviewed (see Chapter 5) indicated that in some cases acquisitions staff simply ignored requirements for SBIR data rights. The mandates have become increasingly clear:

- P.L.112-81 (FY12 NDAA) mandates increased SBIR/STTR technology transition in four sections of Division E “SBIR and STTR Reauthorization”: Secs. 5121, 5122, 5141, and 5165.
- P.L.112-39 (FY13 NDAA) supports small business technology transition: Title XVI “Industrial Base Matters“ includes two sections in Subtitle B and 11 sections in five Parts of Subtitle C that establish processes to increase DoD acquisition contracts and subcontracts to small business, either directly from federal agencies or from industry contractors.
- DON SBIR/STTR PO published a “how to” handbook on use of incentives to increase small business/SBIR-STTR subcontracting (November 2012).

At the same time, DoD hierarchies have sought to ensure that acquisitions leadership understands and complies with these mandates. The range of memoranda discussed earlier in this chapter indicates that significant efforts have been made and are continuing in this area. It also suggests that success is not yet at hand. Recent memos have focused on tracking and reporting, and in particular improving the tracking of Phase III awards. A 2011 memo in the USD AT&L "Better Buying Power" series required industry to review its Independent Research and Development (IRAD) investment strategy in SBIR/STTR projects to ensure alignment with DoD acquisition priorities. In addition, the FY2012 NDAA requires that industry fully report its SBIR Phase III investments.[1] Other sections set small business contracting and subcontracting goals[2] and require improved transparency in subcontracting contracts.

Primes

Prime contractors ("primes") hold an extraordinarily important place in the DoD innovation and technology ecosystem. Both DoD and the primes have been under pressure to improve linkages between the primes and SBIR programs for almost a decade now, dating back to Congressional statements and the first USD AT&L memo on the subject in 2004.

In the case studies presented in Chapter 5 some small companies report working successfully with prime contractors, while others report a dysfunctional relationship. Incentives and risks both have to be addressed: in many cases, primes have minimal incentives to work with SBIR companies, because they themselves have or are developing competing technologies. Small companies pose risks in that or other categories; moreover, primes are not sure that small companies can perform as long-term suppliers.

Therefore, policy in this area has attempted to support the development of incentives to both encourage linkages and minimize or buy down various kinds of risks. In 2006, PEO Subs issued a first-in-DoD instruction to PMs that required development of plans to encourage primes to include SBIR projects.[3]

In 2009, Navy partnered with AF on four Focused Industry Technology Workshops, each hosted by a different prime contractor.

Efforts to engage the primes also include the Navy Opportunity Forum, an annual event usually held near Washington, DC, which brings together selected SBIR companies and projects, Navy acquisitions managers, and staff from primes. The Forum is in general favorably reviewed by participants, although systematic data about ultimate outcomes is not publicly available.

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[1]FY2012 National Defense Authorization Act, P.L. 112-81, Division E "SBIR and STTR Reauthorization," § 5122.

[2]P.L. 112-239, Subtitle C, parts 1-IV.

[3]NAVSEA PEO Submarine Exec. Director, *Operating Instruction #44: Incentivizing Large Business Contractors to Increase Small Business Participation in Submarine Procurement*, June 29, 2006.

However, reviews of the publicly available documentation do not offer any sense of the extent to which these initiatives have been systematically successful. DoD does not appear to track this information, although it seems likely that more detailed information may be available internally, especially at Navy.

CONCLUSIONS

The persistent efforts documented above to deliver SBIR technologies to the war fighter show that DoD has long recognized the need for improvements but that no simple fixes are available in this area. Key areas for policy focus have been as follows:

- Linking SBIR with acquisitions;
- Funding further development of SBIR technologies beyond Phase II; and
- Utilizing SBIR to address specific needs in acquisitions, notably the need for rapid development and deployment of advanced technologies to meet mission needs.

These efforts can yield impressive results. At Navy, the impact on one program of record in particular—Virginia-class nuclear submarines—has been well documented (see Figure 4-6); similar impacts of other weapons programs have been recorded—for example, the F-35 Joint Strike Fighter (Figure 4-8). These

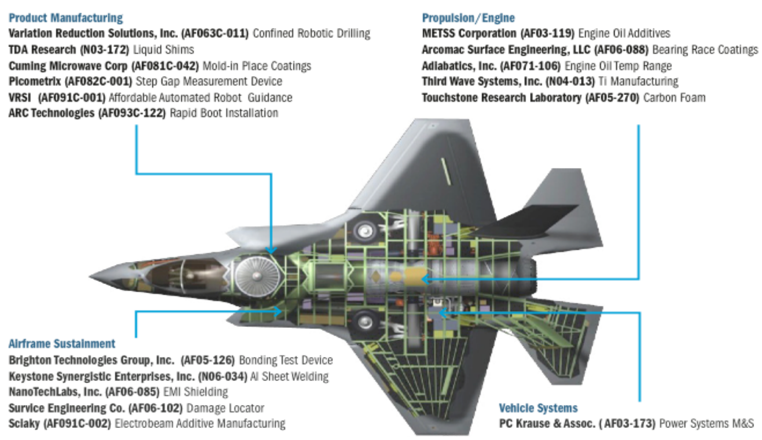

FIGURE 4-8 Navy Phase III contracts for F-35 Lightning II Joint Strike Fighter.
SOURCE: Navy SBIR program office.

illustrations of the key deliverables for the subs and joint strike fighter development programs highlight a positive link between acquisitions and the SBIR program—albeit at a level that does not address the scale of the impact or the extent of more, similar successes in other categories.

5

Insights from Case Studies and Extended Survey Responses

To complement its review of program data, the committee commissioned case studies undertaken in 2010-2012 of 18 SBIR companies that received Phase II awards from the Department of Defense (DoD). This chapter highlights key issues from these cases (presented in full in Appendix F) and also draws on the extended responses received from respondents to the committee's most recent survey of SBIR recipients.[1] These comments and concerns, summarized in text boxes, illuminate some of the details of program operation and illustrate the various roles that SBIR plays in the development of small innovative firms. Their value is derived from the details they offer and the stories they tell. Together, the case studies and excerpts of comments from the surveys provide a broader qualitative understanding of the program, particularly from the user's perspective, and are thus an essential part of the information gathered by the committee to assess whether the DoD SBIR program is meeting all four of its legislative goals.[2]

The qualitative analysis in this chapter is divided into five broad sections: the effects of the SBIR program on the companies; its impact on company missions; other SBIR Congressional objectives; comments and concerns about the SBIR award process and implementation at DoD; and ideas from the companies for improvements.

[1] The 2011 survey covered DoD Phase I and Phase II SBIR recipients with awards 1999-2008. The survey included an open comment box where respondents could describe their company's experience with SBIR.
[2] The committee has drawn on a complement of quantitative and qualitative information including surveys, case studies of firms, as well as discussions with program staff to develop this assessment of the DoD SBIR program.

ROLE OF CASE STUDIES

Case studies were an important part of data collection 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 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.

A wide range of companies were studied: 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 on military applications, and others focused on commercialization primarily through the private sector (see Box 5-1). 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. Rather, they provide qualitative evidence about the individual companies selected, which are, within the limited resources available, as representative as possible of the different components of the awardee population. The case studies, presented in full in Appendix F of this report and highlighted in this chapter, have been verified by the companies that they feature and they have explicitly permitted their use and identification in this report.

COMPANY EFFECTS

SBIR awards can affect companies in a number of powerful ways, ranging from providing the support and sometimes impetus for company formation (e.g., TRX) to funding a commercially critical breakthrough (e.g., Qualcomm). This section draws on company stories to illustrate a number of these effects.

Company Formation and Seed Funding

For a number of companies, SBIR awards were the catalyst for company formation itself. For example, Cybernet was formed as a direct result of an SBIR award. In 1990, Heidi Jacobus won a Phase I award related to her PhD thesis; later that year Cybernet received its first Phase II award, which provided funds to hire Charles (Chuck) Jacobus and to move to new premises. Similarly, OKSI was founded by Dr. Gat in 1991, on the basis of a successful Phase I award. This award had the not insignificant side effect of proving to the Internal Revenue Service (IRS) that the company was in fact a going concern.

Box 5-1

Directory and Profile of Case Studies

Company Name	State	Demographic
Architecture Technology Corporation	MN	
Aurora Flight Sciences	VA	
Cybernet	MI	W
Fetch Technologies		
Giner	MA	
iRobot	MA	
Mayflower Communications	CA	M
Microcosm Inc.	NH	
Nanocomp	CA	
Navsys	CO	W
Nielsen Engineering	CA	
Opto-Knowledge Systems Inc.	CA	M
Optemax	MD	W
Powdermet and MesoCoat	OH	
Qualcomm	CA	
Texas Research International	TX	
TRX Systems	MD	W
Daniel H. Wagner Associates	VA	

NOTE: Demographic describes the company as majority-owned by women or minorities; these data are drawn from DoD awards data, and reflect company self-certification

Completed case studies are provided in Appendix F. A list of individuals interviewed for these case studies is provided at the end of this chapter.

Box 5-2

Seed Capital—Survey Respondents Comments

"Early on the SBIR program made our business possible…we would have never existed without it."

"My target market (Signal Intelligence systems) is critical for our nation's security, but is not an area that Venture Capitalists are interested.… Without the SBIR program, I would not have had the capital to start this company."

"Our company is in existence because of initial SBIR funding. If not for SBIR program, our company would only be a dream."

"The first SBIR contract won by the company was a DARPA Phase I. That served as the start-up capital."

"The SBIR program provided 'seed' funds for us to develop high risk technologies."

"This was our first source of funding. Without it we would not have gone into business full-time. The company has grown to 50 people."

"Without the SBIR program, it is vanishingly unlikely that technology development would ever have attracted start-up funding."

More recently, TRX Systems was founded in part because an SBIR award from the National Science Foundation (NSF) in 2007 provided critical seed capital. TRX founders were well aware of the SBIR program because Chief Technology Officer (CTO) Carole Teolis had been a principal investigator for awards at a previous company.

For a better known company, iRobot, SBIR funding for early-stage investments in multiple technologies provided the key to eventual success. Dr. Frost (CTO) explained that the support iRobot received from the SBIR program for a number of technologies in the mid to late 1990s was critically important to helping the company develop expertise in a range of related areas. Only one of the proposed products (the PackBot) became a commercial success, but that served as a technical and market platform on which the company's future success could be built.

Non-Linear Development and R&D

Innovation rarely moves in a straight line from idea to prototype to product. False starts and multiple initiatives can lead to products not aligned with those originally envisaged. In some important cases, SBIR funding was used by companies to reinvent themselves or to adopt a broader view of their R&D portfolios (see Box 5-3).

ATC reinvented itself several times. As with many consulting companies, ATC determined that its work could lead to commercial software and hardware products. Starting in 1990, the company focused on using SBIR and other funding sources to develop products, which were sold under the brand name Triticom and received several industry awards.

Cybernet adopted a bootstrap strategy typical of mid-West companies, for which venture or angel funding remains elusive. Even though Cybernet was able to raise $5 million in funding for its force feedback projects in the late 1990s, Dr. Jacobus considered this to be the exception rather than the rule. Noting that Cybernet's portfolio-based strategy did not fit well with the standard Silicon Valley/venture capital model, Dr. Jacobus likened her company's strategy to farming—some years are better than others, but no project ever really dies, in contrast to the prune-and-focus approach of the venture model.

Box 5-3

Non-Linear Innovation—Survey Respondents Comments

"The SBIR funding provided 'seed money' to initiate development of high-risk technology that is now finding potential application in areas not anticipated when the project was originally proposed."

"It funded advanced diesel engine technology developments usable in subsequent commercial and military business contracts."

"Pre 9-11, [our company] was focused on the private pilot avionics market. Post 9-11, that market shrank quickly and deeply. [We] made a strategic shift to supply aviation manufacturers with state of the art avionics carrying the highest FAA certification levels.... [T]hat first SBIR became the backbone for our entire line of avionics products. We are a shining example of how the SBIR program can drive both R&D and commercial success."

"SBIR funding has allowed our company to develop technologies outside the scope of our earlier activities."

Aurora tried to craft a comprehensive research and development (R&D) program for prospective products that involved a number of SBIR awards but reached beyond them to seek Phase III and other funding from other, possibly more attractive, sources. One example was the SPHERES program, which was developed for DoD and NASA and focused on nanosatellites.

This is perhaps an unusually complex example, but many companies rely on multiple funding multiple sources and undergo multiple iterations to reach a successful product. TRI, for example, made conscious efforts to commercialize its technology both within and outside DoD. Its efforts led to a spin-off partnership with another organization. A similar spin-off occurred at Powdermet, that time in conjunction with a new funding partner. TRX was developing multiple applications for different agencies off of the same base platform.

Bridge/Growth/Capabilities Funding

Once an initial technology has been developed, multiple barriers may appear before and during the initial period of market launch. Core technologies must be adapted for specific markets and needs; different federal agencies have different requirements; and, to sell into DoD, companies must move through the technology readiness levels (TRLs) until the product's risk has been fully addressed. These developments require time and funding, and the SBIR program often plays a critical role in providing both (see Box 5-4).

A potentially important set of technologies in nanotech is emerging from NCTI, which in 2010 won an oversized Phase II award of more than $4.5 million from the Air Force Research Laboratory (AFRL) to "Scale Up Production, Optimize Properties of Large-Format Carbon Nanotube Sheets for Future Use in Manned and Unmanned Aircraft."[3] This award allowed NCTI to hire Northrop Grumman Aerospace Systems and Cytec Engineered Materials as subcontractors. With SBIR support, NCTI is working to make the jump from batch to mass production for what DoD has identified as a critical technology.

Similarly, SBIR funding was critical for building technical capabilities at MesoCoat and Powdermet, sister companies focused on nanotech-based powders and cladding. The SBIR program funded the hiring of PhD scientists before market sales existed and was essential to maintaining a critical mass for R&D, without which Powdermet would have no substantial technology platform. According to the founder, "Without SBIR, the company would likely have remained a small scale jobbing materials contractor with maybe $1 million in revenues—SBIR was key in supporting the development of in-house capabilities."

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[3] For the full award abstract and details, see Small Business Innovation Research/Small Business Technology Transfer (SBIR/SBTT), <*http://www.sbir.gov/sbirsearch/detail/7699*>, accessed July 11, 2014.

Box 5-4

**Countercyclical and Bridge Funding Support—
Survey Respondents Comments**

"During a recession when our commercial work decreased substantially, the SBIR program kept us from having to lay off people and possibly go out of business."

"Our Phase II spanned the period of 2008-2009, the worst part of the economic downturn. In the absence of this contract, we would have failed to continue operations."

"SBIR….support allowed [the company] to survive the general downtown in technology in the early and mid 2000s."

"The influx of research money helped to keep the company going in a very rough time."

"The SBIR funding helped retain several key, technical folks employed for several years and helped the company stay afloat in difficult financial times."

"We worked on this SBIR during the dot com bust.…We lost almost all of our other business and may have gone out of business if we had not had this Phase II SBIR."

Timing Effects

The survival and growth of a small business is to some extent serendipitous. Because of a general lack of financial cushion and the relatively high fixed cost of staff and facilities, single contracts can make or break small SBIR companies. Stories from case studies illustrate just how important SBIR funding can be if it comes at a critical juncture. Numerous respondents affirmed the key role of the SBIR program in company survival during fiscally challenging times, either in the economy at large or toward the end of R&D funding and the transition to production (see Box 5-5).

iRobot pursued a range of technologies using SBIR awards during the late 1990s. In 1998 it received a DARPA research contract, which helped fund development of the technology that led to PackBot, iRobot's first commercially successful product, which turned out to be an inflection point for the company.

Box 5-5

**Transforming Company Culture through SBIR—
Survey Respondents Comments**

"SBIR led to an absolute transformation in our ability to provide useful technology.… SBIR sponsors push us to develop products and services with on-going value (focus on real commercialization)."

"Company moved from an engineering services company to a company focused on product development with a small portion of revenue still in services."

"Participating in DoD SBIRs significantly raised the profile of the company's engineering capabilities."

"Permitted company to transition from service oriented to design engineering firm."

the product...then developing the technology with an eye on the marketplace."
"We transformed our typical academic approach to a business approach."

The conflict in Afghanistan generated immediate demand for remote-controlled devices to scout within buildings and to address improvised explosive devices (IEDs). These needs expanded after the invasion of Iraq in 2003. This demand for PackBot represented a pivotal point in iRobot's transition from a research company to a product company. Since inception, iRobot has sold more than 4,500 tactical military robots.[4] According to iRobot executives, "The success of the PackBot was key to allowing iRobot to hold a successful IPO and contributes to the continuing financial success of the company."

Qualcomm—now a multi-billion dollar global leader in chip design for cell phones— received eight Phase I awards and four Phase II awards during its first 5 years of operation. SBIR funding came at a pivotal time in the company's development. According to Irwin Jacobs, founder and CEO at the time, "This funding allowed us to pursue several innovative programs that otherwise would not have been possible." In his Senate testimony, Dr. Jacobs noted that SBIR funding had a particularly direct and powerful effect on the company's ability to develop a competency in application-specific integrated circuits (ASICs). Although those ASICs have long since left the market, the competency has remained. Approximately two-thirds of Qualcomm's current revenues are derived from ASICs.[5]

[4] iRobot 10K submitted to Securities and Exchange Commission, Annual Report 2011, p. 3.
[5] Jacobs Senate testimony, op.cit, and interview, April 26.

High-Risk/High-Payoff Research

One of the key tensions within the SBIR program exists between the drive for commercialization—for ensuring that funded projects are not simply more research—and the need to support high-risk projects that are otherwise difficult to fund. The case studies themselves did not tend to draw attention to this tension, in part because most of them focused on projects that were successful commercially. However, many of the survey respondents offered thoughts on this issue (see Box 5-6). Their comments emphasized that almost no commercial funding is available for high-risk projects until preliminary results—at the level funded by SBIR—are available.

Ongoing R&D Funding

The SBIR program has been a general source of ongoing R&D funding for innovative small companies, few of which have the resources to invest sufficiently in high-risk R&D themselves. Venture capitalists are reluctant to engage in this R&D because the risk is too high or the market too small (a

Box 5-6

High-Risk High-Return Research—Survey Respondents Comments

“Almost all the products under development are ‘niche’ technologies that no VC would look at, nor angels. The SBIR program takes risks where private money is nonexistent.”

“SBIR/STTR programs are the only viable source for funding of new ideas and new applications… which include substantial technical risk.”

“Technology for aerospace has a very long developmental cycle (5 TO 10 years) and is often highly specialized with small target markets…. [I]t is extremely difficult to secure VC or other private investment.”

“DoD and NASA SBIR funding provided opportunities and resources for high risk R&D activities.…[I]t’s usually very difficult to obtain private funding to get started due to their inherent high risk since it hasn't been proven. Thus, the SBIR program fill [sic] this gap.”

“The SBIR program has allowed us to develop high risk technology to commercialization.”

particular problem for defense). As one survey respondent noted, “The SBIR program invests in areas where the venture community does not, or does so very reluctantly. As such, the program is critical to maintaining US dominance in many scientific areas.”

That was the case initially at ATC, where the SBIR program funded the research that led to the company developing its own products and moving away from a service delivery strategy. TRI, a long-time provider of Navy technologies, used SBIR as a central plank of its business strategy almost from the inception of the program. It received its first SBIR award from the first round of NSF awards in 1983.

The SBIR program also allows companies to become more attractive partners by funding R&D that commercially oriented partners do not want to touch. Cybernet has discovered that, although it is almost always necessary to have a marketing partner to enter specialty markets, those partners are, according to Dr. Jacobus, “rarely prepared to pay for technology development.” Here the SBIR program funds the technology development that can later be licensed or spun out.

Validation at DoD

Small companies can find it difficult to break into DoD contracting. Some never manage to do so despite the quality of their products and technologies. Often, it is important to work with a prime contractor (see below). Equally important, however, is the ability of a small company to convince DoD acquisitions officers not only that their technology and product have been tested sufficiently and are ready for insertion, but also that the company itself is a reliable and stable provider. From the perspective of several companies, one of the SBIR program’s many virtues is that it provides direct access to DoD acquisitions officers and other staff without the need to work through a prime contractor (see Box 5-7).

Several companies, such as Microcosm, noted that the SBIR program provides a unique gateway for small companies into DoD acquisitions. Without the program, all contacts with DoD would have to be channeled through prime contractors. As a result, small businesses would lose the opportunity to connect directly with customers, and acquisitions would lose direct access to the flexibility and technical capacity of innovative small firms.

ATC’s first federal contracts included a substantial role as subcontractor to the Volpe Center in Boston, which was leading the Federal Aviation Administration’s (FAA’s) efforts to develop next generation traffic control systems. This subcontract led to numerous contracts with the FAA: ATC performed more than 50 projects for the agency, ranging from terminal and tower automation to runway safety. Because of its work for the FAA, ATC provided software development and specialty engineering services to industry leaders such as Ford and Boeing.

Box 5-7

SBIR and Validation at DoD—Survey Respondents Comments

"Provided an opportunity to work closely with DOD customers in a way that would not have been possible without the award."

"The Phase II opened up doors to other government agencies, prime contractors, investors, suppliers, subcontractors and others that we would not have been able to find otherwise."

"Provided the foundation for the technology we use to support DOD and Prime Contractors in designing and evaluating missile system designs using divert jets."

"The SBIR funding allowed the company to gain access to DoD Project Offices.... Without SBIR funding, it is unlikely our company would have had success…meeting our DoD end customers' needs."

"Winning always generates a 'buzz', winning contracts gives immediate credibility.… [A] DOD affiliation was very good."

Even though OKSI could acquire non-SBIR DoD contracts, the program was still invaluable to the company when entering technical areas that were otherwise dominated by either large prime contractors or universities. For example, OKSI undertook a number of non-SBIR contracts with MDA, for whom it developed sensors for many different kinds of missions, in most cases acting as its own prime contractor. SBIR allowed OKSI to build sensors and demonstrate its technology directly to MDA. Without SBIR, according to Dr. Gat, this direct access to the customer would not have been possible.

In some cases, DoD validation is explicit. For example, DoD has, through its Title III Defense Production Act, designated NCTI's products as "critical to national defense."

Ms. Politi said that TRX found enhancement programs within SBIR to be of considerable value and would call for expanding them, particularly at DoD where they can be used to fund company efforts to traverse the difficult and demanding DoD validation process. Developing hardened products is expensive, and enhancement programs can provide key funding in that area. DoD funding in this case required matching funds, which TRX was able to raise from a strategic partner (Motorola) as well as from other investors.

Box 5-8

Validation Effects—Survey Respondents Comments

"It gives us a lot of opportunities to make contacts with VC and commercial companies."

"Having that first contract gave credibility to our fledgling company."

"It is amazing to see the reaction of people at meetings and conferences when they realize that the company actually received and is living on a SBIR Phase II award."

"The SBIR Phase I award put an implied United States Government Department of Defense approval…and provided the creditability…when we discussed teaming arrangements and initiating non-disclosure agreements with other large Prime contractors"

"Utilizing SBIR financing/support, the company has created three direct spinout companies, and licensed technology to two additional companies, creating over 150 total, permanent jobs. And have attracted over $20M in follow-on financing in larger commercial areas."

Validation—Outside Investors and Strategic Partners

Validation effects go beyond DoD. Many companies focused primarily on DoD encounter difficulties in attracting private venture capital because their products are seen to have limited mass market potential and venture capitalists prefer to avoid the tightly regulated DoD acquisitions marketplace. Even so, some companies serving DoD do have substantial non-DoD businesses and access to other sources of strategic funding. Several companies observed that SBIR funding was an important validator both for investors and for strategic partners.

SBIR funding was catalytic for Powerdermet. Between 2005 and 2007, Powdermet won an Army SBIR award in partnership with Caterpillar, through which it applied its technology to thermal spray coatings. This led to a 2x magnitude improvement in processing speed over state-of-the-art coatings. Based on these results, the Third Frontier program in Ohio provided additional funding and the State of Ohio economic development office provided direct funding for business planning. Validation through the SBIR program was important.

As noted above, Qualcomm received SBIR funding at a particularly critical juncture in its early development. But as founder Irwin Jacobs noted in Senate testimony, although SBIR "was not the only source of funding for us at the time, it was one of the critical 'stamps of approval' that allowed us to successfully pursue sources of private capital."[6]

According to the CEO of NCTI, even though the SBIR awards came later in the technology development process than is usually the case for SBIR companies, they provided critical validation for the company and its technology, which strengthened its relationships with prime contractors and customers and its efforts to attract investors. Michael Gurau of Community Ventures, who led NCTI's Series A round in 2006, observed that this validation was especially useful in sectors such as materials and defense where venture funding was scarce and became increasingly important overall as early stage venture capital became even more difficult to attract.

TRX was able to attract outside investors and generate financial support from strategic partners. According to CEO Carol Politi, support from SBIR awards, a Maryland TEDCO grant, and an NSF Phase IIB award provided critical early funding to deliver proof of concept. NSF support in particular was, according to Ms. Politi, central in helping the company raise its first angel funding: the ability to point to a federal contribution that effectively doubled the money of investors was "a huge benefit in raising outside money."

Working Effectively with Primes—Company Perspectives

The case studies and survey responses highlighted the critical importance of being able to work effectively with DoD's prime contractors. Without links to primes, it is exceptionally difficult to consistently transition technology, because most DoD technology-related spending is for major weapons systems that are integrated and delivered by primes, who are also in many areas the suppliers of specific components. This section provides insights into successful partnerships with primes, and the following section into less successful relationships.

DWHA had a very long history of exceptionally fruitful collaboration with a number of primes. For example, several of DWHA's early SBIR awards were used to develop data fusion capabilities for mine warfare: an SBIR award from the Office of Naval Research (ONR) funded development of an optimal routing algorithm that could be used to route a ship to avoid mines, despite inconsistent or even erroneous data. The tool was developed further so it could be tested on the EDG 1000 Navy R&D destroyer that was designed to help locate mines. ONR provided further funding, and DWHA developed tools that were adopted for real-time mine avoidance.

DHWA then teamed with Applied Research Labs of the University of Texas, which provided sensor technology, and SAIC (with whom DHWA had

[6] Jacobs Senate testimony, op.cit.

partnered for more than 20 years) to apply the tools for use by submarines. On other projects, prime partners include Lockheed Martin, Boeing, the Institute for Defense Analysis, Westinghouse, McDonnell Douglas, and SAIC. DHWA also partnered with MIT's Lincoln Labs and Johns Hopkins Applied Physics Laboratory.

Aurora's partnership with Northrop Grumman in UAVs (unmanned autonomous vehicles) dates back to at least 2004. A number of achievement awards attest to Aurora's strong links to primes: it has been a "Platinum Source" supplier for Northrop Grumman since 2008. It has a Supplier Gold certification from Sikorsky Aircraft Corporation—the highest recognition for supplier quality. In 2011, Aurora was named "supplier of the year" by Sikorsky.

Giner Electrochemical Systems managed a joint venture with GM to accelerate the development of fuel cell vehicles. GM took a 30 percent stake in the joint venture and continued to provide research funding through an annual research contract.

There are many other examples, such as:

- Microcosm worked with almost all small-spacecraft prime contractors and on mission and systems engineering for many large commercial and government programs, including Iridium, GPS, Teledesic, and Discover II.
- NCTI announced a major strategic partnership with Du Pont to develop products utilizing NCTI's unique materials and processes, as well as partnerships with Lockheed Martin on the NASA Juno project and Northrup Grumman on AFRL SBIR contracts.
- Over the past 35 years, NEAR developed an extended collection of clients in the United States, which includes almost all of the prime contractors working in aerospace.
- TRI teamed with an array of prime contractors including Boeing, Lockheed Martin, Northrop Grumman, Sigma Coatings Inc. USA, 3M, Hughes, and Textron.
- TRX Systems sold primarily through partner organizations, which include Motorola, Globe manufacturing, Boeing, and Honeywell.

Lessons Learned from Working with Primes

It is striking that companies that cracked the code to working successfully with primes were generally able to replicate the process with multiple projects and multiple partners. As one CEO noted, this was in part a longevity and stability effect: he thought that primes would rarely partner with companies with less than 10 years of operational experience.

DWHA's effective cooperative arrangements were driven in part by the lack of competing interests. DWHA provided highly specialized services that, from the perspective of prime contractors, were not only too small to be worth pursuing, but also too difficult to manage given the very high degree of technical knowledge required. They would not lead to large follow-on contracts, that is, there was no Phase III goldmine at the end of the road, and hence primes saw no need to enter that market.

Similarly, Dr. Dugan observed that TRI's partnerships with primes were possible because primes were generally not interested in entering markets for materials products. They did not see the need for improved materials reflected in DoD itself. In most cases, work on materials for DoD focused on niche applications with small potential markets and few non-military opportunities, and hence is of little interest to primes.

Dr. Upadhyay at Mayflower said that relations with primes largely depended on whether they were primarily acting as systems integrators or as technology developers. Raytheon, for example, partnered with Mayflower on some early contracts as a systems integrator, but lost interest in pursuing partnerships in that area after it bought Magnavox and acquired its own capabilities in GPS. When looking at relationships that worked less well, this issue surfaced a number of times: primes have their own research interests, and while acting as integrators can easily favor their own in-house research if they so choose.

Working Against the Primes—Company Perspectives

It would not be fair to state that there were substantially more negative comments about working with primes. However, the penalty to SBIR companies for conflicts with a prime can be severe and long-lasting. Several interviewees indicated that effective rules were not in place to sufficiently protect small companies.

ATC worked on a number of projects with prime-led teams. However, after a number of failed partnerships, the company decided that the incentive structure at DoD caused primes to squeeze out smaller companies once a contract has been awarded. As Mr. Proctor of ATC noted, "The primes are very keen to have us on the bidding teams; but not so interested in following through with actual funding for technology development or deployment afterwards." Now, ATC will work on a team with a prime only if the prime is the subcontractor to ATC. Mr. Proctor further observed, "The primes would never voluntarily put a small business subcontractor in the critical path of a major project."

Navsys entered a period of severe crisis in 2007, following SBIR awards that led to its technology using GPS to improve the targeting of "smart bombs." The company expanded to 50 employees in anticipation of a Phase III contract, but Air Force instead awarded the contract (and the technology) to Boeing. Navsys was forced to lay off half of its workforce in 2007, and Dr. Brown mortgaged her house to generate the $1.5 million in cash Navsys needed to survive. According to Dr. Brown, "It was a blatant example of how Air Force Space Command didn't follow (Federal) rules designed to protect technology

Box 5-9

Phase III—Survey Respondents Comments

"The Phase III award then allowed great freedom in overcoming the contractual limitations and logistics of receiving other DoD funds by taking advantage of the pre-competed clause of the Phase III."

"Getting to a Phase III without a prime contractor involved has been huge for the product and company."

"SBIR-based initial funding (all 'Phase III') has significantly contributed to our growth, and now is close to 100% of our business."

"SBIR funding and the follow-on DARPA BAA made [the company's] disruptive technology possible. Without this start, the technology would never have left the very initial prototype phase."

"SBIR funding has provided this company with critical R&D resources to develop technologies critical to its growth. Resulting Phase III funding has been significantly greater than $10M."

developed by small business. We appealed to the deputy undersecretary of defense, the Small Business Administration and (former U.S.) Sen. (Wayne) Allard and got the decision reversed, but it nearly put us out of business."

Dr. Brown emphasized that Navsys' problems with Talon Namath had implications far beyond the immediate issue. Not only was DoD at risk of failing to acquire the best technologies, but also there were long-term implications for small high-tech companies that were a key part of the military supply base. Effectively, if there was no path into procurement or if the path was too risky, then the military would have no long-term business model for companies such as Navsys. This Phase III barrier made it much more difficult for companies to lessen their dependence on SBIR funding.

After receiving a Phase III award, OKSI was eventually frozen out by Army's decision to work directly with the primes. Even though the partners signed highly restrictive nondisclosure agreements (NDAs) and the Small Business Administration (SBA) sent a letter to Army requiring it to cease violating the governing SBIR policy directive, Army continued to exclude OKSI. OKSI filed a lawsuit against the prime in question, but eventually decided that fighting such a large corporation made little sense for a small business. Consequently, OKSI became very careful in its dealings with primes. However, as Dr. Gat observed, a technology company working in the defense sector has few options for commercializing its products beyond the primes, given DoD's strong preferences for working with its established contractors.

AGENCY MISSION EFFECTS

Most of the successful companies profiled in this report initially focused on sales within DoD, and many remained so for commercialization. Given the unique characteristics of the DoD R&D ecosystem, and the limitations that can be placed on the transition of technology developed for the military sector to the civilian sector (especially in a globalizing world economy), this is not surprising.

Sales to DoD are a de facto statement that the program is meeting agency mission needs: the primary objective of DoD R&D is to provide new capabilities to the warfighter or to support activities that in turn support the cutting edge of DoD forces. Purchases by acquisitions officers are evidence that this mission is being accomplished. However, there are other indicators that agency mission is being addressed.

Title III Certification

One of the case study companies reached an unusual milestone: NCTI, was designated as firms that have developed technologies regarded as "critical to the national security." For NCTI, a successful Phase I demonstration showed that large-format CNT sheets can meet the functional requirements of EMI shielding and can also withstand the industrial stresses involved in pre-pregging, a process that prepares the material for direct insertion into aircraft manufacturing systems. As a result, Ashton Carter, Under Secretary of Defense for Acquisition, designated the research as a "critical SBIR program," which in turn led to a Phase II award from Air Force of more than $4.5 million in 2010.[7]

Innovative Products for Military Use

SBIR projects often address particular technical problems for the sponsoring agencies— sometimes problems that may have only limited sales potential but are of considerable value. For example, in 2001 ATC started a new focus on airport incursions—blind spots for ground control. It developed a system that alerts the control tower and flashes landing lights as a warning to pilots. The technology underpinning the system was similar to that developed for use on Aegis class warships, for which ATC acted as a subcontractor for Lockheed Martin.

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[7] For the full award abstract and details, see SBIR/SBTT, *Non-Metallic Conductive Material for ESD/EMI Applications*, <*http://www.sbir.gov/sbirsearch/detail/7699*>, accessed June 11, 2014.

Through what it calls its "most significant SBIR-funded work," Aurora developed ducted-fan UASs that can take off vertically, hover like a helicopter, and transition to horizontal wing-borne flight, which is faster and more fuel efficient—technology that originated in DARPA SBIR awards. One SBIR contract supported development of the ducted-fan technology that enabled the company to compete for the U.S. Navy Small Tactical Unmanned Aircraft Systems (STUAS)/U.S. Marine Corps Tier II UAS program.

Cybernet solved the problem of automating the sorting of small arms ammunition, which required hundreds of hours of manual labor. The Automated Tactical Ammunition Classification System (ATACS) sorts ammunition at a rate of 12,500 rounds per hour and has been widely adopted by Army.

DHWA applied mathematics to sea-based search. It was involved in projects such as the following:

- The successful search for the H-bomb lost in the Mediterranean off the Spanish coast in 1966, when a B-52 collided with a tanker.
- The search for the USS *Scorpion* in 1968, an attack submarine that imploded 400 miles west of the Azores, and went to the bottom at a depth of some 2,000 fathoms.
- The successful search for the Coast Guard packet ship sunk off the coast of South Carolina in 1857, with $400 million of gold (from California) aboard.

Giner supplied PEM electrolyzer stacks to the U.S. Navy Seawolf-Class submarine fleet through a partnership with the Treadwell Corporation. Giner technology eliminated the need for gas compressors, which can be bulky, troublesome, costly, dirty, and noisy. Giner then supplied next-generation LPE (low pressure electrolyzer) stacks for the retrofit of all Ohio-class submarines and for replacement of stacks on board the Seawolf class.

Navsys developed the GI-Eye system: a low-cost, tactical-quality inertial unit integrated with a GPS receiver and a digital video camera. This system extracts precise target coordinates from video imagery without requiring any known data points for georegistration. It records the precise location and attitude of the video images, so that the extraction of feature location data is simplified and streamlined. GI-Eye is currently the most important commercial product developed by Navsys, which received more than $500,000 in licensing revenue from this product in FY2010.

Commercialization

Although much of the impact of commercialization is best captured through data generated from the survey and from an analysis of agency data, its full impact is sometimes not easily captured.

Qualcomm was an early SBIR company, receiving awards in the late 1980s. Its success has led to substantial dividends for the taxpayer. In FY2010, the company paid federal income tax of $1.4 billion, not including the personal federal income taxes paid by the thousands of Qualcomm employees. Dr. Jacobs noted that Qualcomm directly employed more than 10,000 people in San Diego in 2007, and money spent by Qualcomm and its employees created and supported more than 26,000 jobs involving a variety of goods and services in San Diego County. As of 2007, Qualcomm was responsible for economic output equal to approximately 3 percent of the Gross Regional Product of San Diego County and supported an estimated 2.4 percent of total jobs. All of these numbers are much higher today, given Qualcomm's continuous and rapid growth. Finally, Qualcomm continues to pour funding in R&D. As of year-end 2010, it was funding R&D at more than $2 billion annually, approximately 19 percent of revenues.[8]

Rapid Response/Sole Source

The SBIR program is credited with rapidly fielding technology-driven improvements—much faster than traditional DoD acquisitions programs can manage. For example, within 60 days, Cybernet developed and fielded the ATACS for the U.S. Army in Camp Arifjan, Kuwait, where the product was used to reclaim serviceable ammunition through a faster, safer, and more consistent inspection process. Cybernet is currently building its sixth ATACS system for the Army. This rapid delivery was made possible in part by the SBIR compete clause, which permitted Army to sole source the contract to Cybernet based on the competition for the previous SBIR award.

OTHER CONGRESSIONAL OBJECTIVES

Innovation

Some of the more formal metrics for innovation (patents, publications) are discussed in Chapter 3. But metrics are a measure, not the object being measured, and they do not capture the multiple dimensions and impacts of successful innovation. Focus on these metrics substantially limits insight into the innovative power of the SBIR program. The case studies reveal efforts that have profoundly transformed the economy or even the world, for example:

- Qualcomm's technology is still embedded in most mobile phones.
- iRobot introduced the first commercially available personal robots.
- Aurora is on the cutting edge of drone technology.

[8] Qualcomm, *Qualcomm Announces Fourth Quarter and Fiscal 2010 Results*, November 3, 2010, p. 5.

Box 5-10

Innovations—Survey Respondents Comments

"The materials and design program is part of a long term transformation in body armor systems."

"We developed a new technique…currently being further developed for measuring velocities in aircraft exhausts."

"Chemistry developed during Phase II is being licensed to carbon fiber manufacturers and has been applied to the development of repair primers for composite aircraft and other composite applications."

"Our technology has saved tens of millions of dollars for DoD. Our fault tolerant architecture is the basis for the ship control architecture for the Virginia Class sub fleet and will be used to upgrade the other sub programs."

"SBIR funding enabled Q-Track to complete development of a breakthrough real-time location system technology: Near-Field Electromagnetic Ranging."

- Giner is providing a core technology for all Navy Virginia-class submarines.
- TRX technology can dramatically enhance the safety of first responders.
- NCTI new materials technology can support profound changes in multiple industries, including aerospace, energy, and personal safety.
- Through automation, Cybernet transformed a mandatory but difficult and time-consuming task (munitions sorting) for Army.
- Powdermet's coatings and claddings should have a large impact in several industries, including energy and defense.

Knowledge Metrics

It is difficult to generate quantitative metrics that fully capture knowledge effects, given the importance of informal knowledge transmission as people change jobs and companies are acquired. Metrics for SBIR tend to focus on patents and peer-reviewed publications as indicators (but not the sum total of knowledge effects). In addition to these metrics, the committee considered links to universities.

Many of the interviewees viewed publishing and patenting as important aspects of their ongoing operations. This finding was noteworthy because patenting has acknowledged difficulties (notably cost and timeliness) and there is less incentive to patent when the market is limited to a specific set of possible buyers (within the U.S. military). In addition, companies have many incentives to keep technical advances secret rather than publish in the scientific literature.

Publications

Throughout its existence, ATC has seen value in publishing technical documents. Founder Kenneth Thurber's biography claims more than 60 peer-reviewed publications and 14 books on local area network (LAN)-related topics.[9] The company published a book on computing architectures[10]and developed its own publishing imprint, through which it distributes Dr. Thurber's book on building a technology company.[11]

Giner personnel publish extensively in leading journals and make significant presentations at technical meetings in the United States and abroad. Key staff have received awards for scientific excellence and solving difficult problems for government and industry.

Microcosm is responsible for a number of key textbooks on space mission engineering. The company created and published *Space Mission Analysis and Design* (SMAD), a 1,000-page text and practical reference work in mission design and concept exploration. Originally developed for Air Force, it is according to Microcosm the most widely used book in astronautics. It includes substantial work directly relevant to low-cost space mission engineering provided by Microcosm personnel.

Navsys has published widely on GPS-related technologies. As of mid-2011, more than 165 technical papers are available on the Navsys web site.

OKSI staff have authored more than 100 peer-reviewed papers in the broad field of opto-electronics. In addition, the company has received four patents in the field of infra-red cameras.

Patenting

In recent years, ATC has worked to patent its technologies. According to the U.S. Patent and Trademark Office (USPTO), ATC was the assignee on 15 patents as of October 2011.[12] The company observed that patenting has only

[9] Dr. Kenneth Thurber's biography page, <*http://www.atcorp.com/index.php/about/senior-management*>, accessed July 11, 2014.
[10] J.A.K. Baker and K.J. Thurber, *Developing Computer Systems Requirements*, Ithaca, NY: Digital Systems Press, 2011.
[11] K.J. Thurber, *Big Wave Surfing*, Edina, MN: Beaver Pond Press, 2011.
[12] See U.S. Patent and Trademark Office (USPTO), ATC search, <*http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=/netahtml/PTO/search-*

recently become important, in part because software's life cycle is so short that patenting is rarely the best way to protect its value.

Other companies have also made extensive use of patenting to protect their intellectual property:

- Giner has more than 100 U.S. patents in the field of electrochemistry.
- Since 2001, iRobot has been the assignee on 130 patents granted by the USPTO.[13]
- As of May 2013, a search on Qualcomm at USPTO returned more than 10,000 hits.

Universities

Many of the companies have deep connections with major research universities. Aurora is a spin-off from MIT and maintains extremely close relations with the university: its R&D center is located in Cambridge, Massachusetts. Aurora highlights these close ties in its corporate mission statement: the Research and Development Center's "mission is to forge cooperative relationships with the Massachusetts Institute of Technology (MIT) and other universities. Aurora's synergistic relationship with MIT merges the innovative ideas from MIT's faculty and staff with Aurora's proven abilities to bring technologies from the lab to products that address the customer's requirements."[14]

NEAR has also worked with universities, including Johns Hopkins University Applied Physics Laboratory and the MIT Lincoln Laboratory.

ATC has worked closely with a number of universities on SBIR-related projects, including the University of Minnesota, South Dakota State University, Cornell University, and Purdue University. However, although it has successfully tapped university technical capacity, ATC is careful to limit and control university involvement. Specifically, ATC wants to ensure that the university has no stake in any IP developed in the course of the relationship. As hired subcontractors, universities and their staff remain focused on solving specific and defined technical problems.

Not all ties to universities have been so positive or long lasting. Optemax was founded to commercialize university technologies, and it focused on laser-based communications in part because of high-level research capabilities at Johns Hopkins University (JHU). However, the relationship with JHU eventually dissolved. According to Ms. Collier (Optemax founder and CEO), JHU staff could not understand the exigencies of commercial R&D,

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bool.html&r=0&f=S&l=50&TERM1=architecture+technology&FIELD1=ASNM&co1=AND&TERM2=&FIELD2=&d=PTXT>, accessed October 10, 2011.

[13] USPTO, iRobot assignee search, accessed September 14, 2012.

[14] Aurora company fact sheet, <*http://www.aurora.aero/Common/Downloads/People/Aurora%20Overview%20Fact%20Sheet.pdf*>, accessed May 24, 2013.

especially the need for secrecy, and insisted on publishing results before they could be commercially protected. These drivers of standard university activity could not be constrained even by the existence of nondisclosure clauses in the licensing and research agreement. Ms. Collier also noted a tension between the needs of commercial activity and JHU's primary funding for research from federal R&D funding. In the end, Optemax relinquished its $250,000 investment and dissolved the partnership.

Dr. Gat from OKSI observed that SBIR contracts require agency approval of publications, which presents a problem for universities whose mission requires the publication of results for peer review. In addition, almost all of OKSI's work was covered by International Traffic in Arms Regulations (ITAR), which placed restrictions on the flow of knowledge that most universities could not accept.

Women and Minorities

Although Cybernet and Navsys are woman-owned companies and Giner is a privately held minority-owned business, TRX, which is legally neither, provided some significant insights in this area.

TRX is not woman-owned, but it is woman controlled. The CEO and CTO are women. Ms. Politi explained that TRX's success in raising outside funds caused it to lose its woman-owned status with the SBA as outside money took a larger stake. So, although the company is less than 50 percent venture owned, it is more than 50 percent owned by outside funders, and therefore is no longer woman-owned. This change highlights a significant weakness in efforts to track the engagement of women (and minorities) within the SBIR program: successful companies may eventually fail to meet the standard SBA definition of woman-owned or minority-owned. Ms. Politi also observed that being woman controlled may help more at DoD, which implemented some new FAR regulations in this area.

Training and Manpower Effects

Several companies observed that the SBIR program provides opportunities for important training in project management and that SBIR companies provide important technical training and mentoring for other companies in their fields and regions.

ATC uses the SBIR program to train young engineers. An ATC engineer wishing to apply for SBIR funding first needs to make the case internally that the project will result in commercial sales, and then writes the proposal, which is valuable training in and of itself. If ATC wins an award, then the engineer is asked to run the project. This process not only provides critical experience, but also serves as a valuable incentive for staff and limits the amount of senior management time involved.

Box 5-11

Training and Manpower Effects—Survey Respondent Comments

"Expanded the technical knowledge base of company staff."

"Important for starting new lines of research and training new PIs."

"SBIR funding allowed us to recruit and train key members of the technical staff whose skills take several years to develop in our specialization area of radio frequency interference mitigation."

"The funding from SBIR awards has been critical to keeping staff employed through a difficult economic climate."

"The program allows us to attract and develop young researchers."

"The SBIR funding helped retain several key, technical folks."

Aside from its own SBIR awards, Microcosm has been very active in the local SBIR community in Los Angeles. The company is on the board of the local small business economic development council and has guided a number of local companies into the SBIR program.

NEAR staff members have served on at least 20 technical committees and government-organized review boards, such as the American Institute of Aeronautics and Astronautics, the Naval Aeroballistic Advisory Committee, and NASA Peer Review Committees.

PROGRAM OPERATIONS

Interviewees offered comments and insights on a wide range of operational issues related to the SBIR program.

Topics

Dr. Gat from OKSI observed that many DoD topics came from research labs rather than from acquisition programs, especially for Army, which tended to create significant gaps between topic authors and acquisitions programs.

The Powdermet CEO said the growing pressure to ensure that the SBIR program generates commercial returns is profoundly misplaced: it is driving selection of projects that are shorter term and lower risk. These types of projects are better suited to other funding streams—either acquisitions within DoD or venture funding in the private sector. In his view, the SBIR program is becoming a substitute for other sources of capital, for example, 6.3-6.5 funding at DoD and venture capital in the private sector. It is becoming an alternative to large company R&D and is being used to lower the cost of capital for venture firms. In short, it is becoming more of a corporate welfare program than a technology investment program.

Matching Money

Ms. Politi (TRX) observed that "matching programs give you a reason to reach out to people, and the double-your-money offer is very, very well received."

Data Rights

Various views on data rights emerged during the case study analysis.[15] Dr. De Luis (Aurora) raised concerns about protecting IP within the SBIR application process; Aurora had experienced problems with IP during Phase III as well. In general, he noticed relatively few IP problems when the government was the only client, but more serious issues for technologies with more commercial applications. Therefore, Aurora had been very cautious about protecting the technology embedded in its Skate micro-UAV project, for example.

OKSI was one of several companies that realized that, in practice, data rights could be ignored. For example, despite awarding what was in effect a Phase III award for the technology, Army later decided to work directly with primes and ignored the legal requirements related to Phase III data rights. It claimed that because the award was not labeled as a Phase III by Army, it did not need to be recognized as such.

Dr. Mike Dingus (TRI) said that contracting officers were a weak link and needed substantially more education about SBIR data rights, because knowledge varied widely between officers. Moreover, there were no effective penalties for violating data rights—in effect, companies were helpless if agencies did not play by the rules. He suggested that penalties should be enumerated and widely published. TRI had never used the sole source provisions of SBIR data rights and did not anticipate using them in the future.

Dr. Brown (Navsys) experienced extended difficulties with Air Force over data rights, when—according to the company and the SBA—it was

[15] SBIR Technical Data rights are defined as "the rights an SBIR awardee obtains in data generated during the performance of any SBIR Phase I, Phase II, or Phase III award that an awardee delivers to the Government during or upon completion of a Federally-funded project, and to which the government receives a license." SBA, SBIR Policy Directive, February 24, 2014.

squeezed out of follow-on implementation work in favor of a prime contractor. This story is discussed in detail in the Navsys case study in Appendix F, but this brief summary illustrates the difficulties of competing with a prime, when the prime is interested in and capable of providing the technology at issue.

Audits

A number of companies based on the West Coast experienced potentially company-breaking problems with the local offices of the DoD audit agency, DCAA. Although it is possible that the worst of these problems was resolved by the shift of some responsibilities away from DCAA, the audit process constituted a major barrier to small business operations.

Microcosm executives said that overall the contracting process is fundamentally broken because it does not effectively support agency objectives. They noted a previous decision to exclude the use of non-employees in handling contracts at DCAA had left an insufficient number of employees in place. According to Dr. Wertz and other interviewees across California, DCAA has applied extremely harsh regulatory practices to SBIR companies, with the effect of severely impacting SBIR-winning businesses:

1) Dr. Wertz (Microcosm), Dr. Mendenhall (NEAR), and Dr. Gat (OKSI all observed that DCAA refused to disclose the basis on which their company had failed the audit, which made it impossible to take the steps necessary to comply with required rules.
2) Even more damaging, during the period in which the company was not in compliance, it could not acquire new contracts from DoD. Given the considerable delays, this meant that Microcosm lost important contracts because of what turned out to be minimal or even trivial breaches of FAR.
3) Dr. Mendenhall (NEAR) said that the company's problems were compounded by the slow response time at DCAA. Its most recent Phase II award came after a gap of 8 months, during which time NEAR would have had to lay off staff had two not moved on to other opportunities. At OKSI, DCAA took 7 months to complete an audit for a 15-person company and was 3 years behind in auditing labor rates.
4) Dr. Gat (OKSI) noted that DCAA prided itself on using a single standard for audits, regardless of the company size, which in his view imposed potentially serious costs on small business.
5) Several interviewees noted that the pass/fail approach adopted by DCAA led to needless delays for minor infractions. For example, OKSI failed because of inadequate written procedures, which had the effect of delaying a number of critical contracts, some of which were critical for not only the company but also the agency.

Both Dr. Mendenhall and Dr. Wertz explained that these difficulties arose largely because DCAA itself received a highly critical report of its procedures from the Government Accountability Office (GAO), which led to a tightening of procedures. DCAA responded to its audit in part by failing large numbers of small businesses, an approach that Dr. Mendenhall described as being a drastic over-reaction.

It should be noted that companies in other DCAA regions did not experience these types of problems.

Contracts

Some interviewees observed that the contracting process and the contracts themselves had become much more burdensome. For example, Dr. Mendenhall provided a copy of a recent Phase I contract for Microcosm at DoD, which inter alia included a clause requiring that Microcosm implement procedures to inform employees that they were not permitted to text while driving.

Dr. Mendenhall also stated that task order contracts were more common, which adds substantially to the costs for the small business. For example, a Microcosm contract named BAE as the owner of the contract. This meant that BAE was paid a fee for managing the contract, was required to do some portion of the work, and was required to retain review responsibilities over the project. Moreover, subcontractors were not permitted to order supplies through a task order contract—BAE must order all material and, indeed, must put under contract all Microcosm subcontractors.

Several interviewees noted that acquisition of a DoD Phase II award requires a large expansion of bureaucratic capacity from the small business. Dr. Wertz noted that in some cases small businesses simply decide not to make the investment and turn away from the SBIR program as a result.

Dr. De Luis (Aurora) said that acquiring a certified Phase III award was almost impossible. He has received two such awards during his entire career.

According to Dr. Wertz (Microcosm), contracting officers (COs) came under enormous pressure, as the volume of contracts increased and the number of COs did not. Many COs had little understanding of the SBIR program, and rules regarding SBIR Phase III awards were almost universally ignored.

Payment Structures

A number of company representatives identified payment processes and structures as problems. Dr. Werz (Microcosm) considered this problem to be a perennial one—there is often a significant mismatch between the cash flow needs of small companies and the rigid payment structures of the federal agencies. Microcosm staff also noted significant differences among the agencies—NASA, for example, disbursed funding in thirds against progress, and, in contrast, Army paid equal amounts monthly. The Army payment structure led to significant problems when expensive pieces of equipment had to be purchased, or when expensive testing was required. Even for Phase II enhancement, which for Microcosm usually focused on prototype development, equal payments were mandatory and had the effect of significantly slowing development. Dr. Mendenhall added that SBIR funding could be overly back-loaded to support the kind of front-end activities required for a successful project.

The interviews also revealed that Army had not been prepared to commit to a second year of SBIR funding, even for Phase II awards. This reluctance introduced significant uncertainty in company hiring decisions and prevented front-loading of payments to cover equipment or testing.

Selection

Most of the concerns about selection were focused on a perceived shift away from innovation toward short-term commercialization. Several interviewees believed that this shift was changing the character of the program.

Commercialization Emphasis

Ms. Collier (Optemax) said that NAVAIR SBIR staff seemed focused on spreading SBIR money to a large number of companies and adopted a highly linear view of technology development and the role of SBIR awards. In this model, a single Phase II award was considered sufficient to move a company's technology past the prototype stage to TRL 6 or better. Ms. Collier noted such direct progress is rarely found in the real world, but that the prevalence of this view at NAVAIR made it difficult for companies to acquire the multiple awards needed to build a substantial platform in an advanced and complex technology such as optics-based wireless communications.

Dr. Sherman (Powerdermet) stated that SBIR awards were being made to established larger companies that could provide more and better data and offer the lowest risk, rather than to the most creative and innovative companies. Although Powdermet continued to win awards to apply its technology to DoD projects, its sister company MesoCoat was not able to break in, despite having more long-term commercial potential and more innovative technology. PEOs in DoD recognized the shift toward faster commercialization, and NSF transitioned to an approach in which each project must be successful, which replaced its previous portfolio investing approach. The emphasis became making sure that one-half of all projects could in some way be described as successful, rather than finding the 1 in 20 or 1 in 50 big disruptive technologies.

Dr. Mendenhall (NEAR) made a slightly different although related point. He said that the SBIR program was increasingly focused on product development as the primary form of commercialization. This meant that firms whose primary objective was to solve problems for the agencies were increasingly frozen out. As a result, the number of topics open to NEAR sharply dropped. NEAR used to identify close to 20 possible topics for a proposal in each solicitation and would then work to reduce the final number to 3-4; at the time of the interview, the company was fortunate to find one topic to which it could respond.

Other Selection Issues

Phase I Reviews

Dr. Mendenhall (NEAR) said that the quality of Phase I reviews in particular had declined, possibly because staff had less time allocated to review them. He noticed a rise in random or not relevant comments, some of which clearly affected the success of the proposal.

Debriefing

Mr. Proctor (ATC) said that, overall, the selection process was fair and the debriefs correctly recognized the strengths and weaknesses of a proposal. He noted that outcomes could be improved if successful proposals were also debriefed.

Accelerated Commercialization

Mr. Procter (ATC) strongly supported new efforts like the Commercialization Pilot Program (CPP) and the RIF at Navy. The company was actively pursuing partnerships with primes on the RIF program. However, the company expected primes to bring a program of record to the partnership and to be willing to act as a subcontractor if the team won.

Dr. Dingus (TRI) believed that the new RIF program will be very popular and that DoD would receive more than 5,000 white papers. However, he noted that the first $25 million had already been allocated and that, if expected funding remained at approximately $3 million per project, then funding would be available for only 25-50 projects. A lower number of projects suggested a much lower success rate than for regular Phase II SBIR awards. Success rates matter to companies: TRI was interested in the CPP but decided that the opportunities in this area were not a good fit in part because of the anticipated level of competition.

Technical Points of Contact and Contracting Officers

The survey gathered a substantial amount of data related to company views of Technical Points of Contact (TPOCs) (see Chapter 6). Case study interviewees added further details and insight.

Mr. Proctor said that it was ATC policy to meet face to face with each TPOC at least once, even if the company had to pay for the travel, to build trust and identify the client's real needs. Microcosm also tried to meet in person wherever possible: the reduction in the timeline for proposals from 7 to 8 weeks made that more difficult.

Some interviewees considered their TPOCs to be very helpful. A TPOC at Kirkland Air Force Base worked to resolve problems for Microcosm and clearly went out of his way to be helpful. However, this experience is the exception rather than the rule, according to Dr. Wertz. In most cases, TPOCs are driven by incentives that direct their attention away from their SBIR projects.

The role of the TPOC can be critical, Dr. Mendenhall noted. During the course of its considerable Phase II experience, NEAR encountered only one unsatisfactory TPOC, who was a staffer close to retirement. However, TPOCs can sometimes stand between the company and the ultimate customer, which NEAR experienced with Navy. This made it difficult to pursue Phase III opportunities effectively.

With recent improvements in the award cycle, there were fewer instances in which the TPOC changed during the course of the project. However this remained a major concern for TRI and other companies. Dr. Werz (NEAR) noted that the cancellation of Phase II awards before project completion was more likely if the TPOC changed.

Commercialization Support Programs

Dr. Jacobus (Cybernet) explained that he participated in almost all of the commercialization support programs over time, but they provided limited value to experienced executives. He strongly supported activities such as the Navy Opportunity Forum, which focused on connecting SBIR companies to the acquisition programs and primes. He suggested that more outreach to small business would be more useful than additional commercialization training.

Dr. Monach (DHWA) found that Navy Opportunity Forum to be very useful and participated every year. The Forum provided a critical opportunity to get the company's technologies and capabilities in front of many potential high-yield customers, mostly connected with Navy, but also with Air Force, Army, and even private-sector buyers. This was the only trade show that DHWA attended. Dr. Monach noted that neither Army nor Air Force offered any equivalent opportunity or forum.

Ms. Collier said that Optemax also participated in the Navy Opportunity Forum but realized that the preponderance of the staff from the primes was marketing staff rather than acquisitions or operations staff. For Optemax, the Forum generated no additional contacts beyond the company's existing network.

Dr. Sherman said that Powdermet received technical support from LARTA (a Los Angeles area nonprofit that supports innovation[16]), which helped with attracting angel funding and capital structuring. Ms. Politi (TRX) observed

[16] See Larta Institute, <*http://www.larta.org*>, accessed July 11, 2014.

that, through NSF, TRX also received commercialization support from LARTA, which was especially helpful in relation to a new collaborative mapping initiative. LARTA's method focused on business planning and partnerships from the start of the Phase I, which could assist in supporting a new initiative within an existing company.

Tracking Commercialization: The Company Commercialization Report

Dr. Monach (DWHA) observed that the company commercialization report (CCR) is a fairly useful way to monitor commercial outcomes from SBIR projects and, with the transition to electronic records, is not especially burdensome. DHWA uses the process in part to track its own outcomes for a particular project.

Dr. Mendenhall observed that the CCR scores generated for DoD applicants do not account for the fact that almost all of the work undertaken by companies like NEAR are covered by ITAR, which means that civilian sector commercialization is severely limited.

REVIEW OF PREVIOUS CASES

Although changes in personnel at many companies made it impractical to systematically re-interview the staff used as information sources for the previous case studies, it is worth providing a contextual framework for the paths taken by these 32 companies, most of which were interviewed in 2006-2007.

A total of 32 case studies were published as part of the NRC's previous report on the SBIR program at DoD.[17] Of these:

- 18 are inactive within the SBIR program
- 14 continue to participate in the SBIR program
- 7 were bought by other companies or in one case private equity investors
- 1 appears to have gone out of business
- 2 companies are no longer eligible because they have more than 500 employees (1 has 2,700 employees)
- 3 companies received more than 500 SBIR awards (from all agencies) and more than $100 million in SBIR funding
- $ per award data indicate that some firms were much more efficient than others in transitioning between Phase I and Phase II

[17] National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, C. W. Wessner, ed., Washington, DC: The National Academies Press, 2009. The case studies were undertaken 2005-2008.

SUGGESTIONS FROM CASE STUDIES

Size of Awards

Mr. Proctor (ATC) approved the shift to Phase II awards of $1 million, which provided sufficient funding to achieve solid research results. However, bridging programs such as the NSF Phase IIB would remain critically important, because they helped companies find full commercial markets for Phase II projects.

Dr. Jacobus (Cybernet) said that Phase I SBIR awards should be kept as small as possible, while ensuring that Phase II funding is sufficient to complete prototype development or a similar level of technology exploration.

Ms. Collier (Optemax) believed that the SBIR program should provide larger amounts of funding for highly promising projects, rather than widely distribute funding across a broad array of recipient companies.

Although Dr. Dingus (TRI) appreciated the increased award size, especially for Phase I, he was concerned about the possible reduction in the number of awards, a trade-off that his company would not favor.

Improving Technical Points of Contact (TPOCs)

Mr. Proctor (ATC) said that variation in the quality of TPOCs was a significant issue. Indeed, if the TPOC was not strongly committed to a project, then it would be impossible for the project to move forward to Phase III. This problem might be alleviated by ensuring that SBIR activities are part of the TPOCs' annual job reviews. ATC also found that when the TPOC changed, the project usually failed to reach Phase III. Mr. Proctor suggested that the agencies consider ways to reduce or eliminate this problem. The problem was to some degree addressed when DoD cut the timeline from initial topic submission to publication in a solicitation from more than 2 years to about 1.

Dr. De Luis (Aurora) said that the TPOC's role and company connection was sometimes a substantial problem. The company's success in engaging the TPOC largely determined whether the company would receive a Phase II award. This became especially important as some TPOCs learned to use the SBIR program to craft larger programs, for example at Ames. Dr. De Luis considered this connection to be so critical that he believed a small percentage of SBIR funding should be taken from the company and applied to the TPOC budget for travel and monitoring purposes. In addition, he strongly urged that a second "commercialization" TPOC be assigned from the acquisitions organization to encourage better Phase III transitions (a point echoed by Dr. Upadhyay from Mayflower, below).

From Dr. Upadhyay's view (Mayflower), many TPOC's "did not have their heart in it." Often, the TPOC assigned to manage an SBIR award was not involved in the design of the topic. Overall, there were poor linkages between the originator of the topic, those who approved and edited the topic, and those who managed its implementation, especially beyond Phase II. Overall, Dr. Upadhyay divided TPOC's into three groups; those from research backgrounds, those from the acquisitions programs, and those from the DoD bureaucracy. He suggested two ways to improve the process.

1) DoD could assign a second TPOC to an award, whose job would be to connect the award to the DoD acquisitions process. This would engage acquisitions and would ensure that DoD maximized its return on its SBIR investment.
2) The SBIR legislation could be adjusted to permit the use of 5 percent of the company's SBIR funding by the TPOC to manage the award, including travel to the company site, which would support deeper engagement.

Selection and Pre-Solicitation Communication

Dr. De Luis (Aurora) believed that the current agency measure of overall program quality (i.e., the percentage of applications that received funding) was a measure of wasted resources for SBIR companies. A success rate of 15 percent for Phase I awards showed that high-quality applications were received, but it also showed that the resources expended by 85 percent of the companies seeking Phase I funding were wasted.

Dr. de Luis recommended that the agencies consider other approaches to improve the fit between proposals and agency needs, for example, exploring ways to adapt the selection process to allow companies a brief rebuttal to preliminary responses from proposal evaluators. He also called for a wider adoption of the "preliminary white paper" approach utilized in some other programs, notably at NASA and DoE.

Dr. Mittelstaedt (Giner) also approved of the DoE pre-submission notice, which encouraged applicants to submit a 2- to 3-page white paper outlining possible research, which agency staff would review prior to full submission. He believed that useful initiative could be more widely applied to the SBIR program. At Giner, no SBIR applications were prepared before the company had contacted the agency point of contact and received assurance that the company's technical approach would be welcomed.

Dr. Mendenhall (NEAR) also supported an expansion of the DoE white paper model, at the end of which companies were notified whether a full proposal was warranted. He said that the SBIR program's low success rate imposed substantial costs on small businesses and that any opportunity to review preliminary comments during the selection process would probably improve outcomes for both the company and the agency.

The DoE white paper model could be extended in other ways to other aspects of pre-application communications between companies and agency staff. At TRI, Dr. Dingus strongly supported all efforts to provide means through which agencies and companies could connect prior to submission of the formal application. He endorsed the Air Force introduction of a pre-solicitation publication indicating areas of possible interest, which he saw as "tremendously beneficial," providing additional time to investigate an area and talk to potential sponsors.

Funding Gaps

Several interviewees noted that funding gaps between Phase I and Phase II still existed (confirmed by results from the NRC survey of recipients).

Dr. de Luis (Aurora) observed that funding gaps, especially between Phase I and Phase II, were often a problem, and he suggested that other agencies and components look closely at the Air Force model, in which Phase II applications were requested 6 months into the 9-month Phase I award, thereby virtually eliminating the potential gap between Phase I and Phase II. It should be noted that Navy and Air Force have addressed this issue through the widespread use of Phase I options to bridge Phase I and Phase II.

Phase III

Dr. Jacobus (Cybernet) recommended that every program office, particularly in DoD and NASA, have an SBIR strategy. Topics were usually generated by staff familiar with current programs, and hence the topics addressed current problems. But by the time the Phase II was issued and completed, those programs were in the past, and the SBIR company was stranded.

Dr. Jacobus also said that agencies should allocate some SBIR funding via the prime, that is, allow the primes some input into the development of topics and the selection of awards.

Admiral Dyer (iRobot) observed that the "Valley of Death" was getting wider, presenting greater challenges to small innovative firms such as iRobot. And despite improvements, most DoD R&D staff still considered the SBIR program to be a tax. He strongly recommended that the SBIR program focus on helping companies actually reach full-scale commercialization, through the provision of considerably more Phase III resources.

Dr. Brown (Navsys) said that Phase III funding had become more difficult to acquire. There were wide variations even within the Services regarding their use of small business in general and SBIR in particular. She believed, for example, that less than 2 percent of SMC contracts by value were with small business. Dr. Brown also said that vertical integration by the primes led to obvious conflicts of interests throughout the procurement process, because primes were effectively positioned to make decisions about whether to fund their own projects/research or those of smaller competitors. She observed that in areas where the SBIR program was especially successful—notably some parts of Navy—a more competitive support base had been encouraged.

Audits/Contracting

Dr. Mittelstaedt (Giner) was particularly concerned by recent changes at NASA, which required completed line-item descriptions for all items to be purchased during the SBIR award at the time of the application. Because the award was a research project, where outcomes were by definition not known and course corrections almost inevitable, such false precision simply added a burden to the company at no benefit to the agency.

Dr. Mendenhall (NEAR) suggested that all SBIR awards be treated as fixed price contract, which would address the difficulties involved in pricing labor and would reduce uncertainty for recipients. He noted that in effect most SBIR Phase II awards were treated as though they were fixed cost, without the concurrent benefits.

The companies that had experienced difficulties with DCAA suggested a number of improvements, including:

- Ensuring that audits were conducted quickly and efficiently
- Requiring that DCAA provide a formal explanation of an audit failure
- Developing a new small business audit

IP and Data Rights

Dr. Brown discussed significant problems related to intellectual property and data rights, which are the life blood of small firms—the value that can be used to generate ongoing revenue. Yet despite clear evidence of growing problems in this area—notably through documented violations by agency staff— there had never been a prosecution. Although the nominal data rights are well designed, in practice they are not sufficiently protected by the agencies especially at DoD. It is not clear whether SBA reports IP violations in the SBIR program to Congress.

Vanishing Phase IIs

Dr. Dingus (TRI) was somewhat concerned that some of the Services, notably Army, could shift priorities quickly even after award of a Phase I, leaving worthwhile projects stranded. For example, TRI's EcoMass project was highly successful, but Army funding for Phase II disappeared despite highly favorable reviews. He believed that a commitment to fund at least one Phase II per topic (provided that solutions were technically successful at Phase I) would be appropriate.

TABLE 5-1 List of Individuals Interviewed for Case Studies

Company Name	Interviewees	Title
Architecture Technology Corporate (ATC)	Gene Proctor	Vice President, Business Development
Aurora Flight Sciences Inc.	Javier de Luis	VP Research and development
Cybernet Systems Corporation	Chuck Jacobus	Co-founder
Daniel H. Wagner Associates	Reynolds Monach	VP Research and Development
Fetch Technologies	Robert Landes	CEO
Giner Inc.	Corey Mittelstaedt	VP Technology
iRobot Inc.	Joseph Dyer	Chief Strategy Officer
	Thomas Frost	VP Strategy
	Bob Kahout	VP Research
Mayflower Communications Inc.	Triveni Upadhyay	CEO
Microcosm Inc.	Jim Wertz	President
	Alice Wertz	CFO
Nanocomp Inc.	Peter Antoinette	CEO
	Michael Gurau	Board member
Navsys Inc.	Alison Brown	CEO
Nielsen Engineering Inc.	Miek Mendenhall	CEO
Optemax Inc.	Shirley Collier	CEO
Opto-Knowledge Systems (OKSI)	Nahum Gat	CEO
Powdermet Inc.	Andrew Sherman	Founder
Qualcomm Inc.	Irwin Jacobs	Founder
	Janet Jackson	Marketing Manager
Texas Research International (TRI)	Michael Dingus	VP and Technical Director

6

Program Management

As with any major government program, the relative success of different Small Business Innovation Research (SBIR) programs at different components and Services depends to a considerable degree on program implementation and program management. In this chapter, the committee undertakes a detailed review of how various services and components have sought to improve the SBIR program's efficiency in recent years. In particular, this chapter explores issues related to the selection of topics, which guide the technical direction of the program; source selection, and which determines which applicants receive funding; and a range of other SBIR process issues, including an extended discussion of Technical Points of Contact (TPOCs), the liaisons between components and companies. The committee also reviews efforts to encourage the participation of women and minorities within the DoD SBIR program. . Data for this chapter is drawn primarily from the National Research Council (NRC) 2011 survey, agency interviews, agency documents, and case studies along with workshops. These sources are discussed further in Appendix A.

TOPIC SELECTION

As DoD has become more focused on improving outcomes from SBIR programs, concerted efforts have been made to ensure that agency needs are clearly defined, that topics match those needs, and that components utilize the results of research conducted with SBIR funding.

In this section, the committee focuses on the process used at Navy, and in particular the Naval Sea Systems Command (NAVSEA).[1] Navy has made

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[1]For an earlier review, see National Research Council, "Review of the Naval Sea Systems Command (NAVSEA) Draft Memorandum, "NAVSEA's 21st Century Engagement, Education, and Technology Initiative," Washington, DC: The National Academies Press, 2008. This report notes that "NAVSEA recognizes the critical challenge of maintaining an adequate number of skilled

available documents describing this process in some detail, but this presentation is not a claim that NAVSEA processes are best practice.[2]

Establishing Agency Needs

The first step in the development of topics at Navy is to define technical needs. Navy Program Executive Offices (PEOs) and Headquarters (HQ) directorates are invited to prepare R&D needs statements. These must address clearly identified technological gaps in critical Navy Research and Development (R&D) or acquisition programs, as well as other Navy objectives. Each submission must meet a number of technical requirements and is presented in the form of a quad chart that includes objectives, needs, references, and appointed contact.

All of the submitted needs are collated by the Navy SBIR program office and are then submitted for review and eventual approval to the Navy SBIR Board of Directors, a committee of flag-level representatives from each PEO and system command within NAVSEA.

The Board of Directors meets at the beginning of each SBIR topic cycle year. It reviews and then selects the needs against which topics can be developed. Only needs approved by the board can be used to justify the topic. Use of a Board of Directors structure also encourages the senior staff to buy into the SBIR program, because it gives them a clear role in directing the program toward their own technical needs and interests.

Topic Development

Once the Navy's technical needs have been established for the upcoming topic development cycle, topic authors from the PEOs and HQ directorates can prepare topics to meet those needs. The broad process of topic development is captured in Figure 6-1.

Topics are developed by technical staff at PEOs and HQ directorates and are then submitted for initial review by the NAVSEA SBIR program manager. After possible revision and eventual approval, topics are then reviewed and approved by the Board of Directors before final submission to the Navy SBIR program office for solicitation approval. They are then forwarded to the Office of Small Business Programs (OSB) for review. In some cases, DoD review rejects proposed topics—most recently, according to Navy staff, because

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Science, Technology, Engineering and Mathematics (STEM) professionals. NAVSEA correctly reasons that this challenge has implications for its own workforce development, and its commitment to address this challenge as it relates to its own mission is commendable."

[2]This section is drawn from NAVSEA, "NAVSEA SBIR Needs and Topic Validation Process," April 2012, and from interviews with Dean Putnam, NAVSEA SBIR Program Manager; Dr. Regan Campbell, PEO SUBS Director for Undersea Warfare; Glen Sturtevant, PEO Ships SBIR Director; and Douglas Marker, PEO IWS SBIR Director, June 25, 2013.

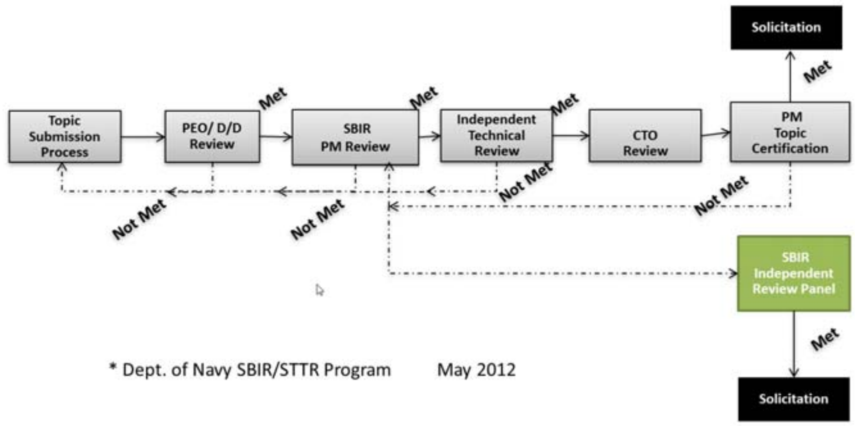

FIGURE 6-1 SBIR topic selection: Current practices at Navy (May 2012).
NOTE: See Appendix D for all DoD acronyms.
SOURCE: Navy SBIR Office.

the technologies they call for are not sufficiently innovative,[3] although Bonnie Heet, SOCOM SBIR Program Manager, noted that these rejections tend to result more from topic duplication.[4]

Aside from this fairly elaborate procedure, NAVSEA uses a well-documented set of criteria to assess and validate topics (see Box 6-1). In addition to setting out detailed criteria, NAVSEA works to enhance the quality of topics by training topic authors. All authors are required to go through topic training provided by the NAVSEA SBIR program office. NAVSEA also provides a "prescription" for writing a quality topic (see Box 6-2). Meeting these requirements helps to ensure topic quality, according to Dean Putnam, NAVSEA SBIR Program Manager.[5]

Although each of the components and Services has its own process for writing topics, and these are likely to differ significantly from the NAVSEA process described above, the general point is that the era in which topic writing was left largely to individual authors, and in which there was almost no linkage between acquisition offices and topics, has largely ended. At the Special Operations Command (SOCOM), for example, topics must be accompanied by a transition plan. In interviews with Air Force (AF) staff, it became clear that

[3]See NAVSEA interviews, note 1.
[4]Interview, Bonnie Heet, SOCOM SBIR Program Manager, June 28, 2013.
[5]Interview, Dean Putnam, NAVSEA SBIR Program Manager, June 25, 2013.

BOX 6-1

NAVSEA Topic Selection Criteria

1. All required fields of the topic template must be completed.
2. Topics must clearly articulate the Board of Directors-approved Navy need and its applicability to the requested technology.
3. Topics must clearly identify and discuss the needed innovation and R&D. Topics must discuss currently available technology, both Government and commercial, and its applicability to the needs identified in the topics.
4. Topics must be technically clearly written so that they are understandable to small business personnel.
5. Topics must be congruent with SBIR funding levels for Phases I and II.
6. Target transition programs must be identified (R&D or Acquisition).
7. Topics must not require secure access for Phase I.
8. Topics must not contain classified information.
9. Grammar, spelling, and clarity are important and, if not addressed, may disqualify a topic. Acronyms must be spelled out and Government jargon must be avoided.
10. Topics must not duplicate one another.
11. Topic references must be publicly accessible and available; and two to four must be provided.
12. Topics must identify high-level technical requirements.

SOURCE: NAVSEA: NAVSEA SBIR Needs and Topic Validation Process, April 2012.

connections with acquisition offices are a high priority: According to AF staff, DoD is now targeting PEO sponsorship for more than 50 percent of topics.[6]

Topic Specialization

One possible area for further innovation in program design may be specialization. For example, SOCOM (which serves Special Forces) tends to focus on needs that are unique to its user base—very lightweight, highly durable, rugged technologies that can be delivered quickly.

In this case, most topics are focused on standalone technologies that are not part of larger weapons systems and hence can be ported to use by other DoD

[6]Interview with Dr. Leslie Perkins, David Sikora, and Richard Flake, AF SBIR Program, June 28, 2013.

BOX 6-2

NAVSEA Prescription for Quality Topics

- Describe the Navy problem to be solved and cite the Navy need identified by the Board of Directors and its relevance to the topic;
- Define the current state-of-the-art of technology available today, both commercial and Government, and its applicability to the need described in the topic—the current state;
- Describe where the Navy needs to be to solve the problem—the future state;
- Identify and describe the technological challenges encountered in bridging the gap between the current and future states;
- Describe the innovation and/or R&D needed to address the technological gaps; and
- Provide sufficient information to guide small businesses in developing high-quality proposals.

SOURCE: NAVSEA: NAVSEA SBIR Needs and Topic Validation Process, April 2012.

components relatively easily. SOCOM targets a Technical Readiness Level (TRL)[7] of 6 or 7 at the end of Phase II—somewhat closer to combat readiness than SBIR awards at other components, which often need to be integrated by developers of larger systems. And as a result, SOCOM relies less on prime contractors to deliver weapons systems, offering more opportunities for SBIR winners to move on directly to contracts with SOCOM.

Because SOCOM has a relatively small SBIR budget (about $10 million) it is highly motivated to find synergies with bigger programs elsewhere. Therefore, it has also developed systems for disseminating white papers received from potential applicants as a means of gauging interest from other potential funders.

The smaller size and focused target audience also makes it easier for SOCOM SBIR to connect to the wider SOCOM supply chain: a single national conference (SOFIC) is held in conjunction with the National Defense Industry Association (NDIA) every year, attracting 7,000-8,000 attendees. Thirty-four SOCOM SBIR contractors attended in 2012, and 14 had booths.[8]

[7] TRL: Technology Readiness Level. This is a widely used metric within DoD to describe the state of readiness of a particular technology. Technologies ready for use by warfighters are at TRL 8-9. Basic research is TRL 1-2.
[8] Bonnie Heet interview, note 4.

SOURCE SELECTION

The selection of specific proposals for awards is known as "source selection" within DoD. It is tightly governed by detailed federal contracting rules. These define, for example, the release of information in applications, who is permitted to view application details, and nondisclosure and conflict-of-interest requirements among evaluators and selection officers.[9] Information flow even after an award is made is also tightly controlled.[10]

Applications details are specific to each component. At Navy, even Phase I proposals must include a commercialization plan. In all cases, they must address the topic, provide evidence that the firm is capable of completing the research successfully, offer at least a brief description for the eventual take-up of the technology, include a detailed budget, and, if possible, indicate interest from PEOs or other potential downstream sponsors.

Currently, Army and Navy are working to focus on the most promising technologies as quickly as possible. Therefore, all their applicants must include an "option" plan for bridging the gap between the end of Phase I and the possible start of a Phase II. AF does not call for an option plan. As a result, Phase I funding is limited to $80,000 at Army and Navy and $150,000 at the Air Force.[11] Once received, the application is subject to a fairly elaborate selection process.

Phase II selection is similar, but with increased emphasis on commercialization. For example, at Navy "Phase II SBIR Proposal Invitation forms must identify the Navy acquisition or R&D program that will potentially transition the contractors' SBIR technology, product or service to Phase III and into the acquisition process. In addition, the NAVSEA SBIR PO requires from the acquisition or R&D program a Transition Memo indicating the desire to proceed with the contractor into Phase II, the potential for Phase III funding, and the requirements to be met by the contractor during SBIR Phase II development."[12] At AF, recent changes in the program—notably the introduction of a shared-cost Phase II.5 and the introduction of new liaison positons between companies and acquisitions - have strengthened the link between Phase II funding and acquisitions. [13] (Note however that under the 2011 reauthorization legislation, DoD components are no longer permitted to

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[9]Federal Acquisition Regulations (FAR) can be found online at the FAR home page, <*http://www.acquisition.gov/far/*>, accessed July 11, 2014.

[10]NAVSEA policy notes that "Post source selection discussions may be prohibited by 15 USC §638, the Privacy Act (5 USC §552a), the Trade Secrets Act (18 USC §1905) and other laws." NAVSEA, "Source selection process small business innovation research (SBIR) program Phase I and Phase II awards," February 2012, p. 4.

[11]DoD SBIR Solicitation FY 13.2.

[12]NAVSEA, February 2012, note 10, p. 18.

[13]Air Force, *NAS Briefing on SBIR/STTR Program*, June 28, 2013.

selectively invite firms to apply for Phase II—all Phase I winners are permitted to do so).[14]

Composition of Evaluation Panels

Source-selection decision makers are a pivotal point in the selection process, so the composition of selection panels is an important question. At DoD, it appears that all components use only DoD personnel. All components appear to employ a selection panel of two or three evaluators. Some components use a lead evaluator, who is charged with both managing the application through the process and resolving conflicting views among the evaluators.

At NAVSEA, a panel is established for each topic, with three evaluators and a chairman, selected by the technology manager for the topic. Each panel must include a topic expert, a Research and Systems Engineering (R&SE) expert, and a mission area expert (the latter two must be from outside the sponsoring program office, and the third must be a government employee).[15]

Selection Criteria

All components must address the selection criteria defined by DoD, which are published in the solicitation itself (see Box 6-4). Different components may score proposals differently. At Navy, scoring is as follows:[16]

(a) Technical Merit—40 points
(b) Qualifications of Key Personnel—30 points
(c) Potential for Commercialization—30 points

Even though applications may require a commercialization plan—and even though commercialization is directly part of the rubric for scoring applications—selection panels are not required to include a member with commercial business expertise.

Selection: Conclusions

The difficulty of selecting from the numerous high-quality proposals also makes it difficult to ensure that all Congressional objectives are met in the course of the selection process.

1) Commercialization. The recent attention paid to this issue—illustrated in this section and others—means that selection is now heavily focused

[14]See Chapter 1 "Introduction," which contains a summary of the reauthorization legislation.
[15]NAVSEA, February 2012, (above, p. 9).
[16]NAVSEA, February 2012 (above, note 9), p. 12.

BOX 6-3

DoD SBIR Phase I Selection Criteria[a]

"The DoD Components plan to select for award those proposals offering the best value to the Government considering the following factors which are listed in descending order of importance, unless otherwise stated in the Component's instructions in Section 8.0 of this solicitation.

(a) The soundness, technical merit, and innovation of the proposed approach and its incremental progress toward topic or subtopic solution.
(b) The qualifications of the proposed principal/key investigators, supporting staff, and consultants. Qualifications include not only the ability to perform the research and development but also the ability to commercialize the results.
(c) The potential for commercial (Government or private sector) application and the benefits expected to accrue from this commercialization.

Firms with a Commercialization Index Achievement (CAI)[b] score at the 20th percentile or below may receive no more than half of the evaluation points available for commercial potential criteria (see Section 3.5.d).[c] Where technical evaluations are essentially equal in merit, cost to the Government will be considered in determining the successful offeror."

[a] Formal selection criteria for Phase II are usually identical to those for Phase I, although more attention is paid to commercialization plans.
[b] The CAI attempts to measure the extent to which a company's SBIR and STTR awards have resulted in commercial activity. See DoD SBIR Desk Reference, Section II—Evaluation and Selection. <*http://www.acq.osd.mil/osbp/sbir/sb/resources/deskreference/02_eval.shtml*>. Accessed August 15, 2013.
[c] Thus, at NAVSEA, for example, firms with a CAI falling into the bottom quintile can score a maximum of 15 out of 30 for commercialization potential.

SOURCE: DoD SBIR Program Solicitation FY 13.2 Section 6.0.

on transition: ensuring that the technologies developed through the SBIR program find their way into use in DoD. This emphasis is demonstrated in the outcomes described in other parts of this report.

Use of the CAI to penalize the lowest-performing score likely enhances commercialization impacts.[17]

2) Agency mission. DoD components have made extensive efforts in recent years to align SBIR topics, awards, and hence outcomes with clearly defined agency needs—as demonstrated by the detailed process used by NAVSEA and described above.
3) Knowledge effects. DoD identifies the "innovation" of a proposal as part of the most important criterion. In addition, there is evidence that the DoD-level review of topics increasingly focuses attention on the need for innovation.
4) Women and minorities. There is no evidence that this Congressional objective plays a role in the selection processes at any DoD component.

It should be understood that in the context of DoD, "commercialization" takes on a special meaning. In general usage, technology commercialization reflects efforts to reach the market and is usually measured by the extent to which such efforts are successful.[18] Commercialization is also a process normally viewed at least in part from the perspective of the company: private firms that do not "commercialize" by generating revenues from the sale of products or processes eventually vanish.

"Commercialization" means something quite different at DoD, where it is widely taken to mean the acquisition of SBIR-funded technologies by end users within DoD—especially by programs of record or other formal acquisition programs within DoD. This issue is discussed in Chapter 4 and in Appendix A.

OTHER SBIR PROCESS ISSUES

Following completion of the first round of NRC analysis and publication of the related reports, the current assessment sought to identify additional information about the process of implementing SBIR awards, with a view to providing management with more detailed information about program operations. This section considers several operational aspects of the program.

Matching Funds

In general, DoD SBIR awards do not *require* matching funds for Phase I or Phase II. However, it is possible that some components favor proposals that include matching funds at this stage. The recent NRC survey addressed this question: 138 DoD Phase II respondents (18 percent) indicated that they had

[17]Although it should also be noted that, although the CAI score is used to identify and down-score the bottom quintile of firms with at least four previous Phase II awards, it is not apparently used in a systematic way to help differentiate among the 80 percent of firms who score above the 20th percentile.

[18]See also the discussion of commercialization in Chapter 4.

matching funds.[19] These matching funds came from a variety of sources. Table 6-1 shows the frequency with which each source was reported by these Phase II respondents.

The source mentioned most often by respondents was non-SBIR federal funding, followed by company funds. Venture Capital (VC) and angel funding together accounted for about 10 percent of responses. Non-SBIR federal funding at DoD is closely aligned with investments from programs of record and other acquisition sources. They can also be aligned with funding from DDR&E (Director of Defense Research and Engineering).

Although matching funds are a very positive signal of long-term interest in a project, adding requirements in this area could constitute a significant burden for small firms. Almost 40 percent of Phase II respondents indicated that it took no more than 2 weeks of full-time effort to find the funds, but 25 percent indicated that it took at least 2 months of equivalent effort (see Table 6-2).

Evidence from case studies adds context to these data. Interviewees suggested that additional funds could be acquired relatively easily by firms that already had funding agreements in place (e.g., partnerships with larger companies), but matching funds requirements could in other cases present a significant hurdle or at least delay.

Uses of matching funds beyond the initial Phase II award (e.g., Navy's Phase 2.5 program) are discussed in Chapter 4.

TABLE 6-1 Sources of Matching Funds for Phase II Awards for Those Reporting Some Matching Funds

	Phase II Respondents (Percent)
Federal non-[SBIR/STTR] funding	40.4
Our own company (includes borrowed funds)	33.8
Another company	27.9
An angel or other private investment source	7.4
Venture capital	2.2
Other (please specify)	16.2
	N = 136

NOTE: Because respondents could choose more than one category, responses do not sum to 100 percent.
SOURCE: 2011 NRC Survey, Question 28.

[19]Matching funds were sought by components only for Phase II awards, so only Phase II respondents were asked this question.

TABLE 6-2 Time Needed to Acquire Matching Funds

	Phase II Respondents (Percent)
No additional effort needed except paperwork	15.3
Less than 2 weeks Full-Time Equivalent (FTE) for senior company staff	23.7
2-8 weeks of effort FTE for senior company staff	35.9
2-6 months of effort FTE for senior company staff	19.1
More than 6 months of effort FTE for senior company staff	6.1
Total	100.0
	N = 131

SOURCE: 2011 NRC Survey, Question 29.

Funding Gaps

Agencies have become much more attuned to problems caused by funding gaps, which can be especially challenging for small firms because they are less likely to have access to other funding sources to keep projects on life support until Phase II funding arrives.

Both Army and Navy include an option to cover the Phase I-Phase II gap in their standard SBIR application process. Companies are required to describe how they would utilize a $70,000 award to cover the gap (which can be taken up by the agency when it decides that Phase II funding will be awarded).[20]

Despite these agency initiatives, 71 percent of Phase II respondents indicated that they experienced a gap between the end of Phase I and the start of Phase II for the surveyed award (see Table 6-3). The data in this table are essentially identical to those for the NRC's 2007 survey (69 percent), which suggests that these initiatives have not yet had the desired impact.[21] This gap had a range of consequences for the company. Table 6-4 indicates the types of impact on respondents who experienced a funding gap.

TABLE 6-3 Funding Gap Between Phase I and Phase II

	Phase II Respondents (Percent)
Yes	70.9
No	29.1
	100.0
	N= 763

SOURCE: 2011 NRC Survey, Question 22.

[20]See DoD SBIR Program Solicitation FY 13.2.
[21]National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, C. W. Wessner, ed., Washington, DC: The National Academies Press, 2009, p. 264.

TABLE 6-4 Effects of Funding Gaps between Phase I and Phase II

	Phase II Respondents (Percent)
Stopped work on this project during funding gap	66.8
Continued work at reduced pace during funding gap	23.2
Continued work at pace equal to or greater than Phase I pace during funding gap	2.4
Received bridge funding between Phase I and II	4.6
Ceased all operations during funding gap	0.9
Other (please specify)	2.0
Total	100.0
	N= 539

SOURCE: 2011 NRC Survey, Question 23.

Two-thirds of respondents reported that they stopped work during this period, while a large majority of the remainder worked at a reduced level of effort. About 1 percent ceased operations. These responses indicate a slight worsening of effects compared to the 2005 NRC Survey, which reported that 58 percent stopped work on the project.[22]

Aside from the direct impact of delayed projects, funding gaps can have long-term consequences, especially for smaller companies, for which there could be insufficient work to retain key project staff during the gap period. Several companies interviewed for case studies noted these dangers.

Ease of Application

The NRC survey also sought to probe more deeply into the process of SBIR application and award management. One question concerned the degree of difficulty involved in applying for a Phase II award compared with applying to other federal programs.

About 40 percent of respondents reported that the SBIR Phase II application process was easier than the process for other federal funding, while about 9 percent of respondents indicated that it was harder (see Table 6-5). These results suggest that the process does not impose undue burdens on applicants.

Funding

Although there are obvious limitations to the utility of asking recipients whether the amount of money provided was sufficient for the project at hand, there is at least some value in determining the extent of positive responses.

[22]Ibid., p. 264.

TABLE 6-5 Ease of Application for SBIR Phase II Award at DoD

	Phase II Respondents (Percent)
Much easier than applying for other federal awards	11.3
Easier	30.4
About the same	40.7
More difficult	6.9
Much more difficult	2.1
Not sure, not applicable, or not familiar with other federal awards or funding	8.6
Total	100.0
	N= 759

SOURCE: 2011 NRC Survey, Question 41.

In this case, about 55 percent of Phase II recipients indicated that they received sufficient funding; about 45 percent indicated that more funding was required. Less than 1 percent reported that they received more funding than necessary (see Table 6-6).

Although awardees often suggest in other contexts (e.g., case study interviews) that the size of awards should be increased (a view especially prevalent before the increases made in recent reauthorization), the survey asked about the possible trade-off between the size of awards and the number of awards. Unless agency funding for SBIR programs increases overall, 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 awards (see Table 6-7).

The survey also asked about the possible expansion of the SBIR program itself. Perhaps not surprisingly, about 70 percent of respondents indicated that they would support an increase in the size of the program even if funding were taken from other federal programs that they value (see Table 6-8).

WORKING WITH PROJECT MANAGERS

Interviews with awardees and even agency staff reveal that one of the critical factors affecting the success of individual SBIR projects is the relationship between the awardee and the agency's project manager (at DoD, the latter is usually called the technical point of contact, or TPOC).

The survey asked a series of questions aimed at identifying ways in which this relationship might be improved. The committee hypothesized that there might be a wide variation in the degree to which TPOCs actually engage with their awardee projects, because there appears to be no DoD-wide standard for this.

TABLE 6-6 Adequacy of Phase II Funding

	Phase II Respondents (Percent)
More than enough	0.4
About the right amount	55.4
Not enough	44.2
Total	100.0
	N= 758

SOURCE: 2011 NRC Survey Question 42.

TABLE 6-7 Views on Trade-off of Larger Awards for Fewer Awards

Should the size of Phase II awards be increased even if a proportionately lower number of Phase II awards are made?	Phase II Respondents (Percent)
Yes	36.1
No	38.8
Not sure	25.1
Total	100.0
	N= 761

SOURCE: 2011 NRC Survey, Question 43.

TABLE 6-8 Increasing the Size of the SBIR Program

Recommendations that the size of the SBIR program be…	Phase II Respondents (Percent)
Expanded (with equivalent funding taken from other federal research programs that you benefit from and value)	72.0
Kept at about the current level	26.1
Reduced (with equivalent funding applied to other federal research programs you benefit from and value)	0.8
Eliminated (with equivalent funding applied to other federal research programs you benefit from and value)	1.2
	100.0
	N= 763

SOURCE: 2011 NRC Survey, Question 44.

Respondents were asked about the frequency of their engagement with their TPOC. A majority reported monthly contact, while 30 percent reported quarterly contact (see Table 6-9).

Interviews indicated that some TPOCs had very positive effects on their awardee companies, while others were of limited help. The survey attempted to gauge impacts by asking respondents how helpful the TPOC had been to their project (see Table 6-10).

Overall, more than one-half of Phase II respondents scored TPOC usefulness at 4 or 5 on a 5-point scale. Conversely, less than one-quarter scored usefulness at 1 or 2 on the scale. Phase II respondents were more likely to score usefulness at 4 or 5, while Phase I respondents were more likely to score it at 1.

Given the significant and ongoing turnover in TPOCs, one important question is the extent to which TPOCs are able to provide technical advice to the awardee about the operations of the SBIR program. In detail, the program is fairly complex, so a technically knowledgeable TPOC can be of great use, especially to companies that are new to the program.

The survey therefore asked respondents to indicate their views on the technical capacity of the TPOC with regard to the SBIR programs. Overall, more than 65 percent reported that their TPOC was extremely knowledgeable or quite knowledgeable about the SBIR program. Only about 4 percent reported that their TPOC was not at all knowledgeable (see Table 6-11).

Because TPOCs are the *technical* point of contact at the agency, they should be technically knowledgeable about the science and engineering involved in the award and, therefore, should be expected to provide valuable direct insights in some cases. About one-third of respondents reported receiving a substantial amount of technical help from the TPOC (scores of 4 or 5 on 5-point scale). However, about 40 percent received low or very low levels of help, which suggests that components should reconsider their expectations for TPOC performance in this area (see Table 6-12).

TPOCs are also sometimes well positioned to provide useful connections to other firms—either other SBIR awardees or other firms with complementary interests or capabilities. These connections may be especially important at DoD, where so much of the acquisitions process runs through the prime contractors. Slightly less than 30 percent indicated substantial support in this area (scores of 4 or 5 on a 5-point scale) (see Table 6-13). Therefore, it does not appear overall that TPOCs prioritize networking on behalf of SBIR awardees as part of their role.

TPOCs may serve as a critical liaison to programs of record and other possible markets for SBIR-funded products and services. Reports from interviewees were mixed: some TPOCs went to great lengths to provide this connection, while others were of little help, often because the original TPOC moved to a new job (see further discussion below).

TABLE 6-9 Frequency of Contact with TPOCs

	Phase II Respondents (Percent)
Weekly	13.2
Monthly	52.3
Quarterly	29.7
Annually	4.8
Total	100.0
	N = 757

SOURCE: 2011 NRC Survey, Question 47.

TABLE 6-10 Usefulness of the TPOC

	Phase II Respondents (Percent)
Invaluable (5)	23.9
4	34.1
3	23.5
2	13.7
No help (1)	4.8
Total	100.0
	N= 757

SOURCE: 2011 NRC Survey Question 48.

TABLE 6-11 TPOC Knowledge about the SBIR Program

	Phase II Respondents (Percent)
Extremely knowledgeable	23.3
Quite knowledgeable	43.5
Somewhat knowledgeable	29.0
Not at all knowledgeable	4.2
	100.0
	N= 756

SOURCE: 2011 NRC Survey, Question 49.

TABLE 6-12 TPOC Technical Support for Project During Phase II

	Phase II Respondents (Percent)
Most helpful (5)	12.9
4	21.6
3	24.1
2	20.6
Least helpful (1)	20.8
Total	100.0
	N= 744

SOURCE: 2011 NRC Survey, Question 50.2.

TABLE 6-13 TPOC Connections to Other Private Firms

	Phase II Respondents (Percent)
Most helpful (5)	11.0
4	18.7
3	18.4
2	21.4
Least helpful (1)	30.5
Total	100.0
	N= 738

SOURCE: 2011 NRC Survey, Question 50.4.

Overall, about one-quarter of respondents scored their TPOC at 4 or 5 on a 5-point scale in terms of providing connections to possible markets. Conversely, more than one-half scored their TPOC at 1 or 2 on the same scale (see Table 6-14).

In addition, the survey asked about specific help with connecting to Phase III funding opportunities. About 40 percent of respondents discussed this connection with their TPOC or the TPOC provided a lot of guidance during the process, while slightly less than 40 percent received no help (see Table 6-15).

These findings suggest that some TPOCs are well connected to acquisitions, but many others are not. Given the importance of Phase III for agency objectives, this may be an area for future DoD review.

The survey also asked about the effectiveness of TPOC guidance in acquiring Phase III funding. Interviewees highlighted this as an important issue, because TPOCs displayed widely varied capabilities, with some being better with the scientific and technical aspects of the project and others with connections to the acquisition programs. About 45 percent of respondents thought their TPOC was very helpful or somewhat helpful in connecting the company to Phase III funding sources, while about 55 percent thought the TPOC was not very helpful or not at all helpful (see Table 6-16).

TABLE 6-14 TPOC Help in Connecting SBIR Awardees to Market Opportunities

	Phase II Respondents (Percent)
Most helpful (5)	10.1
4	16.3
3	21.9
2	20.3
Least helpful (1)	31.4
Total	100.0
	N= 743

SOURCE: 2011 NRC Survey Question 50.5

TABLE 6-15 Working Closely with TPOC on Phase III Funding

	Phase II Respondents (Percent)
The officer provided a lot of guidance during the application process	14.2
We discussed the application in detail	26.3
Not much	20.8
Not at all	17.6
We did not apply for Phase III funding	21.1
	100.0
	N= 754

SOURCE: 2011 NRC Survey, Question 55.

Contacting the TPOC

Beyond the concerns specific to Phase III funding, the survey also sought to determine the ease with which companies could reach the TPOC with questions or concerns, given that TPOCs have many other priorities to manage. Table 6-17 shows that about 90 percent of respondents found it very easy or easy to reach their TPOC.

Several case study interviewees explained that the replacement of a TPOC during the award period can have devastating consequences for the long-term success of the project. TPOCs often serve as the project's champion within the funding agency and as the primary link or liaison to acquisition programs and other sources of further funding. Approximately one-third of Phase II respondents reported that their TPOC for the surveyed project was replaced during the award period (Table 6-18). Although not surprising, this is an important finding that should be the subject of further review by DoD.

TABLE 6-16 Effectiveness of TPOC in Connecting to Sources of Phase III Funding

	Phase II Respondents (Percent)
Very helpful	17.1
Somewhat helpful	27.4
Not very helpful	24.8
Not at all helpful	30.6
Total	100.0
	N= 689

SOURCE: 2011 NRC Survey, Question 51.

TABLE 6-17 Ease with Which Principal Investigator Could Contact TPOC

	Phase II Respondents (Percent)
Very easy	31.5
Easy	58.2
Hard	8.5
Very hard	1.7
	100.0
	N= 752

SOURCE: 2011 NRC Survey, Question 52.

Time Available for TPOC to Work on Surveyed Project

Because they have many other responsibilities, TPOCs may not have enough time to work on all of projects in their portfolio. However, in general, survey responses refuted this concern: almost 80 percent of respondents reported sufficient or more than sufficient TPOC time available (see Table 6-19).

TPOCs: Conclusions

Overall, TPOCs are not performing poorly. In general, they are available to SBIR companies and perform many of the key needed functions. However, there is evidence that the TPOCs have a limited impact, particularly in forging connections between their SBIR companies and other nodes in the acquisitions network or with technical resources. This deficiency is clearly one of the drivers behind recent changes at AF, where dedicated staff have been assigned to this function.

The survey revealed a wide range of effectiveness on several measures, suggesting either that TPOCs need better training and guidance or that they are motivated by incentives that are not well aligned with program objectives. The fact that some TPOCs perform a range of functions very well while others do not strongly suggests room for improvement. Finally, given that about one-third of respondents reported a TPOC change during Phase II, which may severely impact outcomes, the components should look into mechanisms to address turnover.

TABLE 6-18 Replacement of TPOC during Award Period

	Phase II Respondents (Percent)
Yes	32.3
No	67.7
Total	100.0
	N= 750

SOURCE: 2011 NRC Survey, Question 53.

TABLE 6-19 TPOC Time Availability for Surveyed Project

	Phase II Respondents (Percent)
More than sufficient	6.9
Sufficient	72.6
Insufficient	20.5
Total	100.0
	N= 751

SOURCE: 2011 NRC Survey, Question 54.

ADDRESSING WOMEN AND MINORITIES

The committee sought documentation on outreach to women and minorities from OSB and from the major components. The research team also conducted interviews with agency staff at several DoD components. And in February 2013, the committee hosted a workshop at the National Academy of Sciences on diversity in the SBIR program.[23] As well as hearing from other experts and stakeholders, the workshop provided agencies with the opportunity to discuss their efforts in this area, and to identify areas for possible new initiatives. However, the committee was not able to identify any systematic efforts to expand the participation of companies that are majority owned by women or socially and economically disadvantaged groups. In addition, there has not been a concerted effort to attract PIs from these demographic groups. Box 6-4 highlights a variety of perspectives offered by the participants of this meeting to improve the participation of woman and minority-owned small businesses in the SBIR program.

The committee does not support the notion of quotas for demographic groups in an innovation program where merit review drives selection. Moreover, the courts have in recent years rejected mandatory quotas for jobs, for university entrance, and for government contracting.[24] Similarly, a 1976 U.S. Supreme Court decision in *Craig v. Boren* required the application of "intermediate scrutiny" for programs giving preferences by gender.[25]

The rejection of quotas does not however mean that DoD cannot simply ignore one of the four Congressionally mandated objectives for the SBIR/STTR program: to "foster and encourage participation in innovation and entrepreneurship by socially and economically disadvantaged persons."[26]

[23]Workshop on "Innovation, Diversity, and Success in the SBIR/STTR Programs" February 7, 2013, The National Academies, Washington, DC.

[24]Under the 1995 landmark decision, *Adarand Constructors, Inc. v. Pena*,[24] the U.S. Supreme Court required the federal government to apply a high standard of "strict scrutiny" to justify race- and gender-based preference programs.

[25]*Craig v. Boren,* 429 U.S. 190, 197 (1976).

[26]SBA: SBIR Mission and Goals, <*http://www.sbir.gov/about/about-sbir*>, accessed August 27, 2012. This definition has historically been taken to include women. A detailed SBA definition of

BOX 6-4

Improving Participation by Women and Minorities in the SBIR Program

To address the question of how SBIR could better address its mandate to encourage the participation of women and minorities, the committee convened a workshop in February 2013 on "Innovation, Diversity, and Success in the SBIR/STTR Programs" at the National Academy of Sciences. Workshop participants discussed a variety of strategies for consideration across the program, many of which are summarized below. Chapter 7 of this report lists the committee's own recommendations to improve the participation of women and minorities in the Department of Defense (DoD) SBIR program.

- Participants discussed how SBIR agencies could improve outreach to educate women and minorities on the SBIR opportunity to organizations, including Historically Black Colleges and Universities, women minority advocacy organizations, and professional societies, through workshops, webinars, and social media.
- Participants discussed how SBIR managers could be incentivized to foster and encourage this key goal of the SBIR program.
- Participants explored how SBIR agencies might use supplemental agency funds to encourage women and minority participation in their program.
- Participants urged SBIR agencies to identify and adapt agency best practices, such as National Science Foundation (NSF) programs to encourage women and minorities across the length of the career pathway.
- Participants suggested that SBIR agencies speed up processing of awards and contracts, given that delays in disbursing funding particularly affect promising though vulnerable firms.
- Some participants also recommended that SBIR agencies and the Small Business Administration (SBA) develop data and analyze success rates for minority and women applicants, including tracking the number of submissions with successful awards for Phase I and the Phase I to Phase II conversion rate. It was also suggested that the agencies gather and analyze feedback data from women and minority participants and first-time applicants.
- They called on the DoD and National Aeronautics and Space Administration (NASA) SBIR programs to incentivize their prime contractors to track and encourage women- and minority-owned companies.

"socially and economically disadvantaged" is available at <*http://www.sbda.com/sba_8%28a%29.htm*>, accessed August 27, 2013.

- Some participants suggested that SBA should reassess the definition of women- and minority-owned businesses: For example, is a 51 percent minority and women ownership requirement a barrier to attracting additional investment?
- Some participants called on SBA to study other models to encourage women and minority entrepreneurship. This includes pre-SBIR programs, such as the Phase Zero programs under way in some states. Other programs identified as worthy of further study included university-based initiatives to encourage women and minority entrepreneurship.
- Some participants called on SBA to commission a study of the impact of major demographic trends on entrepreneurship.
- A number of participants highlighted the role that universities can play in incentivizing women and minority professors and students to become entrepreneurs. In this regard, they noted that some universities provide credit toward tenure for professors who commercialize their research results. Some also provide credit toward graduation for students who participate in such commercialization initiatives.
- The participants noted that universities can also provide training on how to apply for SBIR, including entrepreneurship classes for doctoral students.

More broadly, many participants recognized the need to promote multidisciplinarity and diversity as contributors to innovation. They noted that disciplinary silos in science and engineering and related academic cultures discourage diversity in participation.

DoD data on applications from and awards to woman-owned small businesses (WOSBs) and minority-owned small businesses (MOSBs) are reviewed in detail in Chapter 2. The analysis reveals not only that the numbers are low, but also that the trend shows no clear improvement over time even though the share of women and minorities in the science, technology, engineering, and mathematics (STEM) workforce continues to grow.

Survey Data on Socially or Economically Disadvantaged (SED) Scientists and Engineers in the DoD SBIR Program

Previous discussions of woman and minority participation in the SBIR program focused largely on WOSBs and MOSBs.[27] In general, these studies did not address the role of PIs, nor did they disaggregate MOSBs by ethnicity. The current study expands the analysis in both directions.

[27]See for example GAO, Small Business Innovation Research: SBA Should Work with Agencies to Improve the Data Available for Program Evaluation, GAO-11-698: Published: Aug 15, 2011. Publicly Released: Sep 14, 2011.

Socially and Economically Disadvantaged Groups

To the committee's knowledge, the current survey is the first to probe beneath standard definitions of "socially and economically disadvantaged" (SED). That is, previous SBIR surveys by the NRC and the agencies (and agency data itself) sought to determine whether the company is majority owned by members of socially and economically disadvantaged groups (SEDGs) as defined by SBA.[28]

Such an analysis is insufficiently granular, because it fails to address important differences within the broad set of SED groups. The current NRC survey addresses this issue by seeking more detailed demographic information from respondents. It builds on Survey 1.0 by addressing the ethnicity of principal investigators (PIs), who often play an important role in the formation of MOSBs and WOSBs.

Socially and Economically Disadvantaged PIs

As with the 2005 Survey, respondents were asked whether the PI for the surveyed project was SED. About 11 percent reported this to be the case (Table 6-20).

The 2011 survey also requested details about the PIs' ethnicity, according to categories derived from SBA definitions, with the addition of an "other" category to ensure that all respondents who wished to claim SED status could. This detailed question revealed some important differences between SED groups (there were no significant differences between Phase I and Phase II respondents) (see Table 6-21). At least 80 percent of SED Phase I and Phase II PIs were Asian Indian or Asian Pacific in ethnicity. In contrast only 9 percent of PIs were Hispanic, 4 percent were Black American, and 3 percent were Native American.

TABLE 6-20 SED PIs as Percentage of Total

Principal investigator for this SBIR award was from a socially/economically disadvantaged group	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Yes	10.3	11.1
No	89.7	88.9
Total	100.0	100.0
	N= 390	763

SOURCE: 2011 NRC Survey, Question 14B.

[28]Different agencies use different terminologies, which change over time. "Minority" is a widely used term, but "socially and economically disadvantaged" is also in use.

TABLE 6-21 Composition of SED PI Grouping, by Ethnicity, as Percentage of SED PIs

SED Group	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Asian-Indian	47.5	37.6
Asian-Pacific	32.5	43.5
Hispanic	7.5	9.4
Black American	5.0	3.5
Native American	5.0	2.4
Other	2.5	3.5
	100.0	100.0
	N= 40	85

SOURCE: 2011 NRC Survey, Question 14C.

These data can be placed in the further context of the survey population as a whole. Overall, of the 1,155 DoD respondents to this question, 1 percent reported said that the PI on the surveyed project was Hispanic, 0.4 percent was Black American, and 0.3 percent was Native American. Overall, 89.2 percent were not SED (see Table 6-22).

SED Company Ownership

Turning from the ethnicity of the PIs of the surveyed projects to the ethnicity of the owners of the surveyed companies, about 10 percent of respondents reported that the company was majority owned by SEDs at the time of the award (see Table 6-23).

However, probing more deeply into the ethnic distribution of SED company owners reveals that the distribution is quite similar to that for SED PIs, which suggests that pipeline theory may be valid: that SED PIs may over time become SED owners. In addition, for smaller firms in particular, the owner may

TABLE 6-22 SED PIs at DoD, by Ethnicity, as Percentage of all Respondents

	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Asian Indian	4.9	4.2
Asian Pacific	3.3	4.8
Hispanic	0.8	1.0
Black American	0.5	0.4
Native American	0.5	0.3
Other	0.3	0.4
All SED	10.3	11.10
	N=3 90	765

SOURCE: 2011 NRC Survey, Question 14C.

TABLE 6-23 SED Majority Ownership

	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Yes	9.3	10.5
No	90.7	89.5
	100.0	100.0
	N= 388	759

SOURCE: 2011 NRC Survey, Question 19B.

also be the founder and the PI. The percentage distribution of SED ownership by ethnicity is summarized in Table 6-24.

The most important point is clear enough, that is, further disaggregation of the SED category reveals low levels, in particular, of black-owned firms winning SBIR awards. Survey responses identified 5 black-owned SBIR Phase I awards and 1 black-owned Phase II award, for a total of 6 out of 1,155 awards surveyed.

Participation of Women in SBIR

Women have traditionally been viewed as socially and economically disadvantaged in the context of the SBIR program, and expanding opportunities for women has been one of the Congressionally mandated goals for the program since its inception. Both agencies and SBA has focused on the participation of woman-owned companies. However, case studies (e.g. TSI) and other discussions with company executives suggest that being a PI leads to company ownership, so the 2011 survey was revised to capture the extent to which SBIR awards went to female PIs.

TABLE 6-24 SED Company Ownership, by Ethnicity and Phase

	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Asian Pacific	33.3	41.3
Asian Indian	41.7	36.3
Hispanic	13.9	17.5
Black American	13.9	1.3
Native American	5.6	2.5
Other	-	2.5
	N= 36	80

NOTE: Columns do not sum to 100 percent because respondents were permitted to select more than one category.
SOURCE: 2011 NRC Survey, Question 19C.

Female PIs

Two findings clearly emerge from the survey responses (see Table 6-25). First, overall, few female PIs are in the DoD SBIR program. Although it is beyond the scope of this study to make comparisons with the overall populations of scientists and engineers, female PIs received only 7 percent of DoD SBIR awards during the study period.

Second, less than 6 percent of Phase II awards went to female PIs, compared to 9.5 percent of Phase I awards. This indicates that projects with female PIs were about one-third less successful in converting to Phase II than were all PIs.

Woman-owned Businesses

The survey also addressed the extent to which SBIR awards were made to woman-owned businesses. Although the percentage of woman-owned firms in the sample was not large, it was distinctly higher than the percentage of female PIs, particularly for Phase II. In addition, although more Phase I respondents than Phase II respondents reported working at a woman-owned business, the difference was not as great as for female PIs (see Table 6-26).

Outreach to WOSBs and MOSBs at DoD

There is little documentation on efforts to attract more WOSBs and MOSBs to the DoD SBIR program. The annual reports to Congress do not describe efforts, and formal requests for information to the Services resulted in no relevant information sources. Interviews with agency staff revealed that outreach has not been a priority for program managers. That said, there have been some efforts, in particular at Navy. A white paper submitted by Richard McNamara, former leader of Team SUBS,[29] is summarized in Box 6-1. After implementation of this outreach program to WOSBs, Team SUBS leadership made additional efforts to reach out to in particular to Hispanic WOSB as well as other WOSBs.

[29]Navy defines Team Subs as "an amalgamation of the Program Executive Office, Submarines (PEO SUB), the Deputy Commander, Undersea Warfare (NAVSEA 07) and the Deputy Commander, Undersea Technology (NAVSEA 073). The Team Submarine concept unifies once diverse submarine-related commands and activities into a single 'submarine-centric' organization with the goal of eliminating traditional 'stovepipe' structures and processes that created impediments and inefficiencies in the submarine research, development, acquisition, and maintenance communities. Team Submarine provides improved communication among the various offices that contribute to the overall success of the United States Submarine Force." Department of the Navy, Research, Development, and Acquisition web site, <*http://acquisition.navy.mil/home/organizations/peos_drpms/peo_subs*>, accessed October 10, 2013.

TABLE 6-25 Gender Distribution of Responses, by Phase

Principal Investigator for this SBIR award was a woman	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Yes	9.5	5.8
No	90.5	94.2
	100.0	100.0
	N= 388	762

SOURCE: 2011 NRC Survey, Question 14A.

The Team SUBS outreach effort focused on targeted outreach to Historically Black Colleges and Universities (HBCUs) and then later to High Hispanic Enrollment Institutions (HHEs). A total of eight HBCUs were visited (Southern University, Jackson State University, North Carolina A&T University (NCA&T), Howard University, Hampton University, Norfolk State University, Tuskegee University, and Florida A&M University). Later visits focused on HHEs such as Prairie View A&M University in Texas.

At each visit, Navy staff met with deans of engineering and focused on recruiting students for Navy STEM jobs, using STTR and SBIR as mechanisms for introducing students and professors to Navy technology and programs. NAVSEA scholarships were initiated at the 13 schools visited to provide Navy with ongoing presence.

Staff found that, in general, students or faculty did not know about Navy programs, SBIR, or NAVSEA. Navy then proceeded to broker relationships between schools and “proven” SBIR companies to provide solid SBIR/STTR partners. Navy funded Battelle to develop a list of skills and categories across all engineering programs at HBCUs. Navy staff also explored a distributed University Affiliated Research Centers arrangement for all HBCUs, which would make it easier for schools to work with Navy.

The eventual result was that two STTRs were brokered with NCA&T, and a small business emerged nearby that became a successful SBIR company and DoD contractor (3Phoenix). However, although these projects successfully led to Phase II funding, there was no follow-on funding beyond that.

Since the end of the 2000s, there have been minimal efforts to build further outreach programs, even at Navy.

TABLE 6-26 Woman-owned Businesses by Phase

Woman-owned	Phase I Respondents (Percent)	Phase II Respondents (Percent)
Yes	13.8	10.1
No	86.2	89.9
Total	100.0	100.0
	N= 390	761

SOURCE: 2011 NRC Survey Question 19A.

BOX 6-5

Outreach to WOSB at Team SUBS

Efforts to expand outreach to WOSBs began in about 2001. Discussions with the key prime contractors (Electric Boat and Northrop Grumman Newport News) revealed that there were not enough WOSBs to meet contracting goals.

- Team SUBS outreach conferences for WOSB begin.
  - Fall 2001. First WOSB outreach conference for Team SUBS at Sweet Briar College. The objective was to link WOSBs to acquisitions officers.
  - Fall 2004. Third WOSB outreach conference.
  - 2005 onward. WOSB outreach conferences held every other year.
  - Overall, about 200 WOSB introduced to key buyers—Navy labs, prime contractors, support contractors, NAVSEA acquisitions officers, 2001-2005.
- SBIR program presented as a centerpiece of small business strategy during annual Team SUBS meetings during this period.
- 2004. Incentive fee introduced into new prime contract for Electric Boat, which acknowledged that it now knew more WOSBs with which to work.
  - Focus on three groups: small businesses, 8(a) businesses, and WOSBs.
  - "Stretch goals" were established over currently subcontract rates (these goals were approximately 35 percent for small business, 4.2 percent for 8(a) businesses, and 3.3 percent for WOSBs).
  - Evaluation occurred in Year 5 of the prime's contract (2009), after all subcontracts had been placed.
  - Outcomes: 54 percent of contracts by value went to small business, 4.8 percent to 8(a) firms, and 6.6 percent to WOSB. Electric Boat was paid most, but not all, of the incentive fee. The share of subcontracts to woman-owned small businesses doubled during the incentive period.

SOURCE: Richard McNamara, "Outreach to WOSB and MOSB in the Navy SBIR program," White Paper, June 2013.

Conclusions: Women and Socially and Economically Disadvantaged Groups

Aside from the steps described above at Navy, which focused on WOSBs more generally rather than woman-owned SBIR companies or woman-owned technology companies, there is no documentation of any persistent efforts to reach out to women and other disadvantaged groups.

As a result, there is no evidence that DoD is meeting the Congressional goal to "foster and encourage" the participation of these groups in the DoD SBIR program. Indeed, the most recent data suggest that the number of such firms in the program has remained flat for women and has decline for minorities over the past decade (see Chapter 2).

OTHER PI DEMOGRAPHICS

Age Demographics

Other demographic characteristics of the PI population within the DoD SBIR program are of interest. While there is no evidence from DoD beyond the survey results discussed below, other agencies have already focused on this issue. According to Sally Rockey, "In 2010, the average age of NIH principal investigators was ages 53 or 54, and 10 percent of NIH principal investigators were over age 65, a significant increase from 1980 when the average age of NIH principal investigators was 36 or 37."[30] The Committee has accordingly hypothesized that, with the aging of the baby boomers, the age profile of PIs at DoD is likely to shift. Survey respondents were asked about their age at the time of the award. The distribution by age was largely similar for Phase I and Phase II. There were more Phase II respondents aged 40-44 years, and more Phase I respondents aged 65 years or older. About 28 percent of respondents overall were older than 54, and about 22 percent were under 40. Fewer than 10 percent of Phase II PIs were younger than 35 (see Table 6-27).

The limited number of PIs at both ends of the age spectrum suggests a challenge for SBIR programs. On the one hand, breakthrough technologies may predominantly be developed by younger scientists and engineers, so the limited number of awards for younger applicants may indicate over-reliance on prior track record in selecting awardees. On the other hand, changing demographics in the United States indicate that successful research programs will have to engage higher numbers of older scientists and engineers, because they are becoming a larger percentage of the total science and engineering workforce.

Citizenship and Immigration Status

Given the considerable debate in recent years about visas for highly skilled technology workers, and the role of foreign-born entrepreneurs, the committee decided to ask respondents about their citizenship or visa status. The

[30]Workshop on "Innovation, Diversity, and Success in the SBIR/STTR Programs" February 7, 2013, The National Academies, Washington, DC.

TABLE 6-27 Respondents by Age of PI at Time of Award

	Phase I Respondents (Percent)	Phase II Respondents (Percent)
20-24	0.3	-
25-29	2.1	2.6
30-34	10.0	6.6
35-39	12.8	11.5
40-44	11.0	18.4
45-49	17.2	17.7
50-54	15.9	16.8
55-59	12.6	12.1
60-64	7.9	8.8
65 or older	10.3	5.5
Total	100.0	100.0
	N= 390	762
MEAN	49	48
MEDIAN	48	47

SOURCE: 2011 NRC Survey, Question 15.

data show limited differences between Phase I and Phase II respondents. About three-quarters of respondents were U.S.-born US citizens, and a large majority of the remainder were naturalized U.S. citizens. About 5 percent overall were not citizens (see Table 6-28).

TABLE 6-28 Citizenship and Visa Status of Respondents

Immigration status of the PI at the time of the award	Phase I Respondents (Percent)	Phase II Respondents (Percent)
American-born U.S. citizen	75.3	78.3
Naturalized U.S. citizen	18.3	16.6
U.S. green card	6.2	4.6
H1 visa	-	0.4
Other (please specify)	0.3	0.1
Total	100.0	100.0
	N= 388	760

SOURCE: 2011 NRC Survey, Question 16.

7

Findings and Recommendations

The findings and recommendations in this chapter address the Statement of Task and are focused on improving the performance of the SBIR program at the Department of Defense against the four Congressional objectives for the Small Business Innovation Research Program (SBIR) program.[1] These objectives have been reiterated in the 2011 program reauthorization and in the subsequent Small Business Administration (SBA) policy Directive that guides program implementation at all agencies. Section 1c of the SBA Directive states 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 program purposes 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), 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."[2]

From the perspective of the Department of Defense (DoD), the second objective is by far the most important, even though it is often conflated in practice with the fourth objective. Many at DoD believe that meeting agency needs in the form of technologies that can help warfighters *is* commercialization.[3] The committee's findings, summarized below, identify accomplishments and issues with regard to each of these program objectives at

[1]See Box 1-2 and the discussion in Chapter 1 of the Committee's task.
[2]SBA SBIR Policy Directive, October 18, 2012, p. 3.
[3]See Chapter 5.

DoD, as well as some specific aspects of program management. The committee's recommendations follow these findings.

NRC STUDY FINDINGS

The SBIR program at DoD is meeting three of its four legislative and mission-related objectives. The program funds the development of mission-critical technologies that meet the specific needs of DoD components; it supports the development of products that reach the market at an appropriate rate and scale; and it encourages the development of transfer of new technical knowledge while connecting companies to universities and research organizations. At the same time, it is clear that DoD has failed to meet the important Congressional objective of increasing the involvement of woman- and minority-owned small businesses.

I. Commercialization

A. SBIR projects at DoD commercialize at a substantial rate. With regard to commercialization, projects funded by the SBIR program are reaching the market at, what is in the Committee's judgment, an appropriate rate, and are also attracting substantial amounts of follow-on investment, which in many cases is a necessary next step toward commercialization.

1. The percentage of Phase II projects reporting sales continues to be greater than 45 percent, based on responses to the National Research Council (NRC) Survey.[4] This rate tracks closely with data from previous surveys and from DoD databases and is appropriate for projects focused on early-stage applied research. An additional 26 percent of projects reported that they anticipate future sales. If these expectations are even partially correct, then this suggests that a majority of SBIR Phase II projects will eventually reach the market.
2. Data from the DoD commercialization database suggest that over time about 70 percent of Phase II projects at DoD reach the market.[5]
3. Projects with very large commercial successes continue to occur but remain rare: about 1.5 percent of Phase II projects reported sales of more than $20 million. This type of skew is not unusual in early-stage finance.[6]

B. Total commercialization continues to be under-reported both in the DoD databases and through the survey instrument.

[4] See Table 3-1.
[5] See Table 3-18.
[6] See Table 3-32.

1. Much commercialization by dollar value occurs in areas not covered by the DoD Federal Procurement Data System (FPDS), which does not track subcontracts executed through prime contractors (primes) at DoD. Nor is FPDS set up to track SBIR projects as they commercialize within DoD, beyond the first Phase III contract.
2. Data from surveys, including the NRC survey, also have limitations. In particular, all outcome surveys capture data at the time of the survey, but SBIR projects typically have a relatively long product cycle, and hence the bulk of sales may take place after the date of the survey.

C. Substantial commercialization also occurs in the private non-defense sector.

Although not a high priority for DoD, this activity nonetheless addresses a core program objective.

1. About a one-quarter of sales by value are to the domestic private-sector or export markets, according to the survey responses.[7]
2. In some cases, these awards have had a highly leveraged impact on entire industries: for example, the massive commercial success of Qualcomm[8] (which still leads the global market for handset chips) is attributed by a founder in part to the acquisition of SBIR awards at a key inflection point, funding critical research and providing the firm credibility vis-à-vis private investors. Similarly, iRobot executives noted that their contribution to an entire new sector of personal robotics (as well as advanced DoD applications) is based on research funded by early SBIR awards.[9]

D. Further investment in SBIR technology is another metric for value.

1. Subsequent investment provides further evidence that SBIR projects generate significant commercial value.

   a. More than 60 percent of Phase II survey respondents reported additional investment funding, which is up slightly from the 2005 NRC survey (54 percent).[10]
   b. Substantial additional funding has been provided by internal company resources and by non-SBIR federal sources (in large part acquisition programs at DoD).

[7]See Table 3-3.
[8]See the Qualcomm case study, Appendix F.
[9]See the iRobot case study, Appendix F.
[10]See Table 3-6.

E. SBIR awardees indicated that overall the SBIR program had a profoundly positive effect on their companies.

Commercialization in the long run requires sustainable companies, and the SBIR program has supported the development of an ecosystem of small innovative companies in the United States.

1. The NRC survey provided SBIR companies with the opportunity to report the overall impact of the SBIR program on the company, as well as to identify specific kinds of impacts.

   a. Twenty percent of Phase II winners reported that the program had a "transformative" effect on their company. Another 57 percent said that it had a "substantial positive long-term effect."[11]
   b. Of the 649 detailed comments received, 4 reported negative effects, and 157 reported transformative positive effects. Widely differing kinds of impact were reported, summarized in Box 7-1.

F. SBIR is associated with modest job growth.

1. NRC survey data indicate that the median size of firms grew from 17 employees at the time of award to 24 employees at the time of survey.[12]
2. However, the data do not suggest that SBIR should be viewed as a substantial direct job creation program.[13]

II. Meeting Agency Needs

A primary objective of the SBIR program is to use SBIR-funded technologies to meet agency mission needs.

A. SBIR projects at DoD are in broad alignment with mission needs of the agency.

1. There is substantial evidence that outputs from the program are taken up by federal agencies and in particular by DoD and by its primes.

   a. Sales are strongly focused on defense. About 60 percent of reported sales by value from SBIR projects go to either DoD directly or to DoD primes (NRC survey data). Of sales recorded in

[11]See Table 3-22.
[12]See Table 3-4.
[13]Further research is needed to gauge indirect employment effects.

BOX 7-1

Different Ways in Which SBIR Awards Helped to Transform Companies

- Provided first dollars, funding company formation
- Funded product areas where VC and other funders were not interested
- Created connections to acquisition programs
- Opened doors to many potential stakeholders in specific technologies, including agencies, primes, investors, suppliers, subcontractors, and universities
- Helped address niche markets too small for primes and other large companies
- Funded technology development
- Enabled projects with high levels of technical risk
- Supported adaptation of technologies to new uses, markets, and industry sectors
- Provided resources for more diversified expertise, allowed hiring of specialists
- Substituted for private capital funding during economic downturns
- Attracted and developed young researchers
- Redirected company activities to new opportunities
- Developed connections to primes
- Reduced costs
- Helped address needs that require high tech at low volume and relatively low cost
- Moved technology up to Technology Readiness Level (TRL) 7-9 (at which point acquisition funding becomes more likely)
- Provided new companies with greater credibility
- Encouraged researchers to enter business full time
- Helped university researchers manage Intellectual Property (IP) and Information Technology Acquisition Review (ITAR) problems
- Transformed company culture to become more market oriented
- Drove researchers to focus on technology transition
- Supported feasibility testing for high-risk/high-payoff projects (Phase I)

SOURCE: Analysis of company responses to 2011 NRC Survey.

the DoD commercialization database, 63 percent go to DoD and DoD primes.[14]

b. SBIR technologies are currently in use by the federal government. More than one- fifth of Phase II respondents reported that their technologies are currently in use by a federal system or program.[15] This portion is higher than the 12 percent figure reported in the 2005 survey.

c. Numerous case studies indicate ways in which specific SBIR projects have made a substantial difference to DoD capabilities, costs, or both. SBIR projects have led directly, for example, to new torpedoes at Navy, to significant components of the Joint Strike Fighter, and to bomb-disarming robots (funded by the Defense Advanced Research Projects Agency [DARPA] and other DoD components).[16]

B. DoD components have made substantial efforts to further align SBIR and mission needs.

1. Components have reformed topic selection procedures to develop better linkages between the SBIR and acquisitions programs within DoD.

   a. DoD policy guidance now strongly emphasizes the need to align SBIR programs with agency needs. DoD calls for 50 percent of topics to be sponsored by acquisition offices.

   b. Topic selection now broadly requires substantial input from Program Executive Offices (PEOs). Navy has pioneered efforts to forge closer linkages; today, more than 90 percent of SBIR topics are sponsored by PEOs or Headquarters directorates.

2. Components have implemented other initiatives aimed at the further alignment of SBIR and acquisitions:

   a. New initiatives (e.g., Phase II.5[17] at the Navy and the Air Force) indicate that some DoD components are experimenting with different ways of enhancing alignment and eventually transition.[18]

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[14]See Table 3-3.

[15]See Table 3-3.

[16]Examples are drawn from extensive discussions with program staff at Navy, Air Force, DARPA, and the Special Operations Command (SOCOM), as well as company case studies, agency success stories, and other sources. Unfortunately, examples are not available from Army, which did not contribute to this study.

[17]Phase II.5 is discussed in Chapter 5. It is a new program designed to provide bridging funds between the end of Phase II and the start of full acquisitions funding. It is typically co-funded between the component SBIR office and an acquisitions program or office.

b. Metrics are now heavily focused on transition. For example, Navy measures both the number of transitions and the dollar amount of Phase III contracts; Air Force focuses on the number of transitions and the percentage of transitions from Phase II awards, as well as the leverage generated through Phase II.5 contracts.

C. Phase III contracts provide direct evidence of value, and total Phase III funding continues to grow.

1. Data drawn from FPDS indicated that in fiscal year (FY) 2009 approximately $650 million in Phase III contracts were signed with SBIR companies.
2. Total Phase III contracts, excluding those at Navy (the Phase III leader), more than doubled between FY2004 and FY2009 (see Figure 7-1).
3. Navy commercialization increased sharply in FY2010, coinciding with the introduction of new commercialization initiatives. [19] (see Figure 7-1).
4. More than one-half of all additional investment reported by NRC respondents came from federal non-SBIR sources. This reflects in part efforts to attract funding using new matching fund requirements: the Air Force program had attracted a total of $337 million in additional investment through FY2013, in part, a response to its own investment of $93 million in SBIR program funds for Phase II.5 transitions.

D. Further investment in SBIR projects beyond Phase II continues to grow.

1. This investment reflects the value of projects that may still not be ready for the market.
2. Both Navy and Air Force now devote 20 percent of SBIR funding to Phase II.5 projects, most of which requires 1:1 matching funding from acquisition programs.

E. Providing execution-year flexibility and the potential for rapid deployment

1. DoD has recognized the need for rapid technology development and deployment in the face of suddenly changing conditions. Previous reports noted SBIR contributions in this area. These have recently been strengthened.

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[18]These experiments are discussed in some detail in Chapter 4.
[19]See the description in Chapter 5.

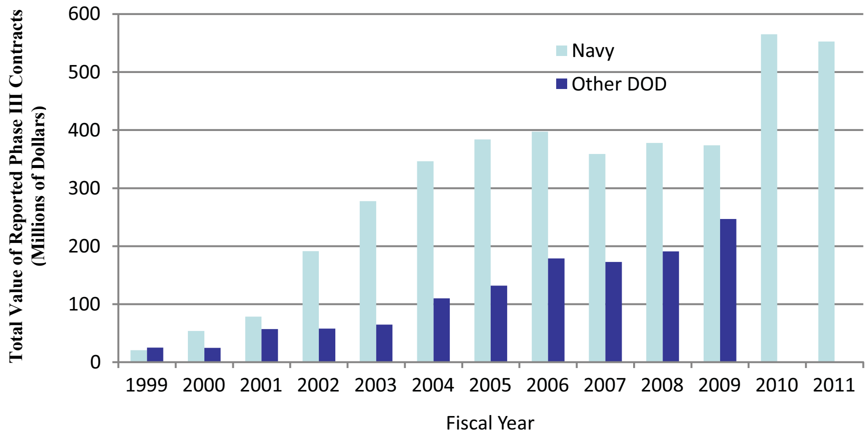

FIGURE 7-1 Phase III contracts reported through the Federal Procurement Data System, by total value, FY1999-2011.
SOURCE: Navy SBIR Program Office.

2. A number of DoD initiatives outside the SBIR program have addressed the need for rapid deployment. For example, the Rapid Innovation Fund (RIF) has provided new ways to address high-urgency needs.

III. Fostering the Participation of Women and Other Under-Represented Groups in the SBIR Program[20]

A. Current participation is low and not increasing.

1. Levels of participation are low and not rising.

   a. Data from DoD indicate that during the study period approximately 15 percent of awards went to woman-owned Small Businesses (WOSBs) and 7 percent to minority-owned Small Businesses (MOSBs).[21]

   b. The share of Phase I awards to WOSBs increased slightly in the early part of the past decade but have since remained flat.[22]

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[20]Legislative language and the SBA policy directive both focus on a slightly different way of addressing essentially the same issue, using the term "members of socially and economically disadvantaged groups." SBA in turn then defines members of these groups (see Chapters 4 and 6 for further discussion). In order to make the report more readable, the committee here utilizes the more easily understood notion of woman-owned small businesses (WOSBs) and minority-owned small businesses (MOSBs).
[21]See Table 6-22.
[22]See Table 6-26.

c. The share of awards to MOSBs has declined since peaking in 2005. MOSB Phase I applications succeed at a lower rate than do non-MOSB applications.[23]
d. The number of applications from WOSBs and MOSBs has not increased according to data provided by DoD. Phase I applications from WOSBs declined by about 10 percent during the period covered by DoD data (FY2007-2011).[24]
e. DoD does not maintain data on woman and minority Principal Investigators (PIs). Data from the NRC survey indicates that these numbers are also low and not rising.

2. DoD has no separate data on Black- and Hispanic-owned small businesses.

   a. The NRC survey indicated that Black- and Hispanic-owned small businesses are themselves a very small share of MOSBs overall. Black-owned small businesses accounted for approximately 0.5 percent of all respondents; Hispanic-owned firms, about 1 percent.[25]
   b. In the NRC survey, companies reported that 11 percent of PIs were minority (using the broad definition approved by SBA) (the same as the 2005 survey). However, further analysis indicates that only 1 percent of PIs were Hispanic, and less than 0.5 percent were African American.[26]

3. Differences in the shares of Phase I and Phase II awards should be explored further.

   a. For each of the 6 years for which DoD provided detailed demographic data, and for both WOSBs and MOSBs, award rates were smaller than application rates—overall by 1.8 percentage points for WOSBs and 3.5 percentage points for MOSBs.[27]
   b. In the NRC survey, companies reported that they had a woman as PI on 10 percent of Phase I awards and only 6 percent of Phase II awards (compared with 4 percent for the 2005 survey).[28]

B. DoD has not made sustained efforts to "foster and encourage" the participation of woman- and minority-owned small businesses.

[23] See Chapter 6.
[24] See Chapter 6.
[25] See Table 6-22.
[26] See Table 6-20.
[27] See Chapter 6.
[28] See Table 6-25.

1. As of August 2013, no component had in place a plan for outreach to these communities.
2. The committee identified limited evidence of activity focused on this objective:

    a. Efforts at Team Subs (Navy) from 2001 to 2008 to reach out to Historically Black Colleges and Universities (HBCUs) and Minority-Serving Institutions (MSIs) appear to have been discontinued.
    b. No similar efforts appear to have been made to reach out to WOSBs within DoD components.
    c. The committee was not provided with any documentation on any other efforts in this direction, beyond the addition in 2013 of a panel on WOSBs and MOSBs at annual SBIR conferences.

3. DoD does not report on or sufficiently track participation by WOSBs and MOSBs.

    a. DoD does not provide an annual report that covers either data on participation or efforts to foster and encourage participation at the different components.
    b. DoD does not appear to track MOSBs at a level sufficient to meet Congressional intent.
    c. DoD does not appear to track the participation of woman and minority PIs in the program.

IV. Stimulating Technological Innovation

A. The SBIR program at DoD supports the development and adoption of technological innovations.

1. Selection of topics and individual projects for funding maintains a strong focus on developing innovative technologies.

    a. Topic selection is monitored to ensure that it focuses sufficiently on innovation. Topics are routinely rejected by DoD-level review for this reason.
    b. Scoring for individual projects is weighted toward technological innovation: 40 percent of the score for an application at Navy, for example, is based on the innovative characteristics of the project.

2. Close integration with acquisition requirements does require careful monitoring to avoid over-focus on short-term needs, which could reduce the likelihood of breakthrough innovations funded in the past (e.g., in telecommunications, robotics, logistics).

a. A number of survey respondents and case study interviewees indicated that they believed DoD was becoming progressively less interested in high-risk/high-reward research, focusing instead on projects that could be reasonably expected to transition within a fairly short period.
b. Although DoD does not currently have any formal targets for transition, it is generally assumed that more transition is better. It should be recognized that there is, at least at the margin, a trade-off to be considered with higher-risk/higher-value research. Managers need to remain conscious of these trade-offs, although formal targets seem unlikely to be useful.
c. No agency efforts exist to identify and highlight exceptionally innovative projects on a systematic basis.

B. SBIR is increasing connections between companies and universities.

1. Survey data indicate that DoD SBIR projects continue to utilize universities in a variety of ways.

   a. More than one-third of DoD Phase II survey respondents reported a link to a university for the surveyed project. In about 20 percent of projects, universities were subcontractors, while almost as many had faculty or graduate students working on the project.[29]
   b. Survey respondents identified 211 different universities as project partners; 28 were mentioned by more than 10 respondents.[30]
   c. About 60 percent of SBIR companies reported at least one academic founder, and about one-quarter reported that the most recent prior employment of the founder was a university.[31]
   d. Data from the survey for linkages with universities, including use of faculty as PIs, use of graduate students as researchers, licensing of technology from universities, and use of a university as a subcontractor, all increased from the 2005 survey, suggesting growing university linkages with the DoD SBIR program.

C. SBIR projects generate knowledge-based outputs such as patents and peer-reviewed publications.

1. Patenting remains an important component of knowledge diffusion (and protection).

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[29]See Table 3-16.
[30]See Table 3-17.
[31]See Table 3-16.

a. Slightly less than 60 percent of Phase II respondents reported filing at least one patent related to the surveyed project.[32]
b. Slightly greater than 20 percent reported filing five or more related patents.[33]

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, SBIR firms continue to contribute actively to scientific publication.

a. About three-quarters of surveyed projects reported at least one resulting peer-reviewed publication.[34]
b. One-quarter reported more than three publications resulting from the surveyed project.[35]
c. Many of the companies interviewed for case studies made a point of indicating that they take a great deal of pride in the number of peer-reviewed publications developed by their scientists and engineers, both within and outside of the SBIR program.

V. Challenges for the DoD SBIR Program

A. Challenges within services and components

1. The "SBIR as tax" mentality among Program Executive Officers (PEOs)

a. Because of its unique funding structure as a percentage of extramural R&D, the SBIR program has often been viewed by R&D program managers in DoD (and at other agencies) as a tax imposed by supporters of small business.
b. Continuing efforts to change this perspective, at both DoD and individual components, have had mixed success as reflected in interviews with agency staff and small businesses. Some components have been more successful than others.

2. Difficulties in integrating SBIR into long-term technology maps

a. While primes have large groups working on these issues, access for small businesses is available only sporadically and requires a

[32]See Table 3-14.
[33]See Table 3-13.
[34]See Table 3-15.
[35]See Table 3-15.

degree of forward planning that may not be simple or cost-effective for small businesses.

b. There is no single voice at the table for SBIR companies during map development processes; they must rely either on champions within primes or supporters within the agency staff community.

3. Contracting and auditing issues.

a. Contracting remains a challenge because Phase III contracts are unusual. They differ in important ways—especially the sole-source option and the SBIR data rights—from standard procurement contracts.

i. Contracting officers may be reluctant to certify Phase III contracts in part because they confer important data rights on the company, which are by statute not negotiable.
ii. Contracting officers may also be reluctant to accept the sole-source rights conferred under Phase III contracts, especially when DoD is under pressure to ensure that contracts are awarded as competitively as possible. Sole sourcing requires contracting office approval.
iii. Recent funding cuts have, according to agency staff and recipient interviews, negatively affected SBIR contracting.

b. The Defense Acquisition University (DAU) is the primary source of training for acquisitions and contracting officers. DAU does not currently require training in SBIR rules and contracting procedures, nor does it provide a regularly scheduled elective class on the SBIR program. Such a course could contribute to a better understanding of the opportunities and processes associated with SBIR funding for small firms.

c. Defense Contract Audit Agency (DCAA) audits are both an overall barrier to entry into DoD programs, and a particular problem for small contractors, especially in some regions during some periods.[36] Although audits are of course necessary to prevent fraud and abuse, DCAA does not appear to have effective procedures in place for addressing the problems its audits continue to cause for SBIR firms, even when no wrongdoing emerges. Among the issues raised by SBIR recipients are:

i. Audits provide no useful feedback. Companies either pass or fail, and they may not be informed about reasons for failure.

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[36] 2011 NRC Survey and Case Studies.

ii. Audits take a long time. Several companies noted that audits of a small company, which they believe could be completed by a competent accountant in 2 weeks, took 18 months or more at DCAA.[37]

iii. Penalties are very severe for small businesses, which are entirely blocked from further federal funding until problems are resolved. This can be catastrophic for small firms dependent on SBIR awards or other federal contracts.

iv. DCAA does not appear to have in place an effective conflict-resolution process for small businesses. Companies report no office within the agency that provides support or advice.

4. Continuity problems are caused by the regular rotation of agency liaisons.

a. Agency and company interviews suggest that eventual project success is closely tied to the existence of effective project supporters within DoD.

b. However, the NRC survey indicates that about one-third of Phase II projects had their Technical Point of Contact (TPOC) replaced during the course of the award. Given that the commercialization transition period (prior to handoff to a PEO) usually extends for at least another year beyond Phase II, it seems plausible that a very substantial portion of all TPOCs are rotated out before a project is completely transitioned.

c. Continuity problems are multiplied by the additional need to train TPOCs before they can act effectively as project liaisons to the acquisition programs. Survey data suggest that fewer than half of TPOCs are "very helpful" or "somewhat helpful" in connecting projects to acquisition funding.

d. Agency and company interviews suggested that, in some cases at least, the SBIR TPOC assignment is regarded as somewhat burdensome and is assigned where possible to the most junior staff available.

B. Challenges in working with the primes

1. SBIR data rights—though clearly necessary and important—involve special considerations.

a. DoD contracts typically require that primes provide all data rights to the contracting agency. SBIR regulations retain rights for the

[37]One case study company is in 2014 completing an audit of labor rates for 2008. See Appendix F.

small company, sometimes making it harder to align its rights with the different rights conferred via the larger project.

b. Primes have no incentives to respect SBIR company-data rights.

2. Primes sometimes work in direct competition with SBIR companies; others cooperate effectively with SBIR companies.[38]

    a. While some companies have a track record of cooperating effectively with multiple primes contractors over a long period that may last decades, others report negative experiences, asserting that primes used SBIR technologies to win contracts and then failed to include them in subsequent work.
    b. There is no quantitative evidence to measure either of these outcomes. It does appear that in cases where there is no direct competition (e.g., Daniel H. Wagner's specialized development of mathematical tools and algorithms), the relationship is likely to be better and more sustained than in cases when SBIR firms provide products or services that the prime could develop or has already developed itself.

3. Primes respond to incentives, but they have not been incentivized to work with SBIR companies.
    a. The committee has not identified any documented cases in which primes were provided with financial incentives to work with SBIR companies.
    b. The Navy found that financial incentives for primes to work with selected demographics on Virginia-class subs had a substantial impact on subcontracting practices.

C. Challenges in tracking outcomes effectively and in reporting

1. There are broad challenges to tracking commercialization for DoD SBIR programs, especially at the company and project levels. Companies move in and out of the program, and tracking in some cases stops when they leave (see below). More generally, commercialization may come years after an award and may involve multiple awards plus considerable additional funding. All of 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.
2. The FPDS is the primary source of program data: it captures all federal contracts larger than $3,000, but remains limited in important ways.

    a. Data entry related to Phase III awards remains somewhat erratic. Contracting officers must be trained to recognize and designate

[38]Other competitors for funds are DoD Labs, FFRDC, and UARCs.

Phase III contracts, which differ from standard contracts and hence require affirmative recognition as such.

b. Phase III designation is limited primarily to the first contract after the end of Phase II and possibly to the second such contract. However, downstream contracts may be very substantial and are not captured by FPDS.
c. FPDS does not capture SBIR commercialization via subcontracts to primes. Evidence from the survey suggests that this accounts for a quarter of all commercialization.
d. FPDS does not capture non-defense or export sales. These too account for about a quarter of all commercialization.

3. The Company Commercialization Report (CCR) is the second major source of data on commercialization. It captures self-reported data from companies that continue to participate in the SBIR program. However, although it covers subcontracts and sales outside the defense sector, it too has important limitations.

   a. Being self-reported, CCR requires periodic cross-checks for accuracy. It is not clear whether these are currently funded by DoD.
   b. Companies not currently participating in the SBIR program have no incentive to participate in CCR and likely do not. DoD has not analyzed how and why companies cease CCR reporting.
   c. CCR provides only aggregate data at the point of updating. It is therefore not useful for longitudinal analysis.

4. DoD does not effectively track the participation of women and under-represented minorities in the SBIR program.

   a. Data collection is limited to self-certified MOSBs and WOSBs. There are no data collected on the demographics of PIs.
   b. Data on the participation of under-represented subgroups—notably African American- and Hispanic-owned businesses and PIs—are not tracked.
   c. Analysis of participation by women and minorities is limited to the reporting of aggregate numbers. There appears to have been no systematic analysis of these data with a view to identifying sources of applications from these groups as well as possible barriers.

5. Even though contract reporting mechanisms allow DoD to track the award of sole-source contracts based on SBIR data rights, DoD does not in practice appear to track the incidence of these contracts in Phase III. This could be a useful data point for understanding how one of the

more important characteristics of the SBIR program is used in practice; the data to do so may be available via FPDS.

6. DoD does not differentiate between small business Phase III awards and legacy Phase III awards to former SBIR companies now either acquired or sized out of the program.[39] Annual and other current reports are limited and provide minimal guidance for program management. The current annual report on the program provided by DoD is limited to a set of numbers that reflect annual awards. This is insufficient for a program of this size, scope, and importance.
7. However, new reporting required under reauthorization imposes significant burdens. DoD staff indicate that following reauthorization the annual preparation of several new reports is required annually, some of which substantially overlap.[40]

D. Challenges in addressing under-represented populations

1. The awards data described in Chapter 2, and the tracking deficits identified in the preceding section, suggest that DoD has not effectively addressed the mandate to foster the participation of women and other under-represented populations.
2. Efforts to address these deficits do not require the adoption of quotas or other approaches that would reduce program effectiveness.

    a. DoD has not made a concerted effort to develop focused or targeted outreach programs.
    b. DoD has not developed benchmarks for appropriate levels of participation, based on a range of factors that might include the incidence of technically qualified PIs, the number of qualified companies that could apply, or repeat applications from previous winners.

E. Challenges caused by unanticipated effects of the reauthorization language

1. In developing the Policy Guidance, SBA addressed section 5111 of the Reauthorization Act, concerning multiple Phase II awards.[41] Under the

[39]Team Subs is the single largest PEO at DoD in terms of Phase III transitions, accounting for more than $1.5 billion in validated Phase III contracts. However, a review indicated that about 30 percent of that amount was accounted for by two legacy companies that were acquired, and another 30 percent went to a single small business that reached the size limits in 2010 (but continues, correctly under SBA and Federal Acquisition Regulation (FAR) rules, to receive Phase III awards based on previous work).
[40]See the description of Program Management in Chapter 6.
[41]The legislative language is contained in the SBIR/STTR reauthorization,

new language, section 4(b)(5) of the Policy Directive reads: "(5) A Phase II awardee may receive one additional, sequential Phase II award to continue the work of an initial Phase II award."[42]

This has been interpreted in ways that introduce substantial and possibly unanticipated inflexibility into program operations. The legislation imposes several limits on the award of SBIR Phase II funding:

a. Only two Phase II awards can be made sequentially to a single company on a single technical topic.
b. Total funding for all Phase II and II.5 awards cannot exceed $3 million without an explicit waiver from SBA.
c. The legislation does not address matching non-SBIR funds, which could presumably be any amount. Air Force data indicate 3.6:1 leverage for SBIR funding (FY2007-2012), which suggests that $1 million on Phase II.5 SBIR funding has been matched by $3.6 million of non-SBIR funding (presumably without requiring an SBA waiver).

2. Agency staff have in discussions indicated that this means that:

a. Only two Phase II awards can be made per topic. This sometimes prevents "reachback"—laudable agency efforts to identify previous SBIR awards that developed technologies of current use, even if they were not transitioned at the time of the award. As a result, agencies other than the original funder (and even other Services or components within DoD) can be prevented from picking up a technology for transition. There is nothing in the legislative language to suggest that this interpretation is correct: the language discusses a second award to a *company*, not a second award per individual *topic.*
b. The second award must follow immediately from the first. There is nothing in the legislative language to suggest this, but it is apparently the interpretation that currently governs within DoD.

"Section 5111: SEC. 5111. ADDITIONAL SBIR AND STTR AWARDS.

Section 9 of the Small Business Act (15 U.S.C. 638), as amended by this title, is further amended by adding at the end the following:
``(ff) Additional SBIR and STTR Awards.--
``(1) Express authority for awarding a sequential phase II award.--A small business concern that receives a Phase II SBIR award or a Phase II STTR award for a project remains eligible to receive 1 additional Phase II SBIR award or Phase II STTR award for continued work on that project." Public Law 112-81, 112th Congress

[42]SBA Policy Directive, section 4(b)(5).

c. DoD Phase II.5 awards must be treated as Phase II awards for the purposes of this policy. This interpretation is understandable: reauthorization still does not permit agencies to use SBIR funds for Phase III, only for Phase II—so, almost by definition, Phase II.5 must be treated as a kind of Phase II; otherwise it would not be permissible to use SBIR funding to make these awards. However, this determination has the potential effect of essentially nullifying even the limited additional flexibility intended under the legislation. As a result, either:

   i. companies that have received only one Phase II are eligible for Phase II.5, but cannot then be awarded a sequential Phase II either from the original agency or from any other agency or component that wishes to adapt their work to new needs; or
   ii. companies that receive a Phase II.5 are ineligible for both sequential Phase II funding and any subsequent Phase II.5 funding for their technology.

d. Legislative intent may be misinterpreted. The language was designed to expand the flexibility of the program by allowing agencies to add an additional Phase II award for projects that were not ready to transition but that still held promise (in ways effectively captured by Phase II.5). There is no evidence that Congress intended to limit reachback, prevent agencies from picking up prior awards from other agencies or components, or limit the provision of additional SBIR awards per topic.

F. Challenges in protecting small business data rights

1. Contracting officers are often unfamiliar with SBIR contracts and data rights, especially as DAU provides no systematic training on this subject.

   a. Unless a contract is officially certified as a Phase III contract, data rights are not protected as required under the legislation.
   b. Contracting officers can be reluctant to sign off on what is to them an unusual form of contract.
   c. Some PEOs are much more diligent than others in ensuring that data rights are protected in the contracting process.

2. There is no systematic reporting on the protection of data rights, and no effort to acquire systematic information.

   a. As noted elsewhere, there are no efforts to acquire granular information from SBIR awardees through regular surveys or other feedback mechanisms. In particular, there is no provision for the acquisition of anonymized information from awardees about program operations.

3. Procedures for addressing problems with data rights are not sufficient.

   a. None of the components appears to have in place systematic mechanisms through which companies can raise difficulties and concerns.
   b. No component-level staff are explicitly responsible for addressing issues related to small business data rights.
   c. SBA has mechanisms in place that can be used, but they are slow moving and in some instances, at least, have proved ineffective in addressing problems even when SBA formally steps into contract disputes after upholding a complaint.

G. Challenges in identifying and transferring best practices

1. There are no formal procedures for identifying and transferring best practices within DoD.

   a. Each component appears to operate almost entirely independently. Air Force is to be commended for recently visiting NAVAIR to seek a better understanding of its approach to SBIR, but this is unusual.
   b. Minimal attention is paid to identifying best practices even within larger components. There do not appear to be formal processes in place to evaluate program management practices, nor to transfer them between PEOs.

2. Transferring best practices is a growing major challenge.

   a. The decision to end the annual SBIR program managers' meeting leaves agency SBIR staff without any organized opportunity to connect in person to similar staff at other agencies and components.
   b. The decision not to hold a further "Beyond Phase II" conference at DoD means that even within the agency, knowledge transfer between components will be more limited.
   c. There are no program manager email lists or online forums that can connect staff on a day-to-day level either within DoD or across all agencies.
   d. There is to our knowledge no newsletter or other publication focused on SBIR program management—again either at individual components, at DoD, or across all agencies. The absence of

conferences where recent experience and best practices are exchanged is a significant limitation on the effective operation of the program.

RECOMMENDATIONS

As noted in the NRC Study Findings section above, the DoD SBIR program continues to generate substantially positive outcomes and has been improving in a number of areas and on a number of metrics, although the lack of progress in meeting Congressional objectives for the participation of women and minorities remains a concern.

As with the Findings, the Recommendations section is organized around the four core Congressional objectives, with an additional section focused on general program management issues.

I. Commercialization

A. Improve Phase III transition[43]

DoD has made significant strides to put in place new mechanisms to encourage Phase III transition. The Phase II.5 program adopted by Air Force and Navy is a particularly helpful innovation, bringing together funding from the SBIR program and program offices (acquisitions) in a new matching-fund format, operating at a scale that could be sufficient to make a significant difference to eventual outcomes.

There are, however, a number of areas where improvement could be made.

1. Aligning incentives for primes. The latter are a critical component of successful transition in that they are the primary pathway into major programs of record.

    a. Primes have few incentives—and many disincentives—to work with SBIR companies. There are some cases in which these partnerships work, and others in which they do not—and many other cases in which primes proceed as though SBIR does not exist at all.
    b. DoD should consider experimenting with different kinds of incentives to encourage primes to work more effectively—and more often—with SBIR firms. There is evidence that such financial incentives do affect the behavior of primes.[44]

[43] See Finding II and Finding IV-B.
[44] See the Chapter 6 discussion of incentives used by Team Subs.

2. Improving outreach to PEOs. It has become apparent that PEOs and Program Contracting Officers (PCO) who have positive views of the SBIR program—and utilize it to address their mission needs—have much more satisfactory transition profiles. However, many PEOs and PCOs are not fully aware of the advantages provided by the SBIR program.

    a. Many PEOs continue to regard the SBIR program as more of a tax than a potential source of solutions to challenging technical problems.
    b. New administrative funding should be used in part to develop better briefing materials for PEOs.
    c. DoD should consider developing a briefing program for all PEOs and PCOs, and should in particular focus on briefings for new PEOs and PCOs.
    d. DoD should consider developing SBIR information modules for integration into DAU courses, particularly those designed for PEOs and PCOs.

B. Continue to explore ways to bring primes and SBCs together[45]

1. Programs to bring primes and small businesses together should be encouraged.

    a. The recent efforts to develop Technology Transition Agreements at Air Force are one example of potentially useful approaches.
    b. Navy has operated the Navy Opportunity Forum for a number of years, bringing together selected SBIR companies and numerous representatives from the primes.
    c. Air Force operates an online showcase of SBIR companies and technologies.

2. Where such efforts prove to be effective, DoD should proactively seek to spread the use of such approaches more widely, perhaps by providing a pot of funding for initiatives that target such activities.

C. Use of financial incentives for components[46]

1. DoD should encourage components to experiment with financial incentives for the adoption of SBIR technologies. Given the substantial disincentives that exist, it is reasonable to address a market failure with corrective incentives.

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[45]See Finding IV-B.
[46]See Findings IV-A, II-A, and V-A.

a. DoD should experiment with explicit use of financial incentives in the form of participation bonuses, similar to those used in the Team Subs program in the middle of the previous decade to enhance utilization of small business concerns (SBCs) and WOSBs.
b. Even where financial incentives are not available, DoD should consider encouraging components to add explicit targets to prime contracts, in the same way that targets for the participation of small businesses more generally have been added to contracts.

2. DoD should ensure that these initiatives are systematically tracked and evaluated (see section below on Tracking).

   a. For this approach to be effective, DoD will need to greatly advance its ability to track the use of SBIR companies as subcontractors to primes.
   b. There are long lags between the initiation of incentives and eventual outcomes (Navy's experiments required a 5-year period between contract agreement and payment on incentives). Thus, tracking must be both consistent and persistent.

D. Highlight exceptionally innovative projects[47]

1. DoD does not have a process for highlighting exceptionally innovative and effective projects. One potential model for informed assessment of scientific/technological impact is the practice of editorial boards for some leading scientific journals that review the articles published by their journal over the previous year and collectively identify the "most influential" few articles of each type featured. These project awards would be separate from agency programs to recognize sustained success by SBIR/STTR companies such as the National Science Foundation's Tibbetts Award or the Department of Energy's SBIR/STTR Small Company of the Year Award.

   a. At each agency or sub-agency program, SBIR/STTR staff and the TPOCs who monitored recently completed Phase II products would identify and evaluate most scientifically/technologically innovative projects in various categories. The "best" one or few projects per category would be identified as Innovation Leaders and recognized with a suitable certificate, a description on the agency's SBIR/STTR website, and a press release. Project categories might include best scientific breakthrough; best

[47]See Findings IV-A and V-G.

hardware development and engineering; best software development and engineering; best commercial potential; etc.

b. In order to stimulate staff engagement, moderate cash awards to the TOPCs who monitored the recognized projects and the author(s) of the solicitation topics addressed by these projects could be provided.

II. Addressing Under-Represented Populations

A. **DoD should substantially enhance efforts to address the clear Congressional mandate to foster the participation of under-represented populations in the SBIR program.**[48]

1. Significant effort and resources will need to be committed if change is to occur as it must. Given the highly disaggregated nature of the program, component-level activity will be required.
2. DoD should *not* develop quotas for the inclusion of selected populations into the SBIR program. Such an approach is not necessary to meet Congressional intent and is likely to reduce program effectiveness.

B. DoD should develop new benchmarks and metrics.[49]

1. Improve participation metrics: The SBIR/STTR program office should work with NSF and draw on work of the NSF indicators group to develop much improved metrics for benchmarking the participation of underserved populations, developing and publishing clear benchmarks based on a defensible analysis of existing data.
2. Disaggregate Benchmarks: Measures of the participation of socially disadvantaged groups must be disaggregated by ethnicity, and attention focused on the clear Congressional intent to support "minority" participation. We do not believe a focus on the current SBA definition of "socially and economically disadvantaged" is in any way sufficient to meet this objective.
3. Customize Benchmarks: Points of reference should be developed separately (though perhaps drawing on a shared methodology) for women and minorities. These benchmarks should be shared with other SBIR agencies. Benchmarks should address key questions that would include, for both SBIR and STTR:

    a. Shares of applications from companies majority-owned by women and minorities.

[48]See Finding III-A.
[49]See Finding III-B.

   b. Shares of applications with woman and minority principal investigators.
   c. Share of Phase I awards.
   d. Shares of Phase II awards.

4. Track Related Program Operations: Metrics should also track related program operations including outreach efforts. (See below.)
5. Components should be required to report annually to OSB on outreach plans designed to meet Congressional mandates.

C. DoD should develop an outreach and education program focused on expanding participation of under-represented populations.[50]
This will require the provision of agency resources and senior staff time, and should be a high priority for the program. DoD and the DoD components will need to make concerted efforts in this area.

1. Develop Outreach Strategy: DoD should develop a coherent and systematic outreach strategy that provides for cost effective approaches to enhance recruitment of both woman- and minority-owned companies and female and minority PI's, developed in conjunction with other stakeholders and with experts in the field.
2. Integrate Outreach Effort: DoD should ensure that outreach to selected populations is an integral part of its overall outreach.
3. Review Selection Processes: DoD should review internal award and selection data and processes to address questions arising from disparities between Phase I and Phase II awards to selected populations.
4. Provide Management Resources: DoD should provide significant management resources as improving participation is likely to be both difficult and a long term effort.
5. Designate Staff: DoD 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.
6. The DoD Office of Small Business (OSB) should improve tracking and metrics against which to benchmark component activities in relation to this Congressional objective.

   a. Metrics should address all aspects of the source-selection process, including the percentages of applications and awards for each subgroup.
   b. Metrics should assess the extent and impact of outreach activities that target under-represented populations.

[50]See Findings III-B and V-D.

c. DoD should improve tracking accuracy by adding a second option to the checkbox for self-certification as a minority-owned firm, which asks respondents to declare which under-represented group or groups they belong to.

7. Metrics and other reporting should be collated annually and included in the proposed revised annual report (see III.A.4 below).

III. Tracking, Data Collection, and Adoption of Best Practices

High-quality data, collected systematically and in a timely manner, are at the core of developing data-driven management. Currently, DoD tracking has significant weaknesses. This matters because high-quality data and analysis are required for the identification and adoption of best practices.

A. Further developing a culture of monitoring, evaluation, and assessment predicated on enhanced information flows.[51]

Now that additional administrative funding has become available through reauthorization, it is very important that DoD address the need for better alignment of data collection, agreed metrics, and utilization of effective evaluation and assessment tools *to guide program management*. The committee anticipates that the development of more careful monitoring and more sophisticated analysis of key variables would substantially improve outcomes over the medium term.

1. DoD spent $1.05 billion in 2012 on SBIR funding.[52] It must deploy appropriate levels of resources to determine how to spend these funds to generate the maximum return. Detailed analysis of outcomes could help to answer many operational questions. For example:

   a. Is it possible to systematically identify topics that transition more effectively?
   b. What are the year-to-year trends in transition achievement?
   c. Is SBIR best suited for certain kinds of technologies or sectors?

2. SBIR companies—like "customers" in other markets—are an important source of information about program strengths and weaknesses. This knowledge is almost entirely excluded from formal program evaluation.

[51]See Findings I-B, III-A and V-C.
[52]Department of Defense, DoD Annual SBIR Report Summary, <*http://www.dodsbir.net/annualreport/annrpt.html*>, accessed February 3, 2014.

a. DoD should develop pathways to provide ongoing feedback from companies about program activities and operations. These could include electronic communication tools such as wikis, listservs, and other emerging social media.
b. Similarly, DoD should consider developing or expanding mechanisms through which SBCs can share information about SBIR projects, helping them to find technical or marketing partners and to navigate the often-complex regulatory and technical environment of DoD programs.
c. DoD should consider introducing annual surveys to probe SBC knowledge about the program more directly. Such surveys can also be an important source of suggestions for program improvement, and can flag obscure but important problems—such as those reported with DCAA—in a systematic way.

3. DoD should develop a more sophisticated approach to analyzing the data that it already has. For example, perhaps limited by the available resources, there have been few systematic efforts within DoD to evaluate factors that tend to encourage successful transitions between Phases, into Phase II.5, and then into Phase III and beyond.

   a. DoD should seek to develop a more consistent approach to the application of quantitative metrics to program management.
   b. DoD should also identify and adopt a much more systematic approach to the current use of success stories, which are little more than promotional material for the companies and the agency. Once improved, success stories could be analyzed to highlight trends and to identify variables playing a key role in successes, as well as help stakeholders understand the extent of program successes.

4. Reporting requirements. We recommend that DoD simultaneously address the gaps in its current reporting and the burdens imposed by the numerous requirements imposed through reauthorization by providing a single much more comprehensive annual report that could, after appropriate consultations, be used to satisfy the reporting requirements of numerous Congressional sponsors. The report should

   a. include up-to-date data on awards and applications by phase, state, and component,
   b. include narrative that described developments and initiatives in the program on an annual basis,
   c. summarize outcomes data from FPDS and CCR,
   d. address the take-up of SBIR-funded technologies within DoD,
   e. address efforts to increase participation among under-represented populations, and

f. reflect any specific additional requirements of sponsors.

B. FPDS must be improved in some significant ways.[53]

1. The accuracy of data recorded in FPDS needs to be improved. Experience at Navy indicates that erroneous data entry is a significant problem.

   a. Coverage of Phase III contracts can be improved by training contracting officers more effectively in the rules governing Phase III.
   b. An additional layer of (incentivized) reviewers can be added by requiring that the SBC be provided with ongoing opportunities to review its FPDS entries, including its Phase III status.

2. FPDS Phase III reporting does not extend to cover all commercialization from SBIR.

   a. DoD should consider ways to track SBIR technologies through FPDS downstream through follow-on contracts: currently, the more successful a technology is, and the more additional contracts it generates, the less likely these are to be certified as Phase III awards.

C. DoD should improve tracking of SBIR company subcontracts through the primes.[54]

1. Under reauthorization, primes are now required to start tracking SBIR subcontracts.[55]

   a. Large prime contracts are, under the reauthorization legislation, required to develop a plan for SBIR technology insertion and to provide reports that reflect both the plan and the extent to which it is realized. DoD should work to ensure that these goals are in place as soon as possible.

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[53]See Findings V-C and I-B.
[54]See Findings I-B and V-C.
[55]Public Law 112-81 112th Congress, Section 5122 a (7)
Insertion incentives.--For any contract with a value of not less than $100,000,000, the Secretary of Defense is authorized to--
(A) establish goals for the transition of Phase III technologies in subcontracting plans; and
(B) require a prime contractor on such a contract to report the number and dollar amount of contracts

   b. DoD should develop standard language for insertion into large prime contracts that reflects the intent of the law by providing both a goal for SBIR insertion and a standard reporting mechanism and timeline.

2. CCR provides unique data and should continue to be used to track commercialization via self-reported data from SBIR companies.

   a. Until the proposed SBA Commercialization Database is fully operational, DoD should continue to utilize CCR.
   b. When the SBA database becomes operational, DoD should ensure that data collected in CCR are seamlessly and completely included in the new database.

IV. Program Management and Agency Mission Objectives

Recommendations in this section are not explicitly designed to address one of the four legislative objectives for the program. They are designed to improve program operations in ways that should enhance the program's ability to address some or all of these objectives.

A. Review and if necessary amend Policy Guidance.[56]

Changes should be made to address guidance at SBA, DoD, or component levels that impose unnecessary rigidity on program operations. Specifically, amendments should be made to

1. encourage rather than obstruct "reachback" to previously funded research; and
2. support the infusion of additional funding via programs similar (but not limited) to Phase II.5.

B. Improved use of TPOCs[57]

1. DoD should identify ways to ensure that the knowledge and enthusiasm of sponsoring TPOCs is not lost to the project. For example, DoD might consider

   a. encouraging wider adoption of programs similar to the Air Force's Technology Agent (TA) strategy—after a review and evaluation of the TA system in operation. This would put in place permanent liaison officers.

[56]See Finding II-B and V-C.
[57]See Finding V-A.

b. considering ways to support ongoing engagement by TPOCs in projects after they have formally handed them on at the end of a rotation.
c. considering mechanisms to improve the transfer of knowledge during handoffs.

2. Given that TPOC rotation is part of DoD structure, DoD should improve training for TPOCs. It should consider

a. identifying and implementing ways to better train TPOCs about the operation of the SBIR program;
b. identifying and implementing ways to better train TPOCs in the operation of acquisition programs so that they can become more effective liaisons between SBIR projects and companies and acquisition programs; and
c. ensuring that SBIR-related programming is in place at the DAU, which should include two elements:

i. curricula and programs for TPOCs; and
ii. parallel curricula as part of standard training programs for acquisitions officers, to ensure that all are familiar with the operation of and opportunities provided through the SBIR program.

C. Protecting small business data rights.[58]

Although the reauthorization provided full support to existing provisions with regard to SBIR company data rights, some companies reported cases in which these rights were breached with only limited recourse.

1. DoD should establish a link on its website for companies to report what they believe to be breaches of data rights.
2. DoD should track reported breaches (whether reported through the website or via other means). OSB should seek ways to

a. track the incidence of reported breaches on an annual basis; and
b. generate a section of the proposed annual report on data breaches, which would include information about alleged breaches disaggregated to the component level, along with a short narrative that explains what OSB has done to explore and if necessary remedy these alleged breaches.

[58]See Findings V-A, V-B, and V-F.

3. DoD should work with SBA to explore mechanisms through which SBIR data rights could be protected more effectively.

D. Identifying and transferring best practices within DoD.[59]

Some parts of DoD are experimenting vigorously with the new tools provided in part through re-authorization and previous adjustments to the program. They should be strongly commended for doing so. However, the point of experimentation is in part to identify best practice and then to encourage its adoption more widely. Neither occurs widely enough within DoD or even within individual components, where activities are often decentralized.

1. DoD should develop a process for tracking experimentation within the SBIR program. This is likely to track the different elements of program management. Tracking should include

    a. annual reports on program initiatives from SBIR component program offices to OSB (which could derive from internal reporting within components that is currently not shared with OSB); and
    b. reports that cover activities down to the appropriate level of experimentation. In some cases—for example some parts of Navy—this occurs even below the level of the PEO.

2. Given the long lags in some cases between experiment and outcome, DoD will need to find mechanisms to measure effectiveness even before quantitative outcomes become available.

    a. These should include input data that reflect the extent of rollout for any given experiment and specific objectives, as well as specific identification of topics and offices involved.
    b. DoD should explore a variety of tools for measuring effectiveness, including surveys of participants (both within DoD and in the primes and small businesses), as well as the application of other possible tools, including the use of social media.

3. DoD needs to focus attention on the development of a comprehensive toolset of mechanisms for transferring both formal and informal knowledge about best practices.

    a. OSB should support the scheduling of annual program manager conferences in Washington, DC, as a means of supporting face-to-face interaction between components across agencies.

[59]See Finding V-G.

b. OSB should deploy online tools that can be used to help share information among SBIR offices, acquisition offices, and supporting functions such as contracting offices and even DCAA.
c. DoD should reinstate the "Beyond Phase II Conference" or provide a similar opportunity for in-person knowledge transfer.

V. Contracts and Audits

A. Auditing: Auditing issues, although technical and only tangentially related to the SBIR program as such, can cause devastating damage to small business and anecdotally appear to represent a significant barrier to program participation for new applicants and to the timely award of contracts by DoD program managers.[60] DoD should address DCAA on issues of concern to SBIR companies as a matter of high priority at senior levels. DoD should:

1. explore with DCAA (and perhaps relevant Congressional staff) the possibility of developing less onerous and more effective auditing procedures for small businesses that can be completed in a more timely manner. This would of course also reduce the burden on auditing staff; and
2. provide all SBIR awardees with up-to-date information about redress procedures within DCAA as part of initial contract information deployment. If these are not satisfactory, then OSB should work with DCAA to improve them.
3. Based on enhanced feedback from SBIR recipients, DoD should include a section in the proposed annual report on auditing concerns.

B. Contracting: SBIR contracts are unusual within the world of DoD contracting. They are accordingly not always handled correctly, and SBIR companies note that contracting issues are sometimes very challenging, especially given recent cuts in the resources devoted to contracting at DoD.[61]

1. DoD should ensure that comprehensive training on SBIR contracting is available to contracting staff at all components.

   a. OSB should work directly with DAU to ensure that a course is developed to cover contracting issues with the SBIR program and that this course is made available to all contracting officers at least annually.
   b. All units that service SBIR contracts should ensure that they have on staff at least one employee who has been certified as

[60] See Finding V-A.
[61] See Finding V-B.

completing SBIR contracts training provided by DAU or an equivalent, to act as an expert resource.

2. Contracting practices vary widely within DoD, and small businesses have little recourse to address problems at the component level. DoD should:

    a. provide opportunities for SBCs to raise concerns about contracting practices at the component level, by mandating that components provide feedback opportunities and by providing its own feedback mechanisms for small businesses related to contracting; and
    b. consider developing an "expert group" of senior contracting officers who can meet virtually and can provide direct advice and support for small businesses in the event of contracting difficulties.

APPENDIXES

Appendix A

Overview of Methodological Approaches, Data Sources, and Survey Tools

This report on the Small Business Innovation Research (SBIR) program at the Department of Defense (DoD), is a part of a series of reports on SBIR at the National Institutes of Health (NIH), National Aeronautics and Space Administration (NASA), Department of Energy (DoE), and National Science Foundation (NSF). Collectively, they represent a second-round assessment of the program by the National Research Council (NRC).

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.[1] 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.[2] "Rather, the NRC Committee conducting 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." 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."

These areas refer to the four legislative objectives of the SBIR program:[3]

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[1]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.
[2]National Defense Authorization Act of 2012 (NDAA) HR.1540, Title LI.
[3]The most current description of these legislative objectives is in the Policy Guidance provided by SBA to the agencies. SBA Section 1.(c) SBIR Policy Directive, October 18, 2012, p. 3.

- Commercialize government-funded research
- Expand the U.S. technical knowledge base
- Improve the participation of women and minorities
- Support agency missions

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.** Only DoD and NSF track outcomes data, and DoD's tracking is insufficient for careful analysis. There are no systematic efforts by agencies to collect feedback from awardees. No systematic efforts have addressed qualitative data.
- **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. And 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 NRC 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 volume on methodology, which was published in 2004 after completing the standard National Academies peer-review process.[4]

[4]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, op. cit., p. 2.

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.[5]

The tools identified in the illustration above include many of those used by the NRC committee conducting the first-round study of the SBIR program. Other tools emerged since the initial methodology review.

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 20 SBIR recipients at DoD. These companies are geographically diverse, demographically diverse, funded by several different components at DoD, and at different stages of the company lifecycle.
- **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 obtained from DoD or DoD components. The committee has analyzed and included these data as appropriate.

[5]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, op. cit., p. 2.

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 government 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; IPO	Patent counts and other IP/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 level; 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 700 observations by firms on the SBIR program.
- **Agency interviews.** Agency staff were 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 NRC 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. We have referenced these works 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 NRC surveys; conversely, data from the survey are used to support analysis throughout the report.

COMMERCIALIZATION METRICS AND DATA COLLECTION

Recent Congressional interest in the DoD SBIR program has 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.[6] Broadly speaking, it means funding for technology development beyond that provided under Phase II SBIR funding. Given the diversity of components within DoD, 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.

While all of the components measure "transition," it is not clear that this means the same thing across DoD. Possible meanings and elements include the following:

- issuance of a certified Phase III contract by a Service or DoD agency (collectively "components") directly to the small firm;
- adoption of a technology by a program of record (Air Force [AF] simply counts technologies that are flown on AF aircraft);

[6]See Chapter 4 for related analysis of commercialization in the SBIR program.

- utilization of a technology in weapons systems that are delivered to the war fighter;
- licensing of technologies to prime contractors (primes) and other parties serving DoD components;
- sale of products and services to primes for use on DoD systems (this may or may not include sale of data rights); and
- any sale of goods or services derived from SBIR-funded technologies, to DoD or to other purchases, including the U.S. private sector, other U.S.-based government agencies, and foreign buyers.

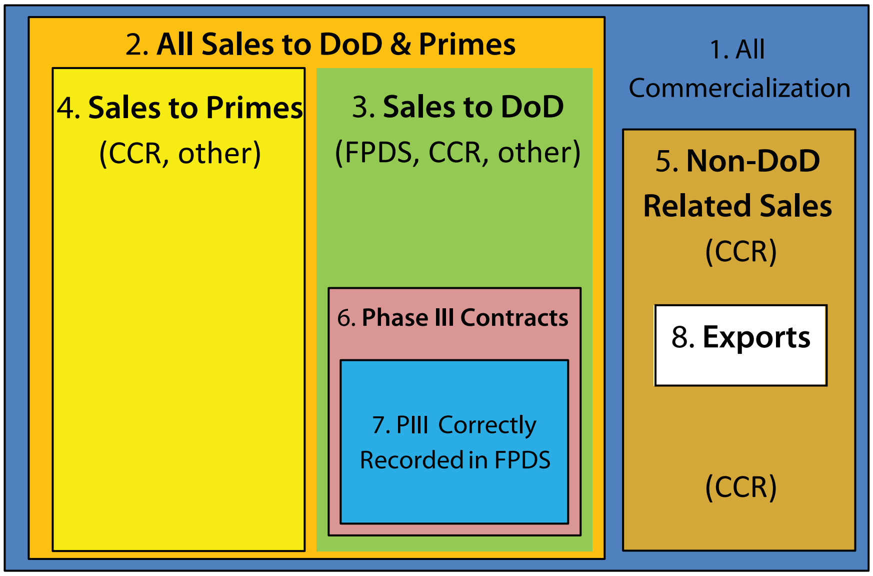
Different kinds of commercialization are recorded and reported differently as well. Figure A-1 shows the different kinds of commercialization and the data sources that can be used to track them. Numbers in the figure are as follows:

1. **All commercialization:** including both DoD-related and private-sector sales and licensing.
2. **All DoD-related commercialization:** including sales and licensing revenues generated from either DoD directly or through primes to DoD.
3. **DoD-only sales and revenues:** from small business directly to the DoD (excludes sales through primes).
4. **Defense-related sales to the primes only:** excluding DoD-direct sales.
5. **Non-DoD related sales:** including all sales in the U.S. private sector and all exports (to both public- and private-sector entities abroad). These sales may be in the defense sector but not to DoD or the primes.
6. **DoD Phase III contracts:** This box represents all the DoD sales resulting from SBIR awards that should be designated as Phase III contracts. However, Phase III currently only rarely covers downstream impacts of SBIR awards beyond the first Phase III contract.
7. **DoD-sales correctly certified as Phase III:** this is the share of all Phase III sales that are correctly entered into the Federal Procurement Data System (FPDS).
8. **Exports:** part of non-DoD commercialization.

Challenges in Tracking Commercialization

The nested boxes in Figure A-1 indicate something of the scale and complexity of the challenges involved in accurately tracking commercialization. So it is useful to break the tracking issue into three broad components:

- within DoD;
- in the DoD primes; and
- all remaining commercialization.



- CCR = Company Commercialization Record
- FPDS = Federal Procurement Data System
- Other = other data tracking methods and tools used by some components

FIGURE A-1 Accounting for commercialization in the DoD SBIR program.
SOURCE: Committee-generated.

Tracking Commercialization Within DoD

The Federal Procurement Data System (FPDS) is the primary tool for tracking commercialization within DoD. FPDS is designed to contain all federal contracts, including all SBIR contracts and all subsequent direct contracts between the federal government and small businesses.[7,8]

All federal contracts for more than $3,000 must be entered into the FPDS.[9] However, while Phase I and Phase II contracts are almost always entered accurately as SBIR contracts, that is not the case for Phase III.

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[7]Information about DoD use of FPDS is drawn from <*http://www.acq.osd.mil/dpap/pdi/eb/federal_procurement_data_system_-_next_generation_fpds-ng.html*>, accessed July 3, 2013, and from interviews with Navy SBIR staff and with the Navy civilian FPDS contractor.

[8]Detailed information about FPDS is contained in the FPDS-NG User Manual, <*http://www.fpds-ng.com/wiki/index.php/FPDS-NG_User_Manual*>, accessed July 3, 2013.

[9]GAO FPDS-Next Generation FAQ, <*https://www.fpds.gov/wiki/index2.php/FPDS-NG_FAQ*>, accessed July 7, 2013.

Interviews with senior Services SBIR staff confirm that Contracting Officers (COs) do not always recognize that a follow-on SBIR contract with a small firm is a "Phase III contract" and hence do not mark the contract as such in FPDS.

In October 2012, the DoD Inspector General (IG) office reported that SBIR and Small Business Technology Transfer (STTR) awards were often incorrectly labeled under the requirements for effective competition; the report stated that SBIR and STTR awards should be viewed as having been competed, but that they were often not marked as such in the FPDS by contracting officers.[10] As a result, SBIR Phase III contracts are not completely reflected in FPDS, and hence that data and analysis based on FPDS systematically undercount the impact of SBIR transitions within DoD.

Some components have tried to address this problem. In Navy, a civilian contractor has been assigned full time to work with FPDS. The contractor double-checks to ensure that all Phase III contracts with DoD are marked as such in FPDS. So far as can be determined, none of the other DoD components uses a full-time contractor or staff member for this purpose. Because the Navy process consistently finds errors, it seems very likely that an unknown number of SBIR Phase III contracts at other components go unrecorded as such. No estimate is available for the amount of under-reporting that can be attributed to this problem.

There is a second and perhaps more important difficulty in tracking commercialization within DoD itself: the limits of Phase III certification. Phase III certification typically covers only the first contract after the end of Phase II. In some cases, Phase III certification extends beyond the first contract, but that does not appear to be typical. For many technologies, this first Phase III contract is only the start of a long journey for the company and the technology. For the most successful technologies, subsequent contracts may cover thousands of units and tens of millions of dollars. This extensive commercialization is not recorded through FPDS. In some ways this is understandable, because there is no obvious way for contracting officers to certify the original sources of complex technologies. Yet as a result, the long-term impact of SBIR awards eludes capture in FPDS.

The DoD Acquisitions Desk Reference defines Phase III as follows:

> SBIR Phase III refers to work that derives from, extends, or logically concludes effort(s) performed under prior SBIR funding agreements, but is funded by sources other than the SBIR Program. Phase III work is typically oriented towards commercialization of SBIR research or technology.
>
> 1. Each of the following types of activity constitutes SBIR Phase III work:

[10]DoD IG Report, DODIG-2013-002, "Improvement Needed With DoD Single-Bid Program to Increase Effective Competition for Contracts," October 4, 2012, p. 12.

i. commercial application of SBIR-funded R/R&D financed by non-Federal sources of capital (Note: The guidance in this Policy Directive regarding SBIR Phase III pertains to the non-SBIR federally-funded work described in (ii) and (iii) below. It does not address the nature of private agreements the SBIR firm may make in the commercialization of its technology.);

ii. SBIR-derived products or services intended for use by the Federal Government, funded by non-SBIR sources of Federal funding;

iii. continuation of R/R&D that has been competitively selected using peer review or scientific review criteria, funded by non-SBIR Federal funding sources.[11]

Although in principle there is no time limit on Phase III certified technologies—and the Small Business Administration (SBA) Policy Guidance document makes this clear—in practice DoD struggles even to make the link between Phase II and the first Phase III contract. There appears to be no standard process in place at any component to help small businesses ensure that subsequent contracts are also certified as Phase III.

Tracking Through the Primes—The Importance of the Company Commercialization Record (CCR)

Once beyond DoD itself, the ability to track commercialization declines substantially. FPDS no longer applies because primes are not required to enter subcontracts into FPDS. As the Air Force (AF) SBIR program manager said, "We have no vision into private-sector transactions between small businesses and prime contractors."[12] Primes are not required to identify or to track SBIR award contracts. There are indeed currently no incentives to do so, and some significant incentives not to.

Primes are sometimes required to meet contracting goals focused on small businesses, among other demographics.[13] However, there is no separate breakout for SBIR contracts. It is doubtful whether the primes themselves track SBIR-related contracts. According to Navy staff, one—but only one—of the primes that serve Navy maintains a database of SBIR-related subcontracts.

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[11] DoD Acquisitions Desk References, Annex A, Section 3, "Definitions," <*http://www.acq.osd.mil/osbp/sbir/sb/resources/deskreference/annex_a.shtml#Target3*>, accessed July 9, 2013.

[12] Interview with David Sikora and Richard Flake, June 28, 2013.

[13] In fiscal year (FY)2012, the target for small business subcontracts at DoD was 36.7 percent of total contract value. See DoD Office of Small Business Programs, "Small Business Goal and Objectives," <*http://www.acq.osd.mil/osbp/about/sbProgramGoals.shtml*>, accessed July 9, 2013.

Some other primes appear to be actively hostile to the notion of tracking and including SBIR-based technologies.[14]

The data rights attached to SBIR-based technologies provide a substantial disincentive for primes to track and identify Phase III commercialization. Technologies certified as SBIR bestow significant data rights on their owners, which may mean that small businesses have substantially more leverage in negotiations with primes.

In the Navy system commands with the deepest commitment to tracking SBIR outcomes, program managers readily admit that they have very limited capacity to track outcomes through the primes. It appears that primes account for a considerable—though uncountable—share of overall commercialization. Estimates from Navy staff at different program executive offices (PEOs) suggested that this share ranges from 25 percent to 50 percent.

Data from both the current and the previous (2005) NRC survey indicate that about 60 percent of Phase II respondents with sales generated revenues either directly to DoD or to DoD primes. Of these, about two-thirds of revenues came directly from DoD, and one-third through the primes. So FPDS misses the approximately one-third of the overall sales made by SBIR companies that through the primes.

Sales and revenues from the primes are collected through the Company Commercialization Record (CCR) (see Box A-1). CCR was introduced in the early 2000s precisely to capture more of the company's commercialization activities, beyond direct DoD contracts. It is the only DoD-wide activity to do so.

However, CCR has some important weaknesses. It is entirely self-reported. Although the contractor managing the database seeks to cross-check reported sales above a benchmark amount, no systematic cross-checks are made between reported sales and FPDS or other data sources. In addition, although companies must sign off on their CCR reports under penalty of perjury, there are nonetheless incentives that would encourage firms to overstate their commercial results: CCR scores are sometimes taken into account in determining funding for subsequent projects, and very low scores are expected to exclude companies from the program altogether. However, it is also fair to say that the inherently fuzzy nature of commercialization reporting allows considerable room for leeway, so companies can interpret commercialization results in the most positive light.

On the other hand, updating CCR is a burden, and it is not clear how comprehensive this process has been: firms that have stopped applying for SBIR funding, have graduated from the program, or have been acquired have no incentive to participate. As a result—as with other data sources—the depth and the completeness of the information captured declines over time. It does not appear that DoD has conducted any recent analysis that would help to determine

[14]Interview with Dean Putnam, NAVSEA SBIR Program Manager, June 25, 2013.

BOX A-1
Company Commercialization Record (CCR)

Every company receiving an SBIR award from DoD becomes contractually obligated to enter subsequent outcomes data into CCR. Companies are contractually required to update this information for a period of 5 years after the end of the Phase II contract.

DoD has limited sanctions against firms that do not provide the required updates. These firms are not allowed to receive any subsequent SBIR awards until they have updated their CCR information. Note that this information must be updated for every previous SBIR award. For some companies, this means updating information on dozens of previous awards every year.

CCR is maintained by a DoD contractor. According to DoD, efforts are made to verify the largest reported commercialization contracts by contacting the firm directly. Firms are also required to enter the contract number for each claimed commercialization contract within DoD. An additional field requires that the firm enter information about the program of record into which the technology is being inserted.

CCR provides information about awards made at other agencies as well, to the extent that firms receiving awards at DoD also received awards at other agencies. Estimates from the contractor suggest considerable overlap with awards at the National Aeronautics and Space Administration (NASA) and to a lesser degree at the Department of Energy (DoE) and the National Science Foundation (NSF). There is minimal overlap with awards at the National Institutes of Health (NIH) in each case. Each DoD awardee is required to report commercialization information about its awards at other agencies as well. It does not appear that other agencies utilize the information collected about commercialization in the CCR database.

CCR data are aggregated, that is, when a company updates a record, all previous data are expunged. This means that the data are not directly compatible with the fiscal year (FY) data collected through FPDS. In addition, there is no automatic linkage between FPDS, the applications and awards datasets, CCR, and DoD topics. This makes it difficult to integrate the data from these multiple sources and to extract relevant information for comprehensive tracking.

SOURCE: Interviews with BRTRC and Navy staff, June 2013.

the extent to which CCR continues to provide useful and important information, or indeed whether the burden on companies should be changed.

Yet despite these weaknesses, CCR remains the only systematic source of information about SBIR commercialization outside FPDS. Therefore not only is it the best source of information about commercialization through the primes, but also it provides a view into commercialization within DoD beyond Phase III and outside DoD.

Unfortunately, perhaps as a result of resource constraints, very little appears to have been done in terms of utilizing CCR results for assessing commercialization. Although Navy has been comparing commercialization outcomes between Program Executive Offices (PEO) for a number of years, using both the Federal Procurement Data System (FPDS) and the Company Commercialization Record (CCR), this has not been the case at other Services or apparently at Office of Small Business Program.

The existence of these different outcome metrics makes it possible at least in theory to compare SBIR-related outcomes across different Services, different topics, different sponsoring organizations, different primes, and indeed different types of technologies. Perhaps now that the additional administrative resources are available, these opportunities to understand how different variables affect program success will be exploited more fully.

Other Tracking Tools

Some components have developed additional tools for tracking outcomes. Although mostly focused on ensuring that the award process runs smoothly, the Navy program managers' database does allow program managers to track contracts that they know about.[15] According to the Navy SBIR Program Office,

> The purpose of this Database is to provide principal support for execution, management and monitoring of the Navy's SBIR/STTR program. The Database is a continuously refreshed repository of data regarding topics, topic generation, and solicitation development; proposal acceptance and maintenance, and evaluation system design; award tracking and reporting; budget planning, monitoring and reporting; computer hardware, software and license maintenance for web and database components; and provision of program technical and administrative support. It includes tools that facilitate the analysis and reporting of program statistics and trends, which support the design and development of program improvement strategies and efforts.[16]

The Navy program managers' database is thus a well-developed tool for helping those responsible for various aspects of SBIR manage the program at Navy. It is not, however, primarily designed for tracking outcomes; to the extent that it does so, it relies primarily on data from FPDS. Some program managers—for example, at the PEO Integrated Warfare Systems (IWS)—also maintain their own database and indeed devote considerable resources to

[15]Private communication, July 11, 2013.
[16]Navy SBIR program support staff, private communication.

consistently populating it. IWS tasks a junior staffer to call SBIR recipients on a regular basis after the end of their Phase II contract to determine whether there has been further commercialization, which is then tracked in the IWS database.[17] This intensive data-gathering approach is similar to that adopted in the past at NSF.[18]

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 CCR. However, in the long term the importance of tracking lies in its use to support program management. By carefully analyzing outcomes and CCR's associated program variables, program managers will 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. CCR is self-reported and subject to a range of conflicting incentives and its own additional limitations. It is also an aggregate measure, not an FY measure, and hence is not compatible with FPDS. In addition, DoD does not make data from CCR and from FPDS available for review, at least not at the disaggregated level necessary for detailed statistical analysis.

OVERVIEW OF THE NRC SURVEY

Our analysis of the SBIR program at DoD makes use of case studies, interviews, and other qualitative methods of assessment. These remain important components of our overall methodology, and a chapter in this report is devoted to lessons drawn from case studies. But qualitative assessment alone is insufficient.

The Role of the NRC Survey

The NRC survey offers some significant advantages over other data sources. It—

- covers all kinds of commercialization inside and outside of DoD;
- provides a rich source of textual information in response to open-ended questions;
- permits some quantitative analysis based on the development of a comparison group, even though the comparison group has limitations;
- probes more deeply into company demographics and agency processes;

[17]Douglas Marker, SBIR Program Manager, IWS, presentation to NRC, June 25, 2013.
[18]See National Research Council, *An Assessment of the SBIR Program at the National Science Foundation*, Washington, DC: The National Academies Press, 2008, Table 5.2-12.

- 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 NRC survey conducted as part of the first-round assessment of the SBIR program (referred to below as the "2005 NRC Survey"[19]). 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 the power of the statistical conclusions being drawn.

We contracted with Grunwald Associates LLC to administer a survey to DoD award recipients.[20] This survey is built closely on the 2005 NRC 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 to a survey focused on the SBIR programs at NSF and NASA.[21]

The primary objectives of the survey were as follows:

- Provide an update of the program "snapshot" taken 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

---

[19]The survey conducted as part of the current, second-round assessment of the SBIR program is referred to below as the "2011 NRC Survey" or simply the "survey." In general, throughout the report, any survey references are understood to be to the 2011 NRC Survey unless specifically noted otherwise.

[20]Grunwald Associates LLC is a research and consulting firm located in Bethesda, Md. The firm specializes in assignments that require an in-depth understanding of multiple market segments, and is experienced in deploying state-of-the-art research methodologies. Grunwald Associates has conducted the annual PBS Survey on Educational Technology and Media for eight years. Grunwald Associates is also one of the core partners on the U.S. Department of Education's Connected Online Communities of Practice initiative, and works with clients such as the National Park Service, AT&T, Adobe, Microsoft, and smaller companies.

[21]Delays at NIH and DoE in contracting with the NRC 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-2
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 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 respondents to the 2011 NRC Survey received awards 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**. Very limited information is available about SBIR awardees: company name, location, and contact information for the PI and the company point of contact, agency name, and date of award (data on woman and minority ownership are not considered reliable). Detailed data is not available on applicants who did not win awards, as the agencies routinely discard failed applications on privacy grounds. DoD rejected NRC efforts to acquire these data, on those grounds. It is therefore not feasible to undertake detailed analysis of non-respondents, but the possibility exists that they would present a different profile than would respondents.
- **Success 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 under-represented in the sample, because PIs could not be expected to complete a questionnaire for each of numerous awards over a 10-year time frame.
- **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 lag**. Although the 2005 NRC Survey broke new ground in data collection, the amount of sales made—and indeed the number of projects that generate sales —are inevitably undercounted in a snapshot survey taken at a single point in time. 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, and 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.

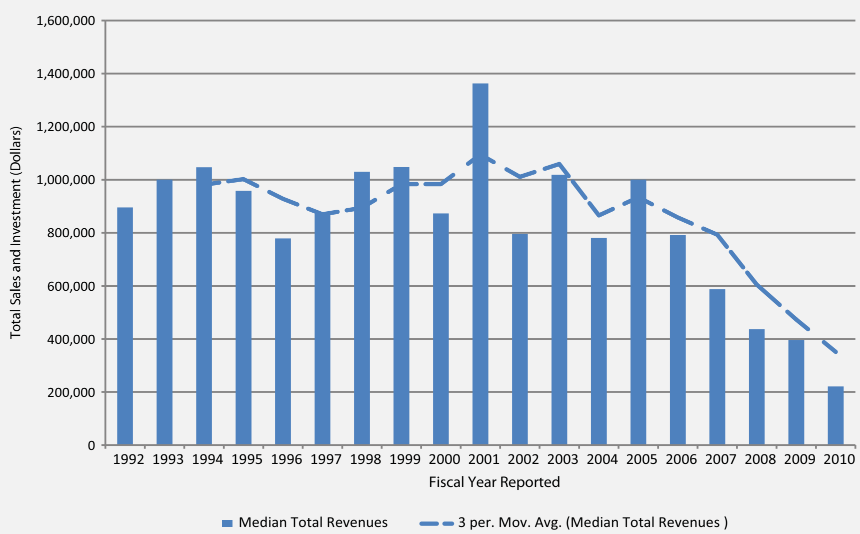

FIGURE Box A-1 The impact of commercialization lag.
SOURCE: DoD Company Commercialization Database.

[a] The limitations described here are drawn from the methodology outlined for the previous NRC survey in NRC, *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] A.N. Link and J.T. Scott, *Evaluating Public Research Institutions: The US Advanced Technology Program's Intramural Research Initiative*, London: Routledge, 2005.
[e] Data from the NRC 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 NRC, *An Assessment of the SBIR Program at the National Institutes of Health*, Washington, DC: The National Academies Press, 2009.

- Reduce costs and shrink the time required by combining three 2005 survey questionnaires—for the firm, Phase I, and Phase II awards—into a single questionnaire.

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 NRC Survey and the 1992 GAO survey.

Given the limited population of winners, the starting point for consideration was to deploy one questionnaire per successful project. However, we 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. This decision was reinforced by DoD's decision on privacy grounds not to provide company-level access to the DoD commercialization database, which contains current POC information.

The survey was therefore designed to collect the maximum amount of relevant data, consistent with our commitment to minimizing the burden on individual respondents and to maintaining 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.

Based on reviewer feedback about the previous round of assessments, we determined that for purposes of contextualization, comparison groups would be developed that would provide the basis for further statistical analysis.

Key similarities and differences between the 2005 and 2011 NRC surveys are captured in Table A-2.

The 2011 NRC Survey included awards made from FY1998 to FY2007 inclusive. This end date allowed 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 NRC survey, which surveyed awards from FY1992 to FY2001. 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 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 NRC study of the SBIR program, we differentiated between the total population of SBIR recipients, the preliminary survey target population, and the effective population for this study, which is the population of respondents that were reachable.

The effective survey population was the denominator for the survey, used to determine both response rates and the limits of statistical precision that are achievable given the number of responses received.

Initial Filters for Potential Recipients

Determining the effective study population required the following steps:

- acquisition of data from the sponsoring agencies (DoD, NSF, and NASA) covering record-level lists of award recipients;
- 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

TABLE A-2 Similarities and Differences: 2005 and 2011 NRC Surveys

Item	2005 NRC Survey	2011 NRC 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		✓
Comparisons and contextualization		
Comparison group		✓
Use of statistical comparisons between groups		✓

- elimination of records for which there were significant missing data—in particular, where emails and/or contact telephone numbers were absent.

Note that this approach does not directly limit the number of responses from a single firm, only from a single PI. This process of excluding awards either because they did not fit the selection profile or because the agencies did not provide sufficient or current contact information reduced the total award list provided by the agencies to a preliminary survey population of approximately 15,000 awards.

Secondary Filters to Identify Recipients with Active Contact Information

This nominal population still included many potential respondents whose contact information was complete, but who were no longer associated with the contact information provided and hence effectively unreachable. This is unsurprising 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. Recipients may have switched companies, 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, 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. This eliminated approximately 30 percent of the preliminary population.
- 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 awardee in the preliminary survey population at NASA and NSF and to a random sample of 1,000 thousand awardees at DoD. On the basis of responses to the telephone survey, we were able to ascertain that on average 47 percent of the respondents with ostensibly not bouncing email addresses were in fact not contactable.

There was little variation between agencies or between programs in the quality of the lists provided by the agencies, based on these criteria, although there was, not surprisingly, considerable variation between Phase I and Phase II awards, especially for DoD.[22]

[22]The share of preliminary contacts that turned out to be not contactable was higher for this survey than for the previous NRC survey in 2005. We believe this is primarily because company points of contact (POCs) have less churn than do program managers (PMs) (often being senior company executives).

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 effective population (emails discontinued once responses were received). In addition, two voice mails were delivered to non-respondents 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 questionnaire recipient.

After members of the data subgroup of the committee determined that sufficient responses had been received and 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.[23] 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 that would require resources beyond those available for this work.

The lack of detailed applications data from the agency makes it impossible to estimate the possible impact of non-response bias. We, therefore, no have 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 Company Commercialization database - results from the survey and the DoD data are similar.

Table A-3 shows the response rates at DoD by phase, based on the effective study population after all adjustments. The extent to which a given response rate is sufficient depends entirely on the uses to which the survey is being put and on the degree of statistical precision required. These issues are addressed below. For purposes of comparison, we provide the response rates for the previous survey and for all three agencies surveyed (see Table A-4).

The higher response rates at NSF for 2011 appear to result from extended agency efforts to encourage participation and from a closer focus on

[23]Many surveys of entrepreneurial firms have low response rates. For example, Aldrich and Baker (1997) found that nearly a third of surveys of entrepreneurial firms (whose results were reported in the academic literature) had response rates below 25 percent. See Howard E. Aldrich and Ted Baker. 1997. Blinded by the Cites? Has There Been Progress in Entrepreneurship Research? pp. 377-400 in Donald L. Sexton and Raymond W. Smilor (eds.), Entrepreneurship 2000. Chicago: Upstart Publishing Company.

TABLE A-3 Response Rates by Agency, Program, Phase, and Population

Phases	Number of Responses	Effective Response Rate (Percent)
DoD SBIR (all)	1,170	28.5
DoD SBIR I	390	22.6
DoD SBIR II	780	32.8

SOURCE: 2011 NRC Survey.

identifying respondents. The higher response rates for Phase I at DoD in 2011 result from more extensive efforts to qualify potential respondents. More current contact data were provided by DoD in 2005, which were not available on privacy grounds in 2011. This may explain the somewhat lower response rate for DoD Phase II respondents in 2011.

Note that all subsequent references to the 2011 NRC Survey in this appendix address only responses for awards made by DoD.

TABLE A-4 Comparing Response Rates for 2005 and 2011

Phase II	2011 NRC Survey			2005 NRC Survey		
	Effective Population	Number of Responses	Response Rate (Percent)	Effective Population	Number of Responses	Response Rate (Percent)
DoD	2,375	780	32.8	2,191	920	42.0
NSF	411	186	45.3	336	162	48.2
NASA	490	179	36.5	543	181	33.3
Phase I	2011 NRC Survey			2005 NRC Survey		
	Effective Population	Number of Responses	Response Rate (Percent)	Effective Population	Number of Responses	Response Rate (Percent)
DoD	1,728	390	22.6	8,843	1,198	13.5
NSF	440	207	47.0	2,270	248	10.9
NASA	426	119	27.9	1,659	303	18.3

SOURCES: 2005 NRC Survey and 2011 NRC Survey.

DOD RESPONSES AND RESPONDENTS

Responses by Year of Award

The distribution of responses by year is largely comparable between Phase I and Phase II, except for 2007, which accounts for a much higher percentage of Phase I awards. There were more Phase II awards from 2004 and 2006. Table A-5 shows DoD SBIR responses by year of award.

For both Phase I and Phase II, more responses were received from more recent years. This is not surprising, because it is easier to successfully contact PIs from more recent awards and the probability of survival increases.

Statistical testing indicates that the year of award is significantly different depending on whether the company received a Phase I or Phase II award, at the .05 level of statistical significance.

The survey primarily reached companies that were still in business: overall, 97 percent of respondents indicated that the companies were still in business.[24]

Effort at Comparison Group Analysis

Several readers of the reports in the first round analysis of SBIR suggested the 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,

TABLE A-5 DoD SBIR Responses by Year of Award

Year	DoD SBIR Phase I (Percent)	DoD SBIR Phase II (Percent)
2000 or earlier	3.8	2.7
2001	3.8	5.6
2002	5.4	6.9
2003	7.7	10.3
2004	9.0	15.2
2005	16.2	16.2
2006	16.4	22.7
2007	37.7	20.3
	100.0	100.0
N=	390	765

SOURCE: 2011 NRC Survey.

[24] 2011 NRC Survey, Question 4A.

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 - Dunn and 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. In the interests of providing researchers with a full view of the data collected, Appendix G includes tables showing both the Phase I only and Phase II survey responses for questions where both groups were surveyed.

Appendix B

Major Changes to the SBIR Program Resulting from the 2011 SBIR Reauthorization Act, Public Law 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.

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[1]U.S. Congress, Public Law 112-81, Sec. 5102 (a)(1)(a).
[2]Sec. 5102(b).
[3]Sec. 5103.

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 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.
   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 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 NIH, DoD, and the Department of Education 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]

[4]Sec. 5103.
[5]Sec. 5104.
[6]Sec. 5105.
[7]Sec. 5106.
[8]Sec. 5107.

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.

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.

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[9]Sec. 5108.
[10]Sec. 5111.
[11]Sec. 5121.

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 3 times the maximum size of Phase II awards.
    c. CRP authority expires after FY2017.

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.

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[12] Sec. 5122.
[13] Sec. 5123.
[14] Sec. 5127.
[15] Especially Sec. 5132, Sec. 5133, Sec. 5138, and Sec. 5161, but specific requirements are found throughout the legislation.

b. Specific areas for improved reporting include

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.

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.

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[16]Sec. 5135.
[17]Sec. 5141.
[18]Sec. 5165.

Appendix C

List of Universities Involved in DoD SBIR Awards

University Name	Number of Mentions
Alabama A&M University	2
Arizona State Polytechnic University	1
Arizona State University	7
Auburn University	3
Binghamton University	1
Boston College	4
Boston University	3
Brandeis University	1
Brigham Young University	4
Brown University	1
California Institute of Technology	8
California State University Long Beach	2
Carnegie Mellon University	5
Case Western Reserve University	7
Catholic University of America	1
Children's Hospital Boston (Harvard)	1
City University of New York	1
Clemson University	3
Cleveland State University	1
College of William and Mary	2
Colorado School of Mines	6
Colorado State University	6

University Name	Number of Mentions
Columbia University	9
Cornell University	8
CUNY New York	1
Dalhousie	1
Dartmouth College	11
Dartmouth Medical School	1
Drexel University	2
Duke University	4
Embrey-Riddle University	1
Emory	2
Florida A&M University	1
Florida Atlantic University	2
Florida State University	5
Fordham University	1
George Mason University	5
George Washington University	1
Georgetown University	1
Georgia Institute of Technology	23
Glasgow University	1
Harvard Medical School	2
Harvard University	2
Illinois Institute of Technology	1
Indiana University	4
Iowa State University	5
IUPUI at Indianapolis	1
Johns Hopkins University	9
Kansas State University	1
Kent State University	2
Loma Linda University	1
California State University Long Beach	1

University Name	Number of Mentions
Louisiana State University	2
Louisiana Tech	1
Maricopa Community Colleges	1
Marshall University	1
Michigan Molecular Institute	1
Michigan State University	4
Michigan Technological University	4
Mills College	1
Milwaukee School of Engineering	1
Mississippi State University	2
Missouri University of Science and Technology	3
Massachusetts Institute of Technology	24
Montana State University	6
Montana Tech	1
Naval Postgraduate School	2
NC State University	4
New Mexico Institute of Technology	1
New Mexico State University	2
Norfolk State University	1
Northeastern University	2
Northwestern University	3
New York University	2
NYU Polytechnic School of Engineering	1
Ohio State University	12
Oklahoma State University	1
Old Dominion University	3
Olin College	1
Oregon Graduate Institute	1
Oregon State University	3
Pennsylvania State University	21

University Name	Number of Mentions
Philadelphia University	1
Prairie View A&M University (Texas)	1
Princeton University	4
Purdue University	19
Rensselaer Polytechnic Institute	7
Rhode Island University	1
Rice University	3
Rush University	1
Rutgers University	7
Ryerson University	1
Saint Louis University	2
San Diego State University	1
Santa Clara University	1
South Dakota School of Mines	1
Southern Illinois University	1
Southern Methodist University	4
St. Lawrence University	1
Stanford Medical School	1
Stanford University	14
State University of New York Upstate Medical University	1
Stevens Institute of Technology	1
State University of New York	1
SUNY Buffalo	6
SUNY Stony Brook	5
SUNY Syracuse	1
Syracuse University	3
Temple University	1
Texas A&M University	9
Texas State University	3
Texas Tech University	2

University Name	Number of Mentions
Tulane University	1
University of Alabama in Huntsville	1
University of California (UC) Berkeley	14
UC Davis	6
UC Irvine	5
UC Riverside	3
UC San Diego	9
UC San Francisco	1
UC San Francisco Medical School	1
UC Santa Barbara	8
UCLA	9
Uniform Service University	1
Universities Space Research	1
University New Mexico	1
University of Adelaide	1
University of Alabama	11
University of Arizona	10
University of Arkansas	7
University of Calgary	1
University of Central Florida	10
University of Cincinnati	4
University of Colorado	28
University of Connecticut	6
University of Connecticut Medical Center	1
University of Dayton	3
University of Delaware	7
University of Delaware Center for Composite Materials (UD-CCM)	4
University of Denver	1
University of Florida	22
University of Hartford	1

University Name	Number of Mentions
University of Hawaii	5
University of Houston	5
University of Idaho	2
University of Illinois	13
University of Iowa	2
University of Kansas	1
University of Kentucky	3
University of Maryland	17
University of Massachusetts	10
University of Miami	2
University of Michigan	17
University of Minnesota	15
University of Mississippi	2
University of Missouri	3
University of Montana	2
University of Nebraska	4
University of Nevada	1
University of New Hampshire	2
University of New Mexico	4
University of New Orleans	1
University of North Carolina	5
University of Notre Dame	6
University of Oklahoma	4
University of Paris	1
University of Pennsylvania	6
University of Pittsburgh	1
University of Reading (England)	1
University of Rhode Island	1
University of Rochester	5
University of San Francisco	1

University Name	Number of Mentions
University of South Carolina	3
University of South Florida	2
University of Southern California	5
University of Southern Mississippi	1
University of Southampton, England	1
University of Tennessee	2
University of Texas	4
University of Texas at Arlington	1
University of Texas at Austin	11
University of Texas at Dallas	5
University of Texas El Paso	1
University of Toledo	2
University of Utah	6
University of Virginia	3
University of Washington	1
University of West Florida	1
University of Wisconsin	7
University of Wyoming	7
University of Virginia	1
Utah State University	3
Vanderbilt University	4
Villanova	1
Virginia Tech	9
Washington University in St. Louis	1
Wayne State University	1
West Virginia University	1
Western Kentucky University	2
Wichita State University	1
Worcester Polytechnic Institute	7
Wright State University	2

University Name	Number of Mentions
Yale University School of Medicine	1
Yale University	3

NOTE: While the survey covered awards made 1998-2007, university involvement is not strictly limited to this time period.
SOURCE: 2011 NRC Survey, Question 60.

Appendix D

Glossary

For additional information see: *Glossary of Defense Acquisition Acronyms & Terms*, Defense Acquisition University Press, July 2005.

A

ACAT	Acquisition Category (e.g., ACAT I, ACAT II, etc.)
AF	Air Force
AFRL	Air Force Research Laboratory
ASN RDA	Assistant Secretary of the Navy, Research, Development and Acquisition

C

CAI	Commercialization Achievement Index
CCR	Company Commercialization Report
CONUS	Continental United States
COTS	Commercial Off-The-Shelf
CTO	Chief Technology Officer
CPP	Commercialization Pilot Program
CRP	Commercialization Readiness Program
CTA	Commercialization and Technology Assessment

D

DAC	Defense Acquisition Challenge (program)
DARPA	Defense Advanced Research Projects Agency
DASAF	Deputy Assistant Secretary of the Air Force
DoD	Department of Defense
DoN	Department of the Navy
DTRA	Defense Threat Reduction Agency
DUSD	A&T Deputy Undersecretary of Defense, Acquisition & Technology

F

FPDS	Federal Procurement Data System (Next Generation)
FY	Fiscal Year

G

GAO	Government Accountability Office

H

HASC	House Armed Services Committee
HHS	Health and Human Services

I

IRAD	Independent Research and Development

N

NDAA	National Defense Authorization Act
NRC	National Research Council

O

OIG	Office of the Inspector General
OMB	Office of Management and Budget

OSD	Office of the Secretary of Defense
OSBP	Office of Small Business Programs
OUSD	Office of the Undersecretary of Defense

P

PART	Program Assessment Rating Tool
PAT	Process Action Team
PEO	Program Executive Office/Officer
PM	Program Manager

R

RAND	RAND National Defense Research Institute
R&D	Research and Development
RD&E	Research, Development, and Engineering
RDT&E	Research, Development, Test, and Evaluation

S

SBA	Small Business Administration
SECDEF	Secretary of Defense
SECNAV	Secretary of the Navy
SYSCOM	System Command

T

TRL	Technology Readiness Level

U

USD A&T	Undersecretary of Defense, Acquisition and Technology
USD AT&L	Undersecretary of Defense, Acquisition, Technology and Logistics

Appendix E

2011 NRC 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. <u>[If none for a particular source, enter 0 (zero)]</u>
    <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 <u>total sales dollars of product(s), process(es) or services to date</u> 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 <u>other total sales dollars (e.g. rights to technology, sale of spin-off company, etc.) to date</u> 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				
b. Sale of Company				
c. Partial sale of				
d. Sale of technology				
e. Company merger				
f. Joint Venture				
g. Marketing/distribution agreement(s)				
h. Manufacturing				
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	

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 F

Selected Case Studies

To complement its review of program data, the committee commissioned case studies of 20 SBIR companies that received Phase II awards from the Department of Defense (DoD), undertaken in 2010-2012. Case studies were an important part of data collection 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 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.

A wide range of companies were studied: 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 on military applications, and others focused on commercialization primarily 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. Rather, they provide qualitative evidence about the individual companies selected, which are, within the limited resources available, as representative as possible of the different components of the awardee population. The case studies presented in this appendix have been verified by the companies that they feature and they have permitted their use and identification in this report.

BOX F-1
Directory and Profile of Case Studies

Company Name	State	Demographic
Architecture Technology Corporation	MN	
Aurora Flight Sciences	VA	
Cybernet	MI	W
Fetch Technologies		
Giner	MA	
iRobot	MA	
Mayflower Communications	CA	M
Microcosm Inc.	NH	
Nanocomp	CA	
Navsys	CO	W
Nielsen Engineering	CA	
Opto-Knowledge Systems Inc.	CA	M
Optemax	MD	W
Powdermet and MesoCoat	OH	
Qualcomm	CA	
Texas Research International	TX	
TRX Systems	MD	W
Daniel H. Wagner Associates	VA	

NOTE: Demographic describes the company as majority-owned by Women or Minorities; these data are drawn from DoD awards data, and reflect company self-certification

ARCHITECTURE TECHNOLOGY CORPORATION INC. (ATC): SBIR CASE STUDY

Based on interview with
Gene Proctor, Vice-President of Business Development
October 21, 2011
Washington, DC

Architecture Technology Corporation (ATC) is a privately held company headquartered in Eden Prairie, Minnesota. It was founded in 1981 by

Dr. Kenneth Thurber—an expert on Local Area Networks (LANs)—to provide publications, seminars, and consulting to the nascent industry.

Over the course of 30 years, ATC has reinvented itself several times. The company originally provided training and seminars focused on LAN development and deployment, with the FAA as a major client. These services naturally expanded to include systems engineering services and consulting on the design and construction of computer networks.

Early work in this area included a substantial role as subcontractor to the Volpe Center in Boston, which was leading FAA's efforts to develop next-generation traffic control systems. This led to numerous contracts with FAA: ATC has now performed more than 50 projects for the agency, ranging from terminal and tower automation to runway safety. This experience led to software development and specialty engineering services to industry leaders, such as Ford and Boeing.

As with many consulting companies, ATC determined that its work could also lead to commercial software and hardware products. Starting in 1990, the company focused on using SBIR and other funding sources to develop products. These are sold under the brand name Triticom and have received several industry awards.

Commercial sales, however, require ongoing research and development, so ATC founded a research and development (R&D) group in 1994. The group focuses on distributed computing, next-generation networking, information assurance, information management, intelligent systems, and reliable computing. ATC has received numerous SBIR awards from agencies including NSF, Defense Advanced Research Projects Agency, other DoD agencies, and NASA.

ATC further expanded its research activities with the 1999 acquisition of Odyssey Research Associates in Ithaca, New York, which is now a wholly owned subsidiary. Odyssey conducts R&D in computer security and reliable systems and has a growing practice in information management.

Several ATC-NY products funded by SBIR awards have evolved into products. These include the Online Digital Forensic Suite™, CYDEST™ (which provides simulated cyber defense training on virtualized computer networks), and the Pedigree Management and Assessment Framework™ (PMAF; which is a general-purpose, extensible system for maintaining the provenance of information that originates in disparate, distributed information management systems).

In 2001, responding to an FAA solicitation, ATC started a new focus on airport security, and in particular on airport incursions—problems posed for ground control in light of airport extensions that left significant blind spots. The system developed by ATC now sends alerts to the control tower and also flashes landing lights as a warning to pilots. The technology underpinning the system was generated through the SBIR support projects, including tools developed to support design of networks for Aegis class warships, where ATC acted as a subcontractor for Lockheed Martin, developing a software package for simulating the operations of all weapons controllers and sensors onboard.

In 2004, ATC spun off Cyber Security Technologies to develop and market its computer forensics products, and it formed a joint venture with RichARO Enterprises in 2007 to market PMAF.

Awards

ATC has received considerable recognitions for its work, including the *LAN Magazine* Product of the Year Award, the U.S. Army's 2002 SBIR Phase 2 Quality Award, and the Minnesota Entrepreneurial Award in 2002. The company is a three-time recipient of the Tibbetts Award (1998, 2000, 2007).

FAA honored ATC in 2002 for "exploring new and advanced technologies for increased runway safety in the National Airspace System" and again in 2005 for "superior support and outstanding commitment to the planning, technical oversight, and production of the FAA Final Approach Runway Occupancy Signal (FAROS) Concept of Operation video."

Products and Commercialization

ATC has reinvented itself a number of times to adjust to changing commercial environments and opportunities. Although initially a consulting company, its development of commercial products led to the application of core technologies in new areas and to the spinoff of a subsidiary to focus on computer security issues.

Even relations with its major federal clients have changed to match changing agency strategy. Mr. Proctor noted that FAA had for most of the 1990s and 2000s used a prime-based model for services delivery. Starting in 2008, the FAA established new contracting vehicles focused on acquiring services directly from smaller companies such as ATC.

As a result, ATC has been providing a range of services to FAA, including development of Quality of Service standards, redundancy assessment, requirements development, and proposal review.

CYDEST™—A Flight Simulator for Network Defenders

ATC's CYber DEfenSe Trainer (CYDEST) provides immersive, tactical-level exercises in computer network defense and rapid digital forensics. It aims to support "in the trenches" personnel such as network administrators, incident first responders, and digital forensics investigators.

"Free play" exercises are run in real time within a virtualized environment using real systems, real attacks, and real defensive tools. CYDEST's training scenarios are complemented by pedagogical training materials integrated into the system.

CYDEST provides flexible training for students while reducing instructor workload. The system is available 24/7/365 from any Internet-connected location, and it automatically evaluates trainee performance, providing instructors with audit records of exercise runs. Auto-assessment also offers dynamic attack scenarios that adapt to trainees' defensive actions.

The system provides exercises on real systems, allowing students to defend against real attacks. It dynamically responds to student actions, altering attack strategy and providing hints in order to personalize training. Scenarios are written to train for specific networks, software, and learning objectives. Student progress is slightly monitored as students use an integrated electronic lab notebook.

STAMINA—Survivable Tactical Ad Hoc Mobile Network Architectures

Several major defense platforms have called for secure and survivable ad hoc wireless tactical networks. ATC is developing a middleware to increase intrusion tolerance and survivability for mobile ad hoc networks. The technology can be applied to future mobile tactical networks, protecting them from sophisticated network and information attacks.

Spinoff Company

In 2004, ATC spun off Cyber Security Technologies Corporation (CST) to focus on software for computer investigations. CST focuses on two emerging markets: technology to enable the investigation of live, running computer systems across a network; and technology to automate the detection and analysis of peer-to-peer (P2P) client programs and associated files. The OnLine Digital Forensic Suite™ (OnLineDFS) enables network-based, real-time investigations of live, running computer systems. It is ideal for rapid incident response, compliance management and e-discovery in enterprises, and for the needs of law enforcement.

OnLine Digital Forensic Suite™ (OnLineDFS)

OnLineDFS is designed to be minimally disruptive, avoiding the often prohibitive expense of shutting down a vital server. It gathers information about the running state of the target computer that cannot be gained any other way. And it saves times, enabling a very rapid response to an intrusion.[1]

No software needs to have been preloaded onto the target machines, and a web-based interface allows the investigator to connect to OnLineDFS and manage an investigation from anywhere with an Internet connection, which need not be high speed.

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[1]See F. Adelstein, "Live Forensics: Diagnosing Your System Without Killing It First," February 2006, <*http://frank.notfrank.com/Papers/CACM06.pdf*>. Accessed July 17, 2014.

OnLineDFS enables the rapid, forensically sound examination of a computer without disrupting the operations of the enterprise. It delivers an extensive suite of functionality for the investigation and capture of volatile and persistent data from the computer under examination.

P2P Marshal™

This is a computer forensic tool to analyze P2P usage on file system images. It automatically detects what P2P client programs were or are present, files that were downloaded or shared using each P2P client, servers with which the computer under investigation had contact, and related information.

This program appears to have particular application for law enforcement efforts to track pedophiles online.

IP and Universities

ATC has throughout its existence seen value in publishing technical documents. Dr. Thurber's biography claims more than 60 peer-reviewed publications and 14 books on LAN-related topics.[2] The company has also published and distributed a book on computing architectures[3] and has developed its own publishing imprint, through which it distributes Dr. Thurber's book on building a technology company.[4]

In recent years, the company has expanded effort to patent its technologies. According to the U.S. Patent and Trademark Office (USPTO), ATC was the assignee on 15 patents as of October 2011.[5] Mr. Proctor notes that only recently has patenting become significant, in part because software has such a short product cycle that patenting is rarely the best way to protect its value.

In fact, Mr. Proctor said that part of the increase in patenting at ATC reflects the growing importance of commercialization metrics at DoD, where patents are one of the metrics feeding into a company's commercialization score. In addition, the company found that individual algorithms could be patented that had applications across a number of potential markets.

ATC has worked closely with a number of universities on SBIR-related projects, including the University of Minnesota, South Dakota State University, Cornell University, and Purdue University. However, although Mr. Proctor noted that ATC sees considerable utility in tapping university technical capacity,

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[2]Dr. Thurber biography page, <*http://www.atcorp.com/About/team.html*>.
[3]J.A.K. Baker and K.J. Thurber, *Developing Computer Systems Requirements*, Ithaca, NY: Digital Systems Press, 2011.
[4]K.J. Thurber, *Big Wave Surfing*, Edina, MN: Beaver Pond Press, 2011.
[5]See USPTO, ATC search, <*http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=/netahtml/PTO/search-bool.html&r=0&f=S&l=50&TERM1=architecture+technology&FIELD1=ASNM&co1=AND&TERM2=&FIELD2=&d=PTXT*>. Accessed October 27, 2011.

it limits and tightly controls university involvement. Specifically, ATC wants to ensure that the university has no stake in any IP developed in the course of the relationship and hires universities as subcontractors to focus on solving specific and defined technical problems.

ATC and the Primes

ATC has worked on prime-led teams in a number of projects. However, after a number of failed partnerships, the company has decided that the incentive structure at DoD is such that, in most cases, primes are likely to squeeze out smaller companies such as ATC once a contract has been awarded. As Mr. Proctor noted, “The primes are very keen to have us on the bidding teams; but not so interested in following through with actual funding for technology development or deployment afterwards.”
As a result, ATC now works on teams with primes only when the prime is the subcontractor to ATC.

Mr. Proctor wondered whether primes should be required to use SBIR-funded technologies for some fixed percentage of their acquisitions contracts. In his view, the primes would never voluntarily put a small business subcontractor in the critical path of a major project.

ATC and SBIR

ATC won its first Phase I award in 1994 and its first Phase II a year later. Since then, the company has won a total of 91 Phase I and 37 Phase II awards (as of 2010), amounting to slightly more than $30 million.[6] At the time of the interview, it expected to compete for 10-12 Phase I awards and 5-7 Phase II awards every year, and Small Business Administration (SBA) data indicates a conversion rate of about 42 percent.

Overt time, the role of SBIR at ATC has changed. Originally a source of R&D funding as the company started to develop its own products, the SBIR program is now much more directly focused on product development. Mr. Proctor observed that this also helps the company use the program as a means to train young engineers. An engineer wishing to apply for SBIR funding first needs to make the case internally that the project will result in commercial sales, then writes the proposal—which provides valuable training in and of itself. If ATC wins an award, then engineer is asked to run the project, which not only provides critical experience, but also acts as a valuable internal incentive for staff and limits the amount of management involvement.

Mr. Proctor noted a number of positive changes in the operations of the SBIR program over the past 10 years. For example, at all agencies the gap

[6]Small Business Administration (SBA), Tech-Net SBIR/STTR awards database, <*https://www.sbir.gov/past-awards*>, accessed October 28, 2011.

between Phase I and Phase II has been substantially reduced, and new funding mechanisms have emerged to help companies manage the remaining gap.

Regarding the scoring of proposals, Mr. Proctor said that he thought the selection process was generally fair and that debriefs in general correctly recognized the strengths and weaknesses of a proposal. He noted that outcomes could be improved if successful proposals were also debriefed.

Mr. Proctor noted that a degree of uncertainty is inevitable when working with the SBIR program and federal agencies. For example, ATC had won a recent Phase I to network the blood supply for the Army Medical Corps. But despite considerable success—and demand from the client—funding of Phase II was diverted elsewhere.

ATC strongly supports new efforts such as the Commercialization Pilot Program and the Rapid Innovation Fund at Navy. The company is actively pursuing partnerships with primes on the latter. However, the company believes that primes must bring a program of record to the partnership and must be prepared to be the subcontractor if the team wins. Despite considerable confusion on launch (especially related to the release of key information that was hitherto classified), ATC sees programs such as these as significant opportunities to be pursued.

Finally, Mr. Proctor explained that ATC policy is to meet face to face with each TPOC at least once, even if the company has to pay for the travel to build trust and identify the real needs of the client.

SBIR Recommendations

Mr. Proctor offered a number of conclusions and suggestions based on ATC's work in the SBIR program:

1. **Size of awards.** ATC approves the shift to Phase II awards of $1 million, which provides sufficient funding to achieve solid research results. However, Mr. Proctor stressed the importance of agencies retaining funding for bridging programs such as the NSF Phase IIB, which helps companies fund full commercial markets for Phase II projects.
2. **Improving technical points of contact (TPOCs).** Mr. Proctor said that variation in the quality of TPOCs is a significant issue—indeed if ATC's TPOC was not strongly committed to a project, then there was no way to move forward to Phase III. One improvement would be to ensure that SBIR activities are part of the TPOCs' annual job review.
3. **TPOC stability.** ATC found that when the TPOC changed, the project usually failed to reach Phase III. He suggested that the agencies consider ways to reduce or eliminate this problem, which to some degree has declined since DoD sharply reduced the time line for initial topic submission to publication in a solicitation from more than 2 years to about 1 year.

Company Update:

Since 2011, ATC has successfully completed an RIF—based on multiple successful Phase II projects, we had a very successful "live fly" test series at Hanscom AFB late last month—the test team confirmed that our CSTAR software module is TRL8 and ready for transition to a tactical project (this continues to be the most problematic part of the SBIR project—finding a program of record that will support the transition).

CYBERNET SYSTEMS CORPORATION: SBIR CASE STUDY

Based on interview with
Dr. Charles Jacobus, Chief Technology Officer and Co-founder
September 15, 2011
By telephone

Cybernet Systems Corporation (Cybernet) is a privately held company headquartered in Ann Arbor, Michigan. Founded in 1989 by Dr. Heidi Jacobus and Dr. Charles (Chuck) Jacobus, the company has completed a large number of DoD contracts and is a certified 8(a) woman-owned small business. 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 PhDs, 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:

- 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; and
- 2004: First Automated Tactical Ammunition Classification System (ATACS).

Defense

Cybernet has worked with every major branch of the U.S. military.

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 5.56 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 small and lightweight 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 aims to apply robotics technology to store, supply, and replace ammunition for military vehicles such as tanks on the battlefield. This product automatically loads 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 new Future Combat Systems program. Boeing had in fact selected Cybernet as supplier when the FCS was cancelled. The design package remains relevant for future programs.

VSIL

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 applies 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

This new project focuses 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

MedStar™ is 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 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.

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.

Automated Transportation

Cybernet is also focused on addressing the federal mandate[7] that one-third of operational ground combat vehicles be unmanned by 2015. Cybernet has converted a minivan into an autonomous ground vehicle and was one of only 35 teams worldwide invited to the National Qualifying Event for the 2007 DARPA Urban Challenge.[8]

Cybernet has developed an approach that uses COTS technology to implement 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 their DARPA Urban Challenge technology to build an automated forklift 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 30 meters of sensed data, which permits them to find and fetch materials. Other Army bases are interested in using the technology to handle ordnance.

Sensors and Robotics

Cybernet has been working in this area for more than 20 years. Currently available products include those based on the company's Computer Vision system, which can be used to recognize objects (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.

NetMAX Robotics focuses on product sales and commercial development of robotics, situational awareness systems, and embedded sensor products. 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, modeling and simulation (with focus on massive multiplayer scale simulations), and network appliances and security. Earlier work in this area included the force feedback work that eventually led to licensing by Immersion (see below).

Currently, Cybernet is working on leading edge applications in gesture recognition from video streams. One product in use today is GestureStorm™,

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[7]2001 National Defense Authorization Act.

[8]The 2007 DARPA Urban Challenge was the third in a series of competitions held by 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.

which allows TV meteorologists to control their on-air weather displays through purposeful gestures.

IP 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 31 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 is rarely the simple linear process sometimes expected.

However, Cybernet has discovered that while Phase I is almost always necessary to find a marketing partner to enter specialty markets, those partners are, according to Dr. Jacobus, 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.

For example, in the late 1990s, Cybernet and Immersion Inc. (see NAS Immersion Case Study) 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 hard to acquire. Even though Cybernet raised $5 million in funding for its force feedback projects in the late 1990s, Dr. Jacobus sees this as 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.

The SBIR Program and Recommendations for Improvement

Dr. Jacobus noted that he was speaking personally, not on behalf of Cybernet.

Overall SBIR provides a critical connection between small business and the defense acquisitions programs. Small business cannot break into the defense business on its own and usually cannot reach DoD contacts without the SBIR program's help. The program allows direct contact with government, which would otherwise view companies such as Cybernet as much too small. Thus the program offers companies a great opportunity to garner wide exposure to a number of agencies and to develop a wide range of technologies.

Dr. Jacobus noted that the program also provides real benefit to the agency. DoD laboratories have major technology transfer problems—as his work on the Army Science Board attests. Providing technically gifted people with sufficient money to maintain a small business and huge incentives to bridge the gap between lab and prototype allows these small companies to couple with DoD on a much richer basis than would ever be possible without the SBIR program. As a result, DoD gets access to a huge field of possible advanced technologies for a small price.

The SBIR program could also be credited with the development of entire industry sectors. For example, technology development primarily initiated by NASA funded everything in the force feedback industry. As a result, it is clear that 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.

- Regarding the size of awards, Dr. Jacobus believed that results would be optimized by keeping Phase I SBIR awards as small as possible, while ensuring that funding for Phase II was 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.
- Successful connection to government initiatives especially in acquisitions would elevate the stature of SBIR program managers
- Still, 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 both 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 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.

DANIEL H. WAGNER ASSOCIATES: SBIR CASE STUDY

Based on interview with
Dr. Reynolds Monach, Vice President of Research and Development
September 19, 2012
By telephone

Daniel H. Wagner Associates ("DHWA") is a privately owned company headquartered in Exton, Pennsylvania, with an additional office in Hampton, Virginia. DHWA was founded in 1963 by Daniel H. Wagner after he left the Burroughs Corporation. Dr. Wagner remained president and chairman of the board until 1985.

The company aimed to combine the power of mathematical theory with Dr. Wagner's operational experience to address complex problems in DoD operations—especially in Navy. Since then, the firm has expanded to serve a wider client base, but has continued to focus on the application of quantitative methods to decision making.

These methods have been applied to many different areas of operational analysis, particularly for Navy and other sea-based organizations. DHWA developed expertise in the application of mathematics to the needs of sea-based search early on, and it has been involved in projects such as the following:

- The successful search for the H-bomb lost in the Mediterranean off the Spanish coast in 1966, when a B-52 collided with a tanker.
- The search for the USS *Scorpion* in 1968, an attack submarine that imploded 400 miles west of the Azores and went to the bottom at a depth of some 2000 fathoms.
- The successful search for the packet ship SS Central America sunk off the coast of South Carolina in 1857, with $400 million of gold (from California) aboard.

Strategy

Providing technical support to Navy still constitutes the core mission for the company. Overall, the company's work for Navy constitutes about 50 percent of the total and has since the early 1990s, when the company made the decision to redirect some of its focus away from Navy. (Indeed, the company had initially been focused almost entirely on anti-submarine warfare (ASW) during its earliest years—a sub-focus within Navy).

Subsequent diversification extended to other parts of Navy, then other DoD components, and then beyond DoD. Currently, areas of interest, in addition to ASW, include mine warfare and unmanned vehicles, where data fusion is an important technology.

Today, DoD accounts for about three-quarters of DHWA revenues, and Navy alone accounts for about one-half, according to Dr. Monach.

Technology Development

DWHA's mission focuses on solving problems for DoD, and to do that it must successfully transition the technology, which in turn requires effective partnerships with primes. In fact, DWHA has a very long history of exceptionally fruitful collaboration with several primes.

This is in part because the company understands the customer at a very deep level; it has worked with Navy for more than 50 years and has developed a deep understanding of how to meet Navy needs and requirements. This knowledge has also been applied successfully to other components in DoD and elsewhere.

One example of paths through which technical solutions emerge, expand, and then are applied to new problems and new solutions is highlighted by DWHA's experience in mine warfare through its environmental data fusion mine countermeasures (EDFMCM) tools. The system is comprised of four components:

- an information collection tool, designed to access data in near real time from multiple sources
- polygon computational tools that resolves conflicting data and identifies "best" information
- a measurement fusion and optimization tool
- a data analysis tool, which relates geospatial data to operational needs.

The net result is a system that gathers data from varied sources and provides ship commanders with optimized routes through potential minefields. This outcome was, however, the result of a long period of development.

A number of early SBIR awards were used to develop environmental data fusion for mine warfare. An SBIR award from the Office of Naval Research (ONR) funded development of an optimal routing algorithm that could be used to route a ship to avoid mines. The tool was developed further so it could be tested on the Navy DDG-1000 R&D destroyer, whose sonar was designed to be able to locate mines. ONR provided additional funding, and DWHA developed tools for real-time mine avoidance.

Once this tool was in place, the submarine force wanted the tool to enable a sub to go through possibly mined areas, finding a route that could be transited with the least risk and at the greatest speed.

DHWA teamed with Applied Research Labs of the University of Texas (which provided sensor technology) and SAIC (which was the prime contractor on the Mine Warfare and Environmental Decision Aids Library (MEDAL) program focused on mine warfare planning and execution), with which DHWA had partnered for more than 20 years.

The new approach was fielded under the APM-09 technology upgrade program, where progress was evaluated. Under this program, the new technology was integrated into a testbed, and fleet operational officers were then brought in to run the operation.

The testbed offered an opportunity to compare the traditional manual model of mine avoidance with the new approach, and the latter demonstrated dramatically improved outcomes. Once performance proved out, the new approach was integrated into the standard software upgrade package that emerged from the APM-09 program, and it will eventually be loaded into every submarine in Navy's fleet. The APM-09 program is funded by PEO IWS 5 (Integrated Warfare Systems—Undersea Systems).

DWHA's expertise can be applied to any area if the problem is challenging enough. Some of its work—notably on data fusion and data optimization—can be transferred with limited difficulty from DoD to other applications, or within DoD. According to Dr. Monach, the company's core technologies are now:

- multiple hypothesis data fusion (used in many different fusion applications);
- non-Gaussian tracking (now called particle filters);
- Bayesian inference (for classification and target association);
- classical optimization (based on Brown's algorithm—named for Scott Brown who worked at DHWA in the late 1970s); and
- genetic algorithms in naval applications.

Nongovernment applications are also important. Base technologies have been applied in several other areas:

- DWHA's crane control subsidiary uses tracking algorithms that are also used to track submarines. Ship-loading cranes run on gantries, where operators traditionally eyeball swinging loads. DHWA applied algorithms to controls that move the crane, limiting and predicting load movements, so that the operator is no longer part of the control circuit.
- DWHA's statistical arbitrage program tracks stock and commodity prices using algorithms transferred from DoD projects—and is also a source of technology for transfer into DoD. Both cases focus on optimal data assimilation and machine learning algorithms.

Commercialization

DHWA works primarily as a contract research house, both directly for DoD and for DoD prime contractors, using its expertise to solve technical problems for clients. Most often, this results in algorithms embedded in software tools that are freely available to U.S. government agencies, because their development was supported by government funding.

The company does in some cases develop software products for sale. These include a suite of math finance tools for retirement planning and portfolio management, an automated assessment system that provides confidence scores for DNA sequence base calls, software to support search salvage and rescue, and tools for cargo handling and crane control.

DHWA does not usually anticipate that its R&D will result in additional licensing revenues or further contracts, except insofar as further upgrades to its tools are requested at a later date. Its business model for commercialization does not include or rely on downstream sales or licensing revenues.

These projects have been commissioned by a wide range of clients. Within DoD alone, DHWA supports the offices and programs listed in Table F-1. DHWA often works for these clients in conjunction with DoD primes, sometimes as a subcontractor and other times as the prime itself, especially on SBIR awards. Prime partners include Lockheed Martin, Northup Grumman, Boeing, General Dynamics, the Institute for Defense Analysis, and SAIC. DHWA has also partnered with NASA's Jet Propulsion Laboratory (JPL), MIT's Lincoln Labs, Johns Hopkins Applied Physics Laboratory (JHU/ARL), and Penn State's Applied Research Laboratory (PSU/ARL).

TABLE F-1 DoD Office Clients

Armament and Munitions Research and Development Capability	OP 953
CNAL	OP 95T
FNOC	OP02
JCMPO	OP-96
MDA (U.S. Army Space and Missile Defense Command)	Philips Laboratory
NADC	SPAWARS
Naval Oceanographic Office	SUPSALV
Naval Research Laboratory	CECOM
Naval Surface Warfare Center Dahlgren Division	U.S. Army Training and Doctrine Command (TRADOC)
NEPRF	U.S. Air Force Electronics Systems Center
NORDA	U.S. Air Force Rome Laboratory
NTSA	U.S. Army TACOM Armament Research, Development and Engineering Center (TACOM-ARDEC)
Office of Naval Research	U.S. Navy Air Systems Command

SOURCE: Daniel H. Wagner Associates.

DHWA also serves an array of clients outside DoD, including other federal agencies such as NIH and DoE and private-sector clients in the biotech, finance, information technology, and transportation sectors.

Other Awards

DHWA has been recognized many times for the quality of its research and the impact of its activities. The company won a SBIR Tibbetts award in 1999, a SBIR Phase 2 Excellence Award in 1997, citations and awards from the Navy and the Defense Logistics Agency, as well as recognition from the Military Operations Research Society and the Operations Research Society American.

Working with Prime Contractors

Although many SBIR companies report difficulties in working with primes at DoD, DHWA has a long record of working with them successfully. Some of its relationships go back more than 20 years—for example, with SAIC, and more than 15 years with Lockheed Martin Mission Systems and Training (MST) - Owego. Dr. Monach observed that, in many cases, the prime knows that DWHA has certain capabilities and will seek to bring the company into a project, or alternatively, DWHA will identify a prime that would be an effective partner for pursuing a particular opportunity.

A review of DHWA's projects shows that almost all are completed on behalf of DoD via contracts from primes (see Table F-2). This effective cooperative arrangement seems driven in part by the lack of competing interests. Other SBIR companies have complained that primes partner with them to acquire technology and then freeze them out of larger contracts.

DWHA provides highly specialized services that, from the perspective of primes, are too small (in dollars)or too difficult to develop given the very high degree of technical knowledge required, but also, and critically, do not lead to large follow-on contracts. There is no Phase III goldmine at the end of the road.

So the incentives under which DHWA partners with primes are very different from those that dominate most other partnerships between primes and SBIR companies There is almost no overlap in terms of markets; DHWA provides unique services that the prime has no interest in replicating; DHWA has its own extensive relationships with DoD and especially Navy; and there is no downstream contract that could be a cause of contention. In addition, DHWA itself has no interest in competing in any of the prime's areas of competence.

Another example of successful links with primes is in the Navy antisubmarine warfare helicopter program, for which DHWA developed an acoustic mission planner that was integrated into the program via a subcontract from Lockheed Martin. Rather than develop the data search and optimization capabilities of the type needed, Lockheed Martin prefers instead to partner with DHWA.

The partnership between DHWA and Lockheed Martin has successfully passed the evaluation stage on this project, and Navy is now requesting more advanced capabilities. The system currently works on a single helicopter, but Navy seeks to optimize the program for 2-4 helicopters doing the same job. DHWA anticipates that the system will be implemented in Navy helicopters in 2016, which will constitute the next major phase of this project.

And as with its partnerships with SAIC on sea mines and Lockheed Martin on helicopters, DHWA is working with Northrop Grumman on unmanned autonomous vehicles, to which it has sold one software system outright.

Uses of SBIR

According to the DHWA web site, the company has won a total of 119 Phase I awards and 48 Phase II awards. The SBA TechNet database shows 104 Phase I awards and 37 Phase II awards since the first award in 1983, providing a total of about $26 million in SBIR funding over the time period.

The bulk of DHWA's SBIR work has been on DoD awards, and more than one-half of these has been for Navy (see Table F-3). DHWA uses SBIR primarily to conduct R&D needed to develop solution to problems specified by DoD agencies.

One example of the complex way this works in practice comes from DHWA's work on managing autonomous vehicles in a Navy program. For the past 4 years, DHWA has been included in the Navy's Trident Warrior program. Sponsored by the Navy Warfare Development Command, Trident Warrior is an annual fleet experiment focused on gaining insights to improve future capability investments. DHWA has been included in projects working on unmanned vehicles, a program of growing complexity. In 2011 the program tested a four-vehicle autonomous group, using DHWA data fusion technology to manage the vehicles. DHWA demonstrated a number of significant new capabilities, including the ability to direct a unit using only data from sensors located on other units.

DHWA has also been working on a DARPA initiative to build unmanned surface vehicles to track diesel submarines. A Phase I award from DARPA funded preliminary data fusion, optimal tracking, and optimal reacquisition work. This was followed by three separate Phase II contracts, looking at data fusion using only passive sensors and at optimal navigation and search in very high sea states.

According to Dr. Monach, SBIR funding is used to take projects to the TRL 6-7 level, typically proving quantitatively that there are good technical reasons to adopt a selected technical approach, based on real-world data. This is

TABLE F-2 Projects and Primes

Project	Agency	Prime Contractor
Acoustic Mission Planner (AMP) for the MH-60R	Navy	SBIR/Lockheed Martin
Non-Gaussian Data Fusion System (NGDFS)	Navy	SBIR
Theater Undersea Warfare Initiative (TUSWI) Non-Gaussian Data Fusion System (NGDFS) Web Service (TNGWS)	Navy	Lockheed Martin
Decision Support for Dynamic Target Engagement (DS-DTE)	Navy	Solers
Object Avoidance for Unmanned Surface Vehicles (OAUSV)	Navy	
Surface Warfare Tactical Decision Aid/Anti-Surface Warfare Tactical Decision Aid (SUWTDA/ASUWTDA)	Navy	
Commander's Estimate of the Situation and Intelligence, Surveillance, and Reconnaissance Tactical Decision Aid (CES/ISR TDA)		SBIR/SAIC
Combat Air Identification Fusion Algorithm (CAIFA)	Navy	
Expeditionary Warfare Decision Aids Engineering and Development Support - MEDAL, JCA, EDSS		SAIC
Environmental Data Fusion for Mine Warfare (EDFMCM) and Current, Wind, and Wave Data Fusion (CWWDF)	Navy	SBIR/SAIC
Ground Attack Data Fusion and Optimization System (GADFOS) and Ground Target Tracking and Identification System (GTIS)	Air Force	
SOAPi Services™—Large Scale Integration of Distributed Systems Exposed as SOAP-Based Web Services	Multiple	SBIR
Target Tracking and Classification System (TTCS)	Navy	SBIR
Cooperative Organic Mine Defense (COMID)	Navy	
Anti-Torpedo Data Fusion and Optimization System (ATDOS)	Navy	SBIR

TABLE F-2 Projects and Primes *continued*

Project	Agency	Prime Contractor
Tactical Environmental Effects for Precision Guided Missiles (METPLAN)	Navy	SBIR
Range Surveillance, Planning, Optimization, and Real-Time Effectiveness (R-SPORTE) System	NASA	CSC

SOURCE: Daniel H. Wagner Associates.

a very different approach from hardware-oriented companies, which in general find it difficult to move projects beyond TRL-4 with SBIR Phase II funding.

DHWA typically does not seek to provide significant input into the SBIR topic development process, preferring to find opportunities among topics included in the solicitation, with a particular focus on topics that seemed ripe for transition. The company's long experience with the SBIR program at DoD and particularly with Navy has given the company a good feel for what will transition, according to Dr. Monach.

In general, DHWA has not had significant problems with TPOC turnover at DoD. Often, the author of the original topic moved on during the process, which required efforts from DWHA to develop a new champion or at least educate the responsible officer about the topic, but DWHA believes this can be achieved effectively.

TABLE F-3 DHWA DoD SBIR Awards by Phase and Component

	Phase I	Phase II
AF	13	4
Army	11	1
DARPA	5	0
MDA	9	2
OSD	5	1
Navy	49	26
DoD Total	92	34

SOURCE: SBA TechNet database, accessed September 19, 2012.

SBIR Program Recommendations

DHWA considers the Navy Opportunity Forum to be very useful and participates every year. The forum provides a critical opportunity to get the company's technologies and capabilities in front of many potential high-yield customers, mostly connected to Navy, but Air Force, Army, and even private-sector buyers are also present. This is the only trade show used by DHWA. Dr. Monach noted that neither Army nor Air Force offer any equivalent opportunity or forum.

Dr. Monach observed that CCR is a fairly useful way to monitor commercial outcomes from SBIR projects and that with the transition to electronic records it is not especially burdensome. DHWA uses the process in part as a way to track its own outcomes for a particular project.

DHWA's company commercialization index is relatively low—in the 60s. Dr. Monach explained that this does not reflect the company's very successful record in transitioning technology and solutions into the Services. He argued that the company has in effect been penalized for its business model, which does not impose further charges on the government for actuations—the standard model for SBIR companies. The CCR—and company commercialization score in particular—primarily measures downstream dollars, not successful transitions.

Dr. Monach suggested that an additional metric reflecting the number of successful transitions would be helpful and would correct the current unbalanced approach.

Overall, Dr. Monach said that SBIR funding levels were acceptable and that reporting did not impose an undue burden. His company did not use the Dawnbreaker service, so he could not comments on that kind of support. It had, however, used a state of Virginia course on writing SBIR proposals, which was useful. He noted that Virginia does a good job of supporting SBIR applicants.

FETCH TECHNOLOGIES: SBIR CASE STUDY

Based on interview with
Mr. Robert Landes, Former CEO
February 9, 2012
Los Angeles

Fetch Technologies ("Fetch") was founded in 1999 by two faculty members from the University of Southern California Information Sciences Institute, Dr. Steve Minton and Dr. Craig Knoblock. The company was formed to address the need for scalable ways to accurately extract information from web pages and from what is sometimes called the Deep Web—databases that are connected to the web but that contain information that must be requested via a web form.

Fetch aimed to develop and commercialize the artificial intelligence (AI) technology to enables organizations of all sizes to access, aggregate, and use real-time 2eb data. Fetch technology is designed to connect millions of websites, to gather data for a myriad of applications, including competitive intelligence, news aggregation, data analysis, and background screening.

Most of the technology was developed in conjunction with SBIR funding, with support from several DoD agencies including DARPA, as well as NSF.

Fetch and its intellectual property assets were sold to Connotate, a Boston-area company, at the end of 2011.

Fetch Technology

Fetch technology automatically aggregates, normalizes, and integrates online data for delivery to the customer in various formats. Its focus is to provide an automated service that acquires and aggregates data and to present it in formats designed for the use of the customer, who can then focus on data analysis and interpretation rather than data acquisition.

The technologies developed at Fetch fit well with the growing need to manage rapidly expanding data flows within the organization. According to a recent IDC Inc. report,[9] world information flows double every 2 years, while the annual cost of managing it has fallen by more than 85 percent since 1985, in part because of technologies like those developed and deployed at Fetch.

Fetch works through intelligent agents—software-driven online bots that constantly update data streams and utilize machine learning technology to adapt to changing data sources. Fetch has developed a library of existing software agents, as well as tools for users to adapt or customize alembics to their specific needs and requirements. These agents can identify specific page elements, even if they are not displayed, using a common format or similar location on the page.

Commercialization

There appears to be something of a contradiction, or at least tension, in the commercialization record at Fetch. Fetch has been highly successful in the deployment of its technologies. Mr. Landes observed that not only was Fetch the technology engine behind major data retrieval applications such as Factiva at Dow Jones and the news operation at Nexus-Lexis, but also it has become the dominant technology in use in the $11 billion criminal records retrieval business. According to Mike Horowitz, Fetch product manager, the company has developed software agents that can address more than 200 sites relevant to

[9]IDC, Digital Universe 2011, "Extracting Value from Chaos," *<http://www.emc.com/leadership/programs/digital-universe.htm>*.

criminal back ground checks.[10] Fetch claims that its technology was used for more than 280,000 background checks during the seasonal hiring season in 2010.[11] In March 2011, the company announced a strategic partnership with S&J Associates, a leading wholesale provider of in-person court records searches.[12]

Indeed, according to the company, Fetch set a record in new and renewal business in the second quarter of 2010, signing deals with O'Reilly Auto Parts, i-Hire, SNL Financial, HireRight, Shopzilla, BurrellesLuce, Zvents, and Geosemble, among others. Fetch also powers the data retrieval engine for SpatialMatch®, an effort designed to help traditional realtors compete directly with the technologies deployed through new data-intensive startups such as Zillow and Trulia.

The tension between technology development and deployment and commercialization has been an ongoing challenge at Fetch. Mr. Landes was recruited as CEO in 2005 with the objective of transforming successful technologies into a fast-growing business.

The company made significant moves toward further commercialization in 2011. In February 2011, it was reported that the company had raised $4.6 million in a B series venture capital round.[13] And in March, xEconomy reported that Fetch had signed a development agreement with In-Q-Tel, the venture capital arm of the intelligence community.

Yet, while technology deployment continued to grow rapidly, financial returns to investors did not grow at nearly the same pace. Indeed, long-term prospects for the company were sufficiently uncertain that at the end of 2011 Fetch was sold to Connotate, a Boston-area data mining company, in what appears to be a primarily non-cash equity swap that left Fetch investors with cash losses.

Universities and Academics

Fetch was founded by academics and claims that, despite its commercial activities, it maintains a strong commitment to academic research. Fetch Labs—an in-house research facility—focuses on the theoretical frontiers of information extraction, information integration, and data analytics.

SBIR and the Evolution of Fetch

Between 2001 and 2010, Fetch received 19 Phase I awards and 13 Phase II awards, primarily from DoD, but also from NSF and NASA, which shows a high conversion rate. For the SBIR program as a whole, on average

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[10]Stephen E. Arnold, Interview with Mike Horowitz, July 14, 2010.
[11]Fetch Technologies press release, January 4, 2011.
[12]S&J press release, March 16, 2011.
[13]*<http://www.socaltech.com/fetch_technologies_raises__4.6m/s-0034091.html>*.

BOX F-2
Fetch Technologies in Action:
Automating Criminal Background Checks

According to Jerry Thurber, President of Tandem Select, the use of AI has been growing rapidly in the background screening industry.[1] AI is needed when the task at hand changes. For example, in background checking, AI "agents" can be used to access and retrieve criminal history data. A growing volume of criminal history data is maintained in secure web sites that are made available for background checks and pre-employment screens. These sites require a person to log into the site, enter his or her credentials, then search for a specific name. The exact navigation for finding records differs from site to site and even from search to search. For example, a search for Jane Doe's criminal record in Colorado may involve a search through three or four pages, while a search for John Doe's criminal record on the same web site may require information that wasn't relevant for Jane Doe search but is relevant for the John Doe search. In other words, the search is situational. AI tools can be "trained" to see and address these situational anomalies.

Mr. Thurber noted that AI can be more accurate than human beings conducting the same searches. Machines do not forget to look at every page or fail to navigate through all the records; they do not get tired or type the wrong information. Once in place, they do their job completely, every time. Nor do AI tools have to sleep. Tandem Select uses AI tools to reduce turnaround time from several hours to several seconds, providing clients with better, faster, and more accurate criminal history results.

SOURCE: Jerry Thurber, Artificial Intelligence in Background Checking: A Quick Introduction. Fetch Technologies

about half of Phase I awards receive Phase II awards, so Fetch was especially successful in completing the feasibility stage of its projects.

According to Mr. Landes, the SBIR program was pivotal in providing the funding needed to develop Fetch's technology. Each of the major technical innovations at Fetch could be linked directly or indirectly to the steady flow of SBIR funding between 2001 and 2010. Yet at the same time, the company's original orientation toward research continued to be fueled by the ready acquisition of more SBIR awards. Mr. Landes believes that the continuing flow of research funding undermined efforts to re-focus the company on commercial outcomes and partially contributed to the eventual sale of the company and its technology. Mr. Landes stressed that, in his view, this should not be seen as a fault of the program; rather, it was management's inability to successfully resolve an inherent contradiction within the company that led to its sale.

GINER INC. AND GINER ELECTROCHEMICAL SYSTEMS:[14] SBIR CASE STUDY

Based on interview with
Dr. Cortney Mittelsteadt, Vice-President, Technology

Giner Inc. is a privately held, minority-owned business headquartered in Newton, Massachusetts. It was founded by José Giner in 1973. The company specializes in electrochemical research, with expertise in electrolyzers, fuel cells, capacitors, and sensors. The company currently has about 55 employees, 14 of whom have PhDs.

In the 1980s, Giner focused on contracts to build electrolyzers for unmanned aerospace vehicles (UAVs), which provided the company with a new technical platform and with increased experience in government contracting. By the early 1990s, Giner had begun to develop fuel cell technologies. This resulted a decade later (in 2000) in the creation of a joint venture, Giner Electrochemical Systems, LLC (GES) with General Motors (GM). GES aimed to accelerate the development of fuel cell vehicles, which Giner continues to believe is the future of automotive transportation. GM took a 30 percent stake in the joint venture and continues to provide considerable research funding through an annual research contract. In exchange, GM owns all the intellectual property generated by GES in relation to transportation and stationary applications.

GM's contribution was substantial—the research contract peaked at about $4 million annually, which for some years accounted for 70 percent of Giner's revenues. However, a reduction in the GM contract and the rapid expansion of Giner's other business reduced GM's share to less than 10 percent of revenues in 2010.

In 2010, Giner bought out GM's share at least in part to better position the company for outside investment. Giner's new business strategy focuses on increasingly attractive opportunities in commercial markets. This reflects a fundamental shift in position as a contract R&D house to a company focused on manufacturing and selling commercial products.

Giner continues to be profitable, with revenues and profits growing substantially since 2006. This revenue growth is almost entirely fueled by the expansion of commercial product sales, which increased from about $700,000 in 2006 to $6 million in 2010.

[14]Collectively referred to as "Giner" below.

Markets and Revenues

Giner divides its markets into six broad categories:

- **Sea.** Giner technologies provide oxygen generators for nuclear submarines and electrolyzer stacks to Treadwell Corp., which develops complete systems for deployment to Navy.
- **Space.** Giner technologies are suited to the demands of space. The company was selected as a vendor by Lockheed Martin for work on the ISIS space program for NASA.
- **Laboratory hydrogen.** Giner products generate hydrogen onsite for laboratories, obviating the need for costly and potentially hazardous storage and transportation. These products are resold by three major original equipment manufacturers (OEM) that handle all sales and service. Giner sees a major opportunity to erode the market share of delivered hydrogen, currently at about 96 percent of the market.
- **Tracking sensors.** Giner sensors detect alcohol for use in personal tracking devices, primarily within the criminal justice system. Giner is the sole supplier for BI, the largest U.S. monitoring supplier to the industry.
- **Health care.** Giner has developed a localized oxygen delivery system that can help to speed recovery from wounds. This is being deployed through an industry startup.
- **Contract research.** This research still accounts for about two-thirds of company revenues, with GM in turn providing a declining share of contract research funding (now less than 10 percent). Giner typically bids on 5 to 10 federal agency contracts per year, and it has strong relationships with DoD, DoE, NASA, and DARPA.

Typically, different sectors require different capabilities: spaceborne technologies focus on reducing weight and power consumption and seaborne technologies used in nuclear submarines focus on reliability, because weight and power are not constraints.

Giner serves both the public and private sectors and has substantial sales to primes in the United States and internationally. In addition to GM, Giner has relationships with the following types of private-sector companies:

- aerospace companies
- defense contractors
- medical device manufacturers
- other product-based companies

Giner undertakes government-sponsored work for various federal agencies, including all branches of DoD, DoE, NASA, NIH, Environmental Protection Agency (EPA), and DHS.

IP and Publications

Giner personnel publish extensively in leading journals and make presentations at technical meetings in the United States and abroad. They hold more than 100 U.S. patents in the field of electrochemistry. Key individuals have received awards for scientific excellence and for solving difficult problems for government and industry.

Technologies

Giner is a world leader in the advancement of electrochemical and proton-exchange membrane (PEM)-based technologies, providing R&D services for a wide variety of electrochemical applications. This core technology has been applied to an increasing range of related technologies and applications.

Giner technologies are based on common components, such as membranes, catalytic electrodes, electrically conductive bipolar current collectors that also distribute and control fluid flow, thin solid bipolar plate separation plates, and other individual cell and overall system components. Improvements made in one technology or product can be readily transferred to other areas.

Power Generation

Growing interest in hydrogen-based power has created opportunities for Giner, which has considerable expertise in hydrogen electrolysis and in fuel cells. Hydrogen (H2) generators produce pure hydrogen fuel from water and electric power at efficiencies approaching 90 percent (HHV basis). With private- and public-sector partners (DoE, General Motors, National Renewable Energy Laboratory, and Parker), Giner is working to improve efficiency, costs, reliability, and durability of PEM technology.

Although the basic technology is well known, the challenge is to ensure that these devices offer real value to customers and end users. Superior energy efficiency and reliability are not in and of themselves sufficient unless product costs are competitive with internal combustion engines and other energy technologies (such as batteries). Giner's core competency in proton exchange membrane and membrane electrode assembly technology allow the company to address this challenge.

Several Giner technologies focus on the hydrogen economy:

- Hydrogen generators allow the manufacture of hydrogen at high pressure while minimizing reliability issues associated with mechanical gas compressors.

- Lightweight electrolyzers (originally developed for aerospace applications) could be used for home garage hydrogen generators, recharging fuel tanks overnight. Unmanned high-altitude aircraft and airships with long mission durations over fixed targets (persistence) have increased interest in the development of closed systems to build regenerative fuel cells (RFCs). These low-mass, high-energy RFCs offer advantages over batteries, because RFCs can repeatedly undergo near 100 percent charge and discharge cycles.
- RFC technology is also a potential multiplier for wind and solar power, because it helps match customer needs and power generation profiles.

Fixed and Portable Chemical Production

Useful chemicals can be made by electrolysis and electrosynthesis. In some cases, on-site manufacturing is critically important, especially where it is either difficult or dangerous to transport the chemicals (e.g., in geographical areas where the transportation infrastructure is poor). Giner has built portable systems that can make a number of materials on site, including chlorine, ozone, hydrogen peroxide, and sodium hypochlorite.

Giner claims to be the world's leading supplier of laboratory hydrogen (H2) generators. Dr. Mittelsteadt identified this as an area of substantial opportunity for Giner, because 96 percent of laboratories still generate their hydrogen offsite.

Oxygen generation has also been a particular focus. Water electrolyzers produce oxygen for applications such as breathing air maintenance in submarines and manned space missions, and Giner has commercialized submarine electrolyzer stacks and continues to improve the technology. Giner supplies PEM electrolyzer stacks to the Navy's Seawolf-class submarine fleet through a partnership with the Treadwell Corporation. Producing gas at high pressure eliminates the need for gas compressors, which can be bulky, troublesome, costly, dirty, and noisy. Giner is supplying next-generation LPE (low pressure electrolyzer) stacks for the retrofit of all Ohio-class submarines and for the replacement of oxygen generation plant (OGP) stacks on-board the Seawolf class, in due course.

Giner is also working with NASA and prime contractors to adapt PEM technology to living and working in a vacuum, where power consumption is a key factor. Electrolyzer efficiency has been used to provide sufficient oxygen for all tasks, including the oxygen for extravehicular activities (EVAs) at an expenditure of less than 250 watts per crew member.

Rapid Sensitive Electrochemical Detection

The ability to sense trace gases and environmental pollutants has widespread application in the workplace, the wider environment, and in homeland security. Giner's sensors and electronics can detect a wide variety of chemicals including hydrogen, carbon monoxide, hydrazine, and trace metals such as arsenic and cadmium.

Many of its sensors use its patented thick-film technology with working, counter, and reference electrodes printed directly onto a substrate. Selection of electrode materials and potentiostatic control allows the selective detection and measurement of gaseous and dissolved species, in some cases to the part-per-billion level. Again, this technology represents an effort to build a platform with applications in many areas.

Short- and Long-Duration Energy Storage

Giner is currently developing different types of energy storage devices (capacitors, lithium batteries, regenerative fuel cells). Stored energy using these devices can be delivered over time periods that range from fractions of a second (capacitors) to hours (regenerative fuel cells).

Electrochemical Sensor Technology

Human skin, the largest organ of the body, can transport water, oxygen, carbon dioxide, and alcohol. Giner's patented electrochemical sensor technology measures the alcohol that passes through the skin and correlates that measurement to blood alcohol levels. This provides a passive, non-invasive method of determining alcohol consumption.

Detection of alcohol is important in criminal justice probation and parole monitoring, as well as in the prevention of alcohol abuse in those who perform critical jobs.

Giner has also developed a prototype neonatal carbon dioxide (CO_2) transdermal sensor for use with newborn babies.

Membrane Electrode Assemblies

Membrane electrode assemblies (MEAs) are the heart of PEM fuel cells and electrolyzers. MEAs are either 3, 5, or 7 layers:

- 3 layer: Cathode and anode laminated to a PEM
- 5 layer: Gas-diffusion layers laminated to 3-layer MEA
- 7 layer: Flow-fields laminated to a 5-layer MEA

Giner manufactures MEAs to customer specifications for research, development, and specialty commercial applications.

Giner and SBIR

Giner has consistency won SBIR awards since the mid-1990s, with 186 Phase I and 77 Phase II awards through 2010, totaling about $62.5 million over 25 years, according to the SBA Tech-Net database.

In 2010 SBIR awards accounted for just under $4 million in Giner revenues, about 30 percent of total company revenues.

According to Dr. Mittelsteadt, Giner has become more strategic and selective in deciding which SBIR opportunities to pursue—reflecting the shift toward commercial products and manufacturing. In his view, “Giner only makes money when it makes things”—the research itself is a platform, not a result.

Dr. Mittelsteadt noted that the SBIR program has over the years contributed in many ways to the core technologies developed at Giner, and therefore its effects can be traced to many of the company’s current products, such as the ISIS technology used at NASA. He noted that this synergy with commercial products was increasingly important, because the size of markets, for example, at NASA, did not justify the company’s efforts. For example, Giner developed a hydrazine sensor for NASA that was successful in determining air quality safety after launch. However, NASA needed only a total of 12 units, and there was no other relevant application for this specific sensor.

SBIR Recommendations and Comments

Dr. Mittelsteadt expressed strong support for efforts aimed at ensuring that any company applying for SBIR funding actually meets the agency’s needs, which reduces costs and increases efficiency for the agency and the company. For example, he approved of the DoE pre-submission notice, which encouraged potential applicants to submit a 2- to 3-page white paper outlining possible research for prior review by agency staff. He believed that this useful initiative could be more widely applied to the SBIR program. At Giner, no SBIR proposals were prepared before the company had contacted the agency point of contact and ensured that the company’s technical approach would be welcomed.

Similarly, Dr. Mittelsteadt noted that the ability to request clarification during the proposal review would likely improve outcomes for both agency and company, by reducing the potential for random responses.

Again, the SBIR program could adopt the DoE approach to broad area announcements (BAAs). DoE BAAs encourage submission of a 5-page white paper and then provides applicants with an opportunity to respond to criticisms and concerns. This more iterative approach seems more in keeping with modern approaches to technology development.

Dr. Mittelsteadt is particularly concerned by recent changes in the application process at NASA, which requires completed line-item descriptions for all items to be purchased during the SBIR award. Given that the award is a *research* project, where outcomes are by definition not known and course corrections almost inevitable, such false precision simply adds burden to the company at no benefit to the agency.

IROBOT:
SBIR CASE STUDY

Based on interview with
Joseph Dyer, Chief Strategy Officer
Thomas Frost, Vice President of Strategy
Bob Kahout, Vice President of Research
September 12, 2012
Bedford, MA

iRobot is a publicly traded company (NASDAQ: IRBT) headquartered in Bedford, Massachusetts. It was founded in 1990 by Rodney Brooks, Colin Angle, and Helen Greiner, all of whom had previously worked in MIT's Artificial Intelligence Lab. The company was for several years primarily a research-focused organization, whose revenues came from grants and contracts. One significant source of funding during this period was SBIR awards from several agencies, although primarily DoD components. The SBA TechNet database indicates that iRobot received 19 Phase I and 10 Phase II awards from 2001 to 2008; company records indicate additional awards prior to 2001.

According to Mr. Frost, the company pursued a range of technologies using SBIR awards during the late 1990s. In 1998 the company received a DARPA research contract, which helped fund development of the technology that led to the PackBot, one of iRobot's first commercial application.

iRobot had at the time several other commercial opportunities—one of which was pursued in parallel and led to a consumer product—the Roomba. Still, successful development of the PackBot turned out to be an inflection point for the company. After 2001, the conflict in Afghanistan generated immediate demand for remote-controlled devices to scout for troops within buildings and to address improvised explosive devices (IEDs). The invasion of Iraq in 2003, and the guerilla war that followed, further expanded the need for robotic devices.

This confluence of technology development and rapidly growing demand was addressed through additional post-SBIR funding from DARPA and through purchases of early products through the new Rapid Equipping Force (REF), an Army organization set up in November 2002 to dramatically accelerate acquisition of COTS and government off-the-shelf (GOTS) technologies.

The iRobot PackBot is a good example of the REF approach: it addressed a clear and growing need, was at an appropriate stage of technology readiness, and was certified for sole source acquisition as a result of the SBIR award (although there is no evidence that sole sourcing played any role at this point).

According to Mr. Frost, REF demand for the PackBot was a pivotal point in the company's transition from being a research-focused organization to a manufacturing and production company. Demand from other DoD components grew after the PackBot was validated by its use in Afghanistan and Iraq, and the company had to ramp up production to meet demand. Reliable and rapidly growing funding from the defense side of the company supported this transition and helped the company prepare for its IPO in 2004. Since inception, iRobot has sold more than 4,500 tactical military robots.[15]

The development of civilian robots continued in parallel, and the first Roomba entered the market in September 2002. The Roomba family has proved to be an enormous commercial success, with more than 7 million units sold.[16]

More recently, the company's focus has further evolved, as the balance of sales has increasingly shifted to the civil side. However, it is clear that funding from DoD and other federal agencies continues to support a range of iRobot research activities, some of which results in improvements to civilian products.

Overall, government sector sales have accounted for slightly more than one-third of total revenues in each of the three most recent fiscal years at the time of this interview, while international sales have grown from about one-third to more than 45 percent over the same period. Within limits imposed by International Traffic in Arms Regulations (ITAR), iRobot has sold tactical robots to governments in more than 15 countries, including the United Kingdom, France, Germany, Sweden, Norway, Italy, Israel, Australia, Republic of Korea, Singapore, Bosnia, Lithuania, Qatar, Taiwan, South Africa, and Canada.[17]

Revenues (it would be best if we could specify revenues of which year) have grown by 88 percent since 2007, and net income shifted from a small operating loss in 2007 to profits of more than $50 million in 2011. The latter was a positive year for both the home and industrial robot divisions, with the former growing revenues by 31.5 percent and the latter by 8.9 percent.[18] At the same time, R&D remains a prime focus for iRobot, which spent more than $36 million (about 7.8 percent of revenues) on R&D in 2011.[19]

Products

iRobot products are clustered around two basic platforms: the PackBot and its successors, and the Roomba.

The PackBot family now includes four models—the PackBot 510, two small unmanned ground vehicle (SUGV) multi-purpose ground robots, the 110

[15]iRobot, 10K submitted to Securities and Exchange Commission, Annual Report 2011, p. 3.
[16]iRobot, ibid.
[17]iRobot, op.cit. p. 8.
[18]iRobot Consolidated Accounts, op.cit., pp. 35-36.
[19]iRobot Consolidated Accounts, op.cit., p. 27.

FirstLook small, light, throwable robot, and the 710 Warrior multi-purpose robot capable of carrying heavy payloads. All of these robots share a number of common platform components. Using iRobot's patented flipper technology, these robots can climb stairs, navigate rubble, and penetrate otherwise inaccessible areas. Tactical robots cost between $20,000 and $350,000, depending on capability and options. PackBots have been extensively deployed in Afghanistan and Iraq, where they are used to scout dangerous areas and to handle IEDs.

The PackBot is designed for multiple configurations, so orders are customized for specific mission needs. SUGVs are lightweight backpackable robots configured to fit into the current model of Army backpacks. More than 300 were delivered for use in Afghanistan in 2011. Ongoing contracts with DoD are supporting continuing design improvement.[20] For example, the Advanced Inflatable Robotics (AIR) research prototypes include a modified PackBot with an inflatable manipulator arm and a fully inflatable "hexabot" that walks on six legs. These were, according to Chris Jones, Director for Research Advancement at iRobot, developed under research initiatives which provided $650,000 from DARPA's Maximum Mobility and Manipulation (M3) Program (launched in 2011).[21]

The PackBot 510 line can be configured to serve five sets of users:

- infantry
- explosive ordnance device
- hazmat technicians
- first responders
- combat engineers

On the consumer side, the Roomba was introduced in 2002 and has sold more than 7 million units to (please specify date). It uses two motorized wheels, which are governed by a set of sensors including a mechanical sensor in the front, an infrared sensor on top, infrared "cliff sensors" along the bottom to avoid sharp drops, as well as acoustic-based dirt sensors. These all operate with the iRobot proprietary command software. More recent versions of the Roomba include HEPA filtering systems, as well as scheduling capabilities.

Intellectual Property

Since 2001, iRobot has been the assignee on 130 patents granted by the USPTO.[22]

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[20] iRobot op.cit., p. 6.
[21] S. Gallagher, Here come the inflate-a-bots: iRobot's AIR blow up bot prototypes, *ARS Technica*, August 22, 2012.
[22] USPTO, iRobot assignee search, accessed September 14, 2012.

Strategy

iRobot was originally an R&D organization, largely performing contract research. With the emerging demand for the PackBot in the early 2000s, the company underwent a profound change of direction to become a product company with the two primary lines of business described above. Mr. Frost noted that this transition was a long and wrenching process and that the company struggled for a number of years to successfully complete the strategic shift.

Once completed, the company faced a second shift in the late 2000s, because it outgrew the SBIR program, which had funded a significant amount of company research. iRobot purchased a second SBIR-winning company, Nekton Research, which subsequently found it difficult to cope with the loss of SBIR funding, because its technology was not sufficiently advanced to attract alternatives.[23]

Current strategy is focused on extending the capabilities of the two main platforms, building a growing number of robots with specialized capabilities or developing modules that can create specialized capabilities within existing lines. Recent products have included under-water robots and pool- and gutter-cleaning robots.

iRobot is seeking strategic partners to utilize iRobot technology in new market segments. In 2011, for example, it signed a partnership agreement with InTouch Health to work in the telemedicine sector.[24] According to iRobot, its main platforms are designed with open interfaces that permit third-source development, and its 2011 annual report indicates that encouraging a community of third-party developers is one of iRobot's current strategic priorities.

This strategy has led the company to develop iRobot Create, in which the vacuum cleaner motor is replaced by a "cargo bay" for mounting devices such as TV cameras, lasers, and other robotic parts. It can then be used as the mobile base for completely new robots.[25] iRobot views these efforts in particular as creating a pathway into the education sector.

iRobot and SBIR

Between 2004 and 2007—when iRobot graduated from the program—the company received 14 Phase I and 10 Phase II awards, which reflects a high conversion rate (the average is approximately 50 percent). SBA's TechNet database reports that iRobot received about $8.5 million in SBIR funding

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[23]According to SBA TechNet database, Nekton won 19 Phase I and 9 Phase II awards between 1989 and 2006, from NASA, DOE, DoD, HHS, and DOC. SBA TechNet database, accessed September 14, 2012.
[24]iRobot, op.cit., p. 7.
[25]For examples of alternative uses for iRobot products, see <*http://www.irobot.com/hrd_right_rail/create_rr/create_fam/createFam_rr_projects.html*>.

between 2001 and 2007. It does not appear that earlier awards are included in the SBA database (which iRobot confirms as accurate).

Mr. Frost observed that, although only PackBot turned out to be a commercial success, SBIR support for all of its technologies in the mid to late 1990s was critically important in helping the company develop expertise in a range of areas.

Admiral Dyer noted that the sole source capacity attached to SBIR awards was excellent in theory but was not much used by the Services in practice. iRobot had not been able to use sole source, to his recollection.

Recommendations

Admiral Dyer observed that the "Valley of Death" is getting wider, presenting greater challenges to small innovative firms such as iRobot. He also said that despite some improvements, most DoD R&D staff still considers the SBIR program to be a tax.

He strongly recommended that funding be focused on helping companies actually reach full-scale commercialization, through the provision of considerably more Phase III resources. The program has a strong track record in helping companies develop promising technologies, but most of the technologies do not result in commercially successful products in large part because funding for the critical transition to a commercial product was not available.

He also observed that, in his experience (he previously served as a Navy program officer with responsibilities for SBIR), most successes were achieved by companies from among the larger SBIR recipients. Small companies rarely had the in-house expertise to commercialize effectively. He thus believed that in some ways Congressional plus-ups are the best available tool for funding the work that will actually move projects to market and create substantial numbers of jobs.

Admiral Dyer does not support cutting off SBIR funding when a firm reaches 500 employees. These are the firms most likely to commercialize, and the Services (and other SBIR agencies) would be well advised to find ways to fund innovative firms that reach this level of growth and development. He noted that the impact on Nekton (see above) had been substantial—in the end, it had not been able to adjust effectively to the switch away from SBIR funding streams. This has made iRobot reluctant to buy another company like Nekton. Therefore, SBA should consider raising the 500-employee limit.

MAYFLOWER COMMUNICATIONS INC.: SBIR CASE STUDY[26]

Based on interview with
Dr. Triveni Upadhyay, CEO and co-founder
September 20, 2011
Burlington, MA

Mayflower Communications Inc. (“Mayflower”) is a privately owned company headquartered in Burlington, Massachusetts. It was founded in 1986 by prominent researchers from the Draper Laboratories, focused on developing cost-effective solutions for high-performance affordable radio navigation and digital anti-jam technologies for government and commercial markets. The researchers left primarily because Draper was positioned to work on a sole source basis with government partners, while they preferred to compete for contracts in the R&D environment.

Initially, Mayflower hoped to find a niche transposing defense-oriented GPS technologies into the commercial sector. Mayflower completed some early work for NASA and for the Federal Aviation Adminstration (FAA). However, despite conversations with auto makers such as GM and other potential clients, in the early 1990s Mayflower determined that the best markets for its products were in fact within DoD.

Mayflower’s focus in wireless communication is to provide wired performance with wireless ubiquity. Toward this end, Mayflower develops smart radio, wired-equivalent access, and versatile network technologies and has a diverse patent portfolio in its core areas of radio navigation, digital anti-jam, and wireless communication technology. A number of Mayflower patented technologies have been reduced to practice in its products.

In 2000, Mayflower spun off Envoy Networks, Inc., with $7 million in initial funding from leading venture capitalists and industry (including Texas Instruments).[27] Envoy Networks focused on developing and marketing third generation (3G) commercial mobile cellular technology and products, and it developed patented technology to enhance the capacity and coverage of wireless cellular networks for both voice and data. It was subsequently acquired by Texas Instruments, Inc. in 2002 for an undisclosed price.[28]

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[26]Material for this case study was compiled from the interview with Dr. Updhyay or the Mayflower Communications web site, accessed September 26, 2011, unless otherwise stated.
[27]*<http://www.thefreelibrary.com/Envoy+Networks,+Inc.+Raises+$7+Million+in+First+Round+Financing+to...-a062124259>.*
[28]*<http://www.ti.com/corp/docs/investor/compinfo/acquisitions.shtml>.*

Technology

As a technology-focused company, Mayflower claims a number of industry leading innovations. These include the following:

- developing and demonstrating a low-cost, embedded data link capability in its GPS receiver
- building a low-cost, low-power GPS Anti-Jam solution
- developing a compact digital antenna solution that leapfrogged legacy large radio frequency (RF) antenna solutions
- developing an integrated temporal and spatial filter solution that robustly extends the capability of an antenna nulling solution beyond its degree of freedom

Mayflower also participated (in the 1990s) in the U.S. delegation helping to develop the International Civil Aeronautics Organization (ICAO) standards for Aeronautical Mobile Satellite Communications.

In a teaming arrangement with Alliant Technologies, Inc. (ATK) (a Fortune 500 company), Mayflower was involved in the Ballistic Trajectory Extended Range Munitions (BTERM II) Demonstration Program. Mayflower provided its GPS antenna AJ electronics to ATK/Draper for use in Navy BTERM II projectiles.[29]

Mayflower also developed and applied its GPS/anti-jam technology to the Navy's Guidance Integrated Fuze (GIF) Demonstration Program and is developing miniaturized anti-jam antenna electronics and a single-chip SAASM GPS receiver for use in the GIF guidance electronics unit.

Anti-Jam Module

Mayflower's anti-jam GPS GEU offers a powerful, high-performance, small-size, low-cost solution for precision-guided munitions. Production cost is decreased by using commercially available components, miniaturizing the enhanced GPS receiver and anti-jam module unit, and using "accelerometers only" inertial navigation systems without including the more expensive gun-hard gyroscope that is not available commercially. This GPS anti-jam technology addresses multiple wideband jammers for gun-launched rolling projectiles by utilizing a conformal antenna.

The GIF program seeks to replace the existing NATO standard fuze on existing stockpiled Army, Navy, and Marine Corp ammunition with a low-cost, fuze-sized module.[30]

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[29]BTERM II is an alternative to the extended-range, gun-launched projectile and to the Extended Range Guided Munitions program.

[30]*<http://www.dodsbir.net/SuccessStories/display_story.asp?id=SS00000432>*.

The anti-jam module uses patented digital signal processing algorithms (temporal and spatial processing) to protect against different kinds of jammers and provides protection against multiple jammers. It can work with up to four antennas and has been successfully tested on a railgun to withstand more than 8,000 Gs of shock. Cost is reduced because the module can connect to any COTS GPS receiver through a conventional RF interface. It requires limited power, is 3.15 inches in diameter, and weighs 53 grams.

Low-Power Anti-Jam Module

Mayflower's low-power anti-jam module is designed around the company's proprietary semiconductor chips and connects to Mayflower GPS receivers with digital or RF interface. It can connect to any COTS GPS receiver through conventional RF interface. It requires less than half the power of Mayflower's anti-Jam module.

Integrated GPS C/A-Anti-Jam

This product combines Mayflower's anti-Jam solution with high-performance C/A code GPS receiver. It is targeted at applications that require a GPS receiver and anti-Jam solution but have limited space and power resources.

Customers

Mayflower serves both government and private sector markets.

Government

Mayflower has served a range of government clients, including:

- Navy: SPAWAR, NAVSEA, and NAVAIR commands and Naval Surface Warfare Center and Office of Naval Research
- Army: CECOM, Army Aviation & Missile Systems Command, and SMDC
- Air Force: AFRLs in Dayton, Ohio, and Rome New York, Philips Laboratory, Space Flight Test Center, 746th Test Squadron, GPS Wing
- JPRS: JTRS JPEO, San Diego, CA
- Department of Transportation
- Federal Aviation Administration
- NASA: Johnson Space Center, Marshall Space Flight Center, Jet Propulsion Laboratory

Industrial Customers

Dr. Upadhyay noted that, although Mayflower has a number of large industrial companies as customers, relations with primes to a considerable degree depend on whether the latter were primarily acting as systems integrators or as technology developers. Raytheon, for example, partnered as a systems integrator with Mayflower on some early contracts, but it discovered after buying Magnavox that it had acquired its own capabilities in GPS and was therefore less inclined to pursue partnerships with companies such as Mayflower in that area.

Intellectual Property

In 2010, Mayflower received a patent for its Antijam Filter System and Method for High Fidelity High Data Rate Wireless Communication. This technology filters interferences so that clean filtered signals are subsequently processed for data extraction using widely available wireless communication technologies. The anti-jam filter is especially effective when the number of receiver antennas exceeds those of the transmitter. Overall, according to USPTO, Mayflower has received four patents.

Awards and Recognition

Mayflower was SBA's 1998 Graduate of the Year. Mayflower's current and past customers include DoD (Air Force, Army, and Navy), Department of Transportation (Federal Aviation Administration), NASA, and numerous industrial customers. GPS Wing (GPSW) designated Mayflower as an Authorized SAASM P(Y) Code GPS Receiver Developer, one of the seven companies (and the only small business) to be so recognized.

TABLE F-4 Mayflower Communications Patents

7,994,971	GPS-based measurement of roll rate and roll angle of spinning platforms
7,852,964	Anti-jam filter system and method for high-fidelity high-data rate wireless communication
5,596,600	Standalone canceler of narrow band interference for spread spectrum receivers
5,268,927	Digital adaptive transversal filter for spread spectrum receivers

SOURCE: U.S. Patent and Trademark Office online database, accessed September 26, 2011.

Mayflower and SBIR

Over much of its history, Mayflower has relied more on commercial contracts than the SBIR program for revenue. This approach is reflected in the funding stream from SBIR, which reached $2 million in only one year prior to 2008, averaging approximately $700,000.

Since 2008, Mayflower has been especially successful. Not only did it receive more than $10 million in SBIR funding in 2008-2010, but also it succeeded in transitioning 9 of its 10 2007-2010 Phase I awards into Phase II—a remarkably high success rate, which suggests that DoD customers are increasingly appreciative of the technology being developed at Mayflower.

According to Dr. Upadhyay, more than one-half of the recent growth at Mayflower is attributable to its success with SBIR projects. Dr. Upadhyay noted that the SBIR program provides a critical pathway for small businesses, because it offers a route through which small companies can talk directly to DoD staff and betters positions the companies in discussions with primes. This positional strength helped Mayflower develop positive relationships with a number of large companies working with DoD, notably Boeing and BAE Systems, as well as with Draper Laboratories. As a consequence, Mayflower has become a company that sells products, not technologies—a much more desirable strategic position in his view.

Recommendations for Improving the SBIR Program

Dr. Upadhyay identified the need for improvement in the role and operations of the TPOC from the defense services. In his opinion, many TPOCs "do not have their heart in it." Often, the TPOC assigned to manage an SBIR award is not involved in the design of the topic. Overall, there are poor linkages among the originator of the topic, those who approved and edited the topic, and those who managed its implementation, especially beyond Phase II. Overall, Dr. Upadhyay divided TPOC's into three groups: those from research backgrounds, those from the acquisitions programs, and those who are part of the DoD bureaucracy. He suggested two ways in which these issues might be resolved.

1) DoD could assign a second TPOC to an award, whose job would be to connect the award to the DoD acquisitions process. This would engage acquisitions and would ensure that DoD maximizes its return on its SBIR investment.
2) SBIR legislation could be adjusted to permit the use of 5 percent of SBIR funding—currently provided to the company— to the TPOC to manage the award (e.g., travel to the company site) and become more deeply involved with the company.

MICROCOSM INC.:
SBIR CASE STUDY

Based on interview with
Dr. Jim Wertz, President
Ms. Alice Wertz, Chief Financial Officer
Hawthorne, CA

Established in 1984, Microcosm is a small business specializing in reducing space mission cost. The company started as part of Ithaco, Inc. (now part of BF Goodrich) before going independent. During the 1980s, Microcosm worked primarily as a subcontractor to the primes on space-related projects. However, by the late 1980s this work began to dry up, as primes began to take the work in-house.

At about this time, Microcosm discovered the SBIR program, which in the company's view had the huge advantage of permitting it to act as its own prime, connecting directly to customers in the government. A run of five successful SBIR projects starting in 1993, which all converted to Phase II, helped to fund development of the company's core technologies.

Since then, Microcosm has slowly built up its technical capacity by providing a range of space-related products and services, while continuing to improve its core low-cost launch technology. The latter is now at or close to deployment across a range of launch profiles.

The family of products includes two suborbital vehicles and a series of progressively heavier duty configurations, using a multi-module launch architecture. Total vehicle costs range from less than $200,000 to about $29 million for the largest vehicles, which are capable of lifting 13,000 lbs to low Earth orbit. This exceeds an order of magnitude cost improvement compared to existing launch capacities in use at NASA.

Given the difficulties in funding innovative concepts such as Scorpius® and the new NanoEye micro-scale observation satellite, that any small company might experience, Microcosm generates ongoing revenue through its Space Systems Division, which serves the industry's needs in mission and systems engineering and in space orbit and attitude systems.

Technology and Core Capacity

According to Dr. Wertz, Microcosm has always focused on cost containment and cost reduction. For much of its history, this meant that the company worked to some degree at cross-purposes with the mainstream of the industry, where the need for success in launching payloads was much more important than any cost considerations.

Dr. Wertz believes that the industry, in recent years, has increasingly valued the approach adopted at Microcosm, and he anticipates that with increasing cost pressures—and the advent of a commercial space sector—

opportunities for Microcosm will continue to expand. Microcosm has worked in a number of areas related to reducing space mission cost:

- **Autonomous Orbit Control.** Microcosm has developed and flown algorithms for fuel-optimal precision orbit maintenance. The code can be used as a ground-based tool or can fly on-board to provide fully autonomous orbit control.
- **Attitude Determination and Control Systems (ADCS).** Microcosm designs, analyzes, integrates, and tests complete attitude determination and control systems. Its tools—such as AttSim—support efficient development of ADCS systems for gravity gradient, zero momentum, momentum biased, or thruster controlled systems.
- **Constellation Design and Management.** Microcosm is a world leader in this segment, with a particular focus on systems- and mission-level analytics, pragmatic solutions that work on-orbit, and cost-reduction mechanisms. Dr. Wertz edited the current standard text, *Orbit and Constellation Design and Management*. Autonomous on-board orbit control, described above can dramatically reduce the complexity, cost, and risk of constellation design and management.
- **Formation Flying.** Microcosm has recently extended the current state-of-the-art in formation flying by developing dynamic models based on a linearized state transition matrix methodology.
- **Autonomous Rendezvous and Docking.** Microcosm's work supports development of autonomous rendezvous and docking (AR&D) guidance, navigation, and control systems.

Currently, the Launch Systems Division of Microcosm is developing the Scorpius® family of ultra-low-cost launch vehicles. These vehicles offer the potential for an order-of- magnitude reduction in the cost of launching payloads to low Earth orbit (LEO).

Once these launch vehicles are in full operation, Microcosm estimates that projected recurring launch costs will be approximately $5 million for the smaller Sprite (1000 lb payload) and $29 million for the much larger Exodus capable of delivering 13,000 lbs to LEO. The Scorpius® project is primarily funded by Air Force, though a suborbital target vehicle was developed, but as yet not flown for the Missile Defense Agency.

Microcosm's Space Systems Division focuses on space mission architecting, mission and systems engineering, and related orbit and attitude analysis services. The company claims to have unparalleled experience in space mission engineering among small companies and even among larger companies. The division has worked with almost all small-spacecraft prime contractors, and it has worked on mission and systems engineering for many large commercial and government programs, including Iridium, GPS, Teledesic, and Discover II. These projects cover a range of system engineering areas, such as spacecraft, navigation, attitude, and orbit control systems design and performance analyses, on-board autonomy, orbit and constellation design, coverage analysis, mission utility assessment, and cost estimation.

Products

Although much of Microcosm's work takes the form of contracts for helping to manage different aspects of space missions, the company has developed a number of products that it sells to the industry. These include the following:

- Microcosm has more than one dozen contracts, four patents, and several commercial and flight software systems in the area of autonomous navigation and on-board orbit control, a core capability. The company has similar expertise in attitude determination and across the range of mission management and applications.
- The company also developed and patented the Microcosm Orbit Control Kit (OCK), an onboard software system that autonomously maintains the spacecraft in a pre-defined (or adjustable) station-keeping box. The OCK uses sensing, control, and computing hardware already on board most spacecraft and typically requires less propellant than orbit maintenance done from the ground.

Recent developments of particular significance revolve around the use of composite materials for fuel tanks and, in the case of NanoEye, for creating a unibody spacecraft structure, which is also the propellant tank.

By using composite materials and combining the propellant tank with the structure, Microcosm can reduce the weight of the spacecraft very significantly. For spacecraft, weight is the principal driver of cost.

The Scorpius® high-level propellant tank exceeds current requirements in several areas. The cost is less than \$275 per ft^3, the weight is less than 1.6 lb/ft^3 at 600 psi, and it meets life cycle, strength, and reliability thresholds. Microcosm believes this approach will deliver an order-of-magnitude reduction in tank cost. The all-composite fuel tank has been successfully flown on the Microcosm SR-XM-1 launch vehicle and on a Garvey Spacecraft Corp. rocket.

Publications and Knowledge Transfer

Unusual for a small business, Microcosm is responsible for a number of key textbooks on space mission engineering. The company created and published *Space Mission Analysis and Design* (SMAD), a 1,000-page text and practical reference work in mission design and concept exploration. Originally developed for the Air Force, the text is, according to Microcosm, the most widely used book in astronautics. It includes substantial work directly relevant to low-cost space mission engineering provided by Microcosm personnel. These efforts are directly in line with the Congressional mission for SBIR.

Microcosm also published *Reducing Space Mission Cost* (RSMC), a follow-on to SMAD that discusses spacecraft design, construction, testing, launch, and mission operations. It addresses both traditional and radical cost reduction methods and describes 11 case study missions in detail. Microcosm publications also include:

- *Space Mission Engineering: The New SMAD* (Space Technology Library, Vol. 28, J.R. Wertz, D.F. Everett, and J.J. Puschell, eds., 2011)
- *Reducing Space Mission Cost* (Space Technology Library, J.R. Wertz, ed., 1996)
- *Spacecraft Attitude Determination and Control* (ISBN: 9027712042, J.R. Wertz, ed., 1994)
- *Orbit and Constellation Design and Management* (Space Technology Library, J.R. Wertz, 2001)
- *Mission Geometry; Orbit and Constellation Design and Management—Spacecraft Orbit and Attitude Systems* (Space Technology Library, Vol. 13, J.R. Wertz, 2001)
- *Reinventing SMAD—Methods for Dramatically Reducing Space Mission Cost and Schedule,* in preparation.

Microcosm also provides two training workshops on “Space Mission Engineering” and “Reducing Space Mission Cost.”

Microcosm and SBIR

Microcosm has received 48 Phase I and 25 Phase II awards, totaling approximately $24 million.[31] The company is a strong proponent of the SBIR program and has used SBIR funding to start almost all of its major technology initiatives, according to Dr. Wertz. He also said that, with success rates above normal, the company is well regarded within the program.

Aside from its own SBIR awards, Microcosm has been very active in the local SBIR community in Los Angeles. The company is on the board of the local small business economic development council, and has guided a number of local companies into the SBIR program.

However, Microcosm raised a number of issues, which it believes has seriously negative effects on the development and take-up of technologies through the SBIR program.

[31]SBA Tech-Net database, accessed February 25, 2012.

DoD Contracting Process

Microcosm executives agreed that overall the contracting process is fundamentally broken because it does not effectively support agency objectives. The Obama Administration made an early decision to exclude non-government employees from handling contracts, but had insufficient employees to replace them.

In addition, contracts have become much more burdensome. For example, a recent Phase I contract at DoD included clauses requiring Microcosm to implement procedures to inform employees that they are not permitted to text while driving.

Task order contracts, which are more common, add dramatically to costs for the small business. For example, a recent contract assigned a prime contractor as the owner of the contract—requiring them to be paid a fee for managing the contract, that the prime contractor do some portion of the work, and that they retain review responsibilities over the project. Moreover, subcontractors are not permitted to order supplies through a task order contract—they must order all material and must put all Microcosm subcontractors under contract to the prime, which makes the management needed to get the work done both awkward and challenging. Some DoD officials have limited understanding of the process. They do not, for example, see the difficulties caused by requiring small businesses to operate as subcontractors to primes.

Payment Structure

Microcosm executives noted that the significant mismatch between the cash flow needs of small companies and the rigid payment structures of the federal agencies is a perennial problem. There are significant differences between the agencies: NASA, for example, disburses funding in thirds against progress, but the Army pays equal amounts monthly. Army's payment structure leads to significant problems when expensive pieces of equipment must be purchased or expensive testing is required. Dr. Wertz points out that recent SBIRs have had a payment structure with no up-front payment, small fixed payments well into the program, and a large final payment at the end—i.e., the small business is effectively financing the federal government.

Indeed, Dr. Wertz observed that NASA Centers require cash payment for testing and equipment use, which can lead to delays. For one Microcosm project, important design decisions had to be delayed until testing could be completed much later than was optimal, because the company had to accumulate sufficient funds to pay for the relevant design optimization.

Rigid payment structures also mean that projects are essentially fixed cost, with no billing against hours permitted, despite attracting all the bureaucratic problems of rate-based contracts (see below). For some agencies, this problem is magnified in Phase II. For Microcosm projects, the Army was not prepared to commit to a second year of SBIR funding even for Phase II awards, which introduced significant uncertainty in company hiring decisions. Even for Phase II enhancements, which for Microcosm is usually focused on prototype development, equal payments are mandatory and have the effect of slowing development significantly.

Contracting Officers and TPOCs

Contracting officers (COs) are under enormous pressure, as the volume of contracts have increased and the number of COs has not, according to Dr. Wertz. Many COs have little understanding of the SBIR program, and rules regarding SBIR Phase III awards are almost universally ignored.

Some TPOCs have been very helpful. One TPOC at Kirkland Air Force Base worked to resolve problems for the company and went out of his way to be helpful. However, he was the exception rather than the rule. Most TPOCs are confronted by incentives that lead them to pay little attention to their SBIR projects.

NANOCOMP TECHNOLOGIES INC. (NCTI): SBIR CASE STUDY[32]

Based on interview with
Peter Antoinette, CEO
Michael Gurau, CEI Community Ventures (investor)
September 19, 2011[33]
Concord, NH

Nanocomp Technologies Inc. (NCTI) is a privately held company headquartered in Merrimack, New Hampshire. It was formed in 2004 by three founders—then-CTO David Lashmore (the inventor), President and CEO Peter Antoinette (the business leader) and Bob Dean, owner and President of Synergy Innovations, a technology innovation laboratory in Lebanon NH. The company currently employs about 77people and is located in a 100,000 ft. sq. state of the art manufacturing facility at its headquarters.

What Are Carbon Nanotubes and How Are They Made?

Carbon nanotubes (CNTs) are a special form of carbon related to graphite, a hexagonal lattice of carbon, which is commonly found in pencils, lubricants, and even contacts in electric motors. CNTs differ from ordinary graphite because the carbon atoms are formed into a different completed

[32]All factual information in this case study is drawn from the interview and from other material made available by NCTI, unless otherwise referenced.
[33]Some factual information updated August 2014 by Mr. Gurau.

structure. In graphite the atoms form long, flat, parallel planes, while CNTs are usually a single sheet formed from a layer of pure graphite rolled into seamless cylindrical hollow fibers, with a diameter of 1 to 10 nanometers and lengths generally tens of microns long. Hence most CNTs have a high aspect ratio—they are hundreds or thousands of times longer than they are wide.

Since not long after the discovery of carbon Buckyballs in 1985, it has been clear that CNTs have extraordinary properties.

- **Strength.** In 2000, a multiwalled carbon nanotube was tested to have a tensile strength of 63 gigapascals (GPa); equivalent to a breaking strain of 6,422 kilograms on a cable 1 mm thick. [34] It has been established that single- and multi-walled nanotubes can produce materials with unmatched toughness[35]
- **Electrical conductivity.** In theory, metallic nanotubes are extremely good conductors of electricity; they can, for example, carry an electric current at a density more than 1,000 times greater than copper.[36]
- **Thermal conductivity**. Nanotubes are good conductors of heat along the direction of the tube, comparable to copper,[37] but are also good insulators laterally to the axis.
- **Low weight**. Finally, CNTs are extremely lightweight in comparison to materials that they might replace—notably copper in wiring, steel in structural applications, and shielding.

Clearly, CNTs have enormous potential.

Challenges of Commercializing CNTs

The promise of CNTs has been limited by three core challenges:

1) **Material limitations**. Commercially available CNTs are generally short—usually tens of microns long. Short tubes exhibit CNT characteristics to a reduced degree, which makes materials using them less competitive for many applications.
2) **Material format.** Commercially available CNTs are generally available only in powder formats. This is a substantial disadvantage—as with most powders, these can be difficult to incorporate into final

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[34]M-F. Yu, O. Lourie, M.J. Dyer, K. Moloni, T.F. Kelly, R.S. Ruoff, Strength and breaking mechanism of multiwalled carbon nanotubes under tensile oad, *Science* 287(5453):637-640, January 28, 2000.

[35]A.B. Dalton, et al., Super-tough carbon-nanotube fibres, *Nature* 423(4):703, 2003.

[36]S. Hong, S. Myung, Nanotube electronics: A flexible approach to obility, *Nature Nanotechnology* 2(4):207-208, 2007. Metallic nanotubes can carry an electric current density of 4 × 109 A/cm2, which is more than 1,000 times greater than those of metals such as copper.

[37]D. Mann, Q. Wang, K. Goodson, H. Dai, Thermal conductance of an individual single-wall carbon nanotube above room temperature, *Nano Letters* 6(1):96-100, 2005.

manufactured goods. Most final applications for CNTs will require that they be incorporated into formats that are more useful to end users—cables, mats, sprays, etc.

3) **Health and safety.** Working with powder—particularly CNT fibers of this short length-- involves substantial health and safety challenges, both for the workforce and for potential users of products based on powder form CNTs. A number of studies have shown that CNTs are potentially harmful to human health; CNTs at the short length that the vast majority of manufacturers produce can in some cases cross membrane barriers,[38] while the shape of CNTs is somewhat similar to asbestos.[39] Final products made from traditional powdery nanotubes may tend to have poor bulk properties, exhibiting less than optimal strength and conductivity.
4) **Cost.** Inefficiencies in the manufacturing process—and the very low volumes currently being generated—mean that the cost per unit for CNTs is orders of magnitude higher than for materials whose manufacturing was optimized decades ago, such as aluminum or copper. According to NCTI, significant amounts of impurities are usually generated in CNT manufacture, and hence extensive and expensive post-growth purification is usually needed to remove these impurities.

NCTI Technology[40]

NCTI sees its competitive advantage in four areas:

1) The length of its nanotubes
2) A unique integrated manufacturing process
3) Safety
4) Capacity to develop intermediate products

NCTI has developed methods to continuously produce very long, pure, carbon nanotubes, in the millimeter range of length, at high growth rates. These CNTs have an aspect ratio measured not in the hundreds or even thousands, but almost one million. And longer nanotubes mean greater strength, higher conductivity, easier handling, and greater product safety.

[38] J. Kolosnjaj, H. Szwarc, F Moussa, Toxicity studies of carbon nanotubes, *Advances in Experimental Medicine and Biology* 620:181-204, 2007.
[39] C.A. Poland, R. Duffin, I. Kinloch, A. Maynard, W.A.H. Wallace, A. Seaton, V. Stone, S. Brown, et al., Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study, *Nature Nanotechnology* 3(7):423, 2008.
[40] Descriptions of NCTI technologies and products are derived from material provided by NCTI. These claims have not been independently verified (although a search found no evidence to the contrary).

At the same time, NCTI's process produces very pure materials that do not require post-growth purification. High initial purity, combined with high output production rates hold the promise of achieving excellent process economics and product affordability as the process is scaled.

Moreover, as noted above, CNTs have not until now been provided in commercially attractive formats. The NCTI process fabricates its nanotubes into structurally strong and electro-thermally conductive fibers, yarns, and sheets.

Yarns have been plied on commercial wire braiding machines to produce CNT wires ranging from 33 gauge to 22 gauge or lower.

It is also possible to impregnate CNT rolls on commercial equipment with a wide variety of commercial resins including Bismaleimide toughened epoxy (BMI) and the cyanate ester family.

The material can be further doped to increase electrical conductivity, to enable conductor and electromagnetic interference (EMI) shielding applications that require high conductivity.

Taken together, these advances mean that some of the advantages of CNTs identified in the laboratory are now being delivered at commercially significant scale—and which can therefore be used to address a range of potential markets.

- **High Strength**—NCTI's spun conductive yarns exhibit breaking strengths up to 2.1 GPa expressed and fracture toughness that is higher than products such as Kevlar® or Twaron®. CNT sheets have breaking strengths, without binders, that range from 500 MPa to 1.2 GPa depending upon tube orientation. For reference, aluminum breaks at 500 MPa, carbon steel breaks around 1 GPa.
- **Electrical Conductivity**—NCTI yarns and sheets carry more current than copper and are more conductive than copper at high frequencies. Therefore, they can be used as a substitute for copper or other metal braid in single or multiple conductor shielded cable. Weight savings here may range from 30 to 50 percent.
- **Thermal Conductivity**—NCTI products can transfer more heat than copper or silver on a per weight basis.
- **Thermoelectric behavior**—NCTI products demonstrate a Seebeck coefficient of greater than 60 μV/ºK and power greater than 1 watt/gram.
- **Extremely Lightweight**—NCTI products are less than half the weight of aluminum.

NCTI's sheets and yarn articles are composed of a continuous mesh of long bundles of nanotubes that connect to one another to form long, interlaced fibers. As a result, these materials have high integrity, which in turn sharply limits CNT release during processing. NCTI sheets and yarns have been crushed, cut, torn, sanded, ripped, and twisted while being monitored by the most sophisticated detection equipment available. In no case were any CNTs released to the environment.

It should be noted also that NCTI has developed a manufacturing process that is carbon-negative, being based primarily on bio-fuels as a source of energy for production furnaces; uses iron as a catalyst in place of the potentially more toxic catalysts such as cobalt or molybdenum used in many CNT production platforms; and is operated as an entirely sealed closed-loop process.

Finally, NCTI has been delivering product to customers for some years; in 2009 it announced that it had delivered a 10 km cable to a Fortune 100 client. To date, The Company has delivered more than 2 million meters of its conductive yarn to commercial and government customers.

Business Strategy

NCTI is seeking to position itself as the provider of a unique class of “intermediate inputs”—products where CNT materials have been worked into an intermediate product that is then sold to a company that incorporates it into a final product.

In pursuing this strategy, NCTI has created value-added components such as conductive cables, thermal straps, EMI shielding “skins,” and high strength sheets or yarns for incorporation into final end-user products.

Currently, NCTI is focused on demonstrating the efficacy of its technologies in a range of applications. Most recently, in August 2011 NCTI sheets were used to provide EMS shielding on the June spacecraft. NCTI material was used as a surface layer on several critical components of the flight system’s attitude control motor struts and the main engine housing. The Juno spacecraft will travel through Jupiter’s extremely strong radiation belts,” and NCTI offered an alternative to traditional aluminum foil typically bonded to the surface of composites. By including CNT sheet layers during fabrication of the composite, Lockheed was able to integrate electrostatic discharge (ESD) protection directly onto the structure.

The Juno mission could be an important inflection point for NCTI: not only did it mean that NCTI’s core technology was now space qualified against the rigorous standards set by NASA in support of a very important space mission, but also NCTI showed that it could be a reliable partner to a prime contractor, supporting its business strategy as a provider of intermediate inputs.

Over the medium term, NCTI expects to explore opportunities in an increasingly varied range of sectors and applications, beginning with very high-value/high-margin opportunities. These are clustered in aerospace, where the electrical and low-weight characteristics of NCTI products are especially competitive. With the cost per pound of launch to orbit at $20,000 or more, any weight reduction for space-based applications is immediately attractive even at relatively low volumes and high production costs. The Company’s sheets are presently qualified and being bid in large government (special forces) ballistic armor applications in which these sheets enable lighter, thinner and higher performance personal armor protection.

NCTI sees particular opportunities in areas where at least two of its core competitive advantages in electrical conductivity, tensile strength, and low weight can come into play.

NCTI has also successfully developed important connections to prime contractors, an area where small SBIR companies can have difficulty. The company has worked with Lockheed Martin on the Juno project, and Northrup Grumman is now a subcontractor to NCTI, which is acting as the prime for the Air Force Research Library (AFRL) SBIR contracts.

Nanocomp and SBIR

Unlike many companies that use the SBIR program as the first pump-priming funding to start the company, NCTI is positioned to use the program to fund critical development work along the transition from batch to mass production.

In 2010, NCTI won an oversized Phase II award of more than $4.5 million from the AFRL to "Scale Up Production, Optimize Properties of Large-Format Carbon Nanotube Sheets for Future Use in Manned and Unmanned Aircraft."[41] The award is designed to support NCTI's work on developing replacements for metal-based EMI shielding and electrostatic discharge ESD components on manned and unmanned aircraft. The Phase II award will support NCTI's work to optimize CNT functional properties for shielding requirements and to scale up production volume while reducing the cost of finished CNT-based pre-pregged products. Northrop Grumman Aerospace Systems and Cytec Engineered Materials will act as subcontractor to NCTI in this Phase II contract.

The Phase II AFRL award builds upon successful demonstration under Phase I that large-format CNT sheets can meet the functional requirements of EMI shielding, as well as withstand the industrial stresses involved in pre-pregging, a process that prepares the material for direct insertion into aircraft manufacturing systems. This research has been officially designated by Ashton Carter, Under Secretary of Defense for Acquisition, as a "critical SBIR program," which helps to explain the very large size of the award.

According to Mr. Antoinette, even though the SBIR awards have come later in the technology development process than is sometimes the case, they have provided critical validation for the company and for its technology, which has helped in discussions with prime contractors and customers and in attracting investors. Michael Gurau of Community Ventures, who led the Series A round in 2006, observed that these awards would be important when NCTI sought further funding to expand production. He noted that this validation is especially useful in sectors such as materials and defense, where venture funding is scarce,

[41] See <*http://www.sbir.gov/sbirsearch/detail/7699*> for the full award abstract and details.

and is becoming increasingly important overall as early stage venture capital appears to be entering a "death spiral."

Mr. Antionette also observed that the SBIR program should be viewed as one of several related ways in which government works with small companies such as NCTI to support the development and commercialization of innovative technologies. In NCTI's case, this support has resulted in world-leading technology. Much of this funding has been on the basis of shared risk, because government funding does not cover the full cost of development. It is also usually on the basis of highly competitive funding competitions such as SBIR, which ensures that the government is awarding contracts to high-quality producers.

Mr. Antionette said that companies like the SBIR program because, even though the success rate for applications is quite low, it is regarded as a fair competition and successful companies receive numerous benefits.

Other Government Support

NCTI has successfully attracted attention and financial support from a range of U.S. government agencies and programs beyond SBIR:

- **Army**. In 2004, NCTI received $2 million from Army's Natick Soldier Systems Center.
- **NASA.** The Juno space mission in 2011 potentially marks an important inflection point for the company.
- **Army/ManTech**. Funded through Army's Manufacturing Technology Program (ManTech), NCTI will work in partnership with Northrop Grumman to develop manufacturing best practices for a next generation of CNT cabling and tapes, intended for near-term insertion into aircraft as a replacement for conventional copper-based wires and cables.
- **DoD certification.** DoD, through its Title III Defense Production Act, has designated NCTI's products as "critical to national defense." To date, the Company has been awarded $25M in TIII funding to scale its manufacturing capacity.

Together with the SBIR awards discussed above, NCTI has received continuous government funding for the past 4-5 years. This funding complemented the A round of financing closed in 2006 and enabled subsequent venture capital financing rounds in 2009 and 2011. This funding has been especially important because there are limited opportunities to attract outside investment for products that are based in materials science and focused initially on defense markets.

NAVSYS:
SBIR CASE STUDY

Based on interview with
Dr. Alison Brown, CEO and Co-founder
September 13, 2011
Washington, DC

NAVSYS Corporation (NAVSYS) is a privately held company headquartered in Colorado Springs, Colorado. Founded by in 1986 by Dr. Alison Brown, the company "uses advanced technology and novel system architectures to improve on conventional GPS equipment and methods for specific market applications."[42] The company now employs 35 staff, up from 31 in 2009, and had revenues of more than $6 million in 2010, up by over two-thirds from 2007.

Dr. Brown started NAVSYS after leaving Litton Industries in California when her husband got a teaching job at the Air Force Academy, and the company has continued to leverage Dr. Brown's early experience at Litton working with GPS and inertial technology.

The company's first contract was to build a translator to receive and relay the GPS signal from a ground station at Vandenberg Air Force Base in California.

This line of business was extended, and NAVSYS grew rapidly after the French conglomerate Dassault Group hired it to develop a GPS system for a missile test range on the west coast of France. Subsequent contracts from the Federal Aviation Administration and the Japanese government were acquired, focusing on making the GPS system more reliable and accurate for civilian aviation.

NAVSYS also developed cell phone technology in partnership with the Colorado Department of Transportation and the Colorado State Patrol, winning a grant from the Federal Highway Administration aimed at developing systems that would permit emergency dispatchers to determine the location of emergency calls from cell phones.

Business Model

NAVSYS has focused primarily on licensing its technology for use in larger systems, primarily in the defense sector. The company has also been successful in acquiring Phase III contracts from DoD.

NAVSYS entered a period of severe crisis in 2007. SBIR awards had led NAVSYS to develop technology that used GPS to improve the accuracy of "smart bombs." The company had expanded to 50 employees in anticipation of a Phase III contract, but the Air Force instead awarded the contract (and the

[42] Annual Report, 2010.

technology) to Boeing. NAVSYS was forced to lay off one-half of its workforce in 2007, and Dr. Brown mortgaged her house and other assets to generate the $1.5 million in cash NAVSYS needed to survive. According to Dr. Brown, "It was a blatant example of how Air Force Space Command didn't follow (Federal) rules designed to protect technology developed by small business. We appealed to the deputy undersecretary of defense, the Small Business Administration and (former U.S.) Sen. (Wayne) Allard and got the decision reversed, but it nearly put us out of business." A loan from First National Bank of Monument—guaranteed by Dr. Brown—has now been largely repaid. According to the 2010 annual report, only $250,000 is now owed.

Since the 2007 crisis, NAVSYS has refocused to some extent away from military and toward commercial markets. Technologies developed at NAVSYS include tools for use in police helicopters to keep cameras trained on suspects and to test telecommunications equipment. After the controversy over the 2007 Boeing contract (see below), NAVSYS has continued to receive Phase III funding from DoD, and the move into civilian markets has offset sagging revenue in 2011 due to delays in military contracts as a result of the federal budget impasse in Congress.

Dr. Brown expects to double the size of NAVSYS, both in employees and revenue, by licensing technology it developed to incorporate location information into digital photos and developing lightweight, inexpensive but secure GPS receivers for military personnel.

She also wants to transition ownership of the company to an employee stock ownership plan that now owns about 4 percent of its stock.

Technologies and Products

NAVSYS has developed a number of commercial products and services primarily based on the GPS technologies developed with support from SBIR funding. NAVSYS products fall into three main groups:

- GPS receiver products
- GPS/Inertial products. The GPS/Inertial InterNav contract with FLIR Systems generates significant licensing revenue streams and continuing product sales; NAVSYS is now seeking similar relationships in other markets for GPS/Inertial software
- Simulator products

GPS Inertial Video System (GI-Eye)

The GI-Eye system consists of a low-cost, tactical-quality inertial unit integrated with a GPS receiver and a digital video camera. The key element is however the proprietary software developed by NAVSYS. This system is used to extract precise target coordinates from video imagery without requiring any known data points for georegistration. It records the precise location and attitude of the video images, so that the extraction of feature location data is simplified and streamlined. Commercial applications for this system also exist in the Geographic Information System (GIS) and digital mapping industries in speeding the collection of geographic data and attribute coordinates. GI-Eye is currently the most important commercial product developed by NAVSYS, which received more than $500,000 in licensing revenue from this product in FY2010.

Targeting systems have been developed for both commercial and government applications, including the National Geospatial-Intelligence Agency and Office of Naval Research and FLIR Systems' Star SAFIRE airborne electro-optic imaging system. The tools can be used for stabilized thermal, low-light, and television imaging systems designed for surveillance and reconnaissance aboard airplanes, helicopters, and UAVs.

GI-Eye technology has been extended to other products at NAVSYS, including the InterNav GPS system, which allows images to remain centered on a specific target location as the aircraft maneuvers, reducing jitter and operator loading.

Software Defined Radio

Joint Tactical Radio System (JTRS) radios[43] require GPS position and time for networking and waveform initialization. NAVSYS uses a "GPS-Lite" solution to provide software to reduce power requirements and weight.

POSCOMM[44] Software Defined Radio

POSCOMM technology provides GPS-like signals broadcast within the industrial, scientific, and medical radio band (ISM) that can be used for navigation by software-defined radios equipped with POSCOMM software. NAVSYS believes this technology has potential to meet the need for an indoor positioning system to support first responders and also military operations in urban terrain.

TIDGET®

The base TIDGET sensor is a low-cost device that can be used for locating vehicles and other objects when combined with a communications data link. The device is much simpler than a conventional GPS receiver, which reduces costs, increases response times, and requires less power drain.

[43]The Joint Tactical Radio System (JTRS) is planned to be the next-generation voice-and-data radio used by the U.S. military in field operations after 2010.
[44]Positioning and Software Communications defined radio.

TIDGET has been used for a wide range of applications, such as tracking radiosondes, sonobuoys, dropsondes, air-deployed pallets, and even buffalo, tapirs, and penguins.

NAMATH Tactical Control Station (TCS)

The NAMATH TCS was developed under a Phase III SBIR contract to improve GPS accuracy for the Air Force Small Diameter Bomb (SDB) and was transitioned into operational use in late 2006. According to Lt. Gen. Frank G. Klotz, then Vice Commander of Headquarters Air Force Space Command, now the Air Force Assistant Vice Chief of Staff, "Talon NAMATH ensures the most up-to-date GPS data possible is provided directly to the cockpits of aircraft carrying out attacks against enemy targets. When employed with the Air Force's newest precision weapon, the small diameter bomb, this capability makes strikes more precise, and therefore more effective, while at the same time limiting collateral damage."[45]

TALON NAMATH: Illustrating The Procurement Challenge for SBIR Companies

The Talon Namath system was very successful technically—delivering more than initially expected, according to Dr. Brown. The system was lauded by senior Air Force staff, including Lt. Gen. Frank G. Klotz, then Vice Commander of Headquarters Air Force Space Command (SMC), and General Kevin P. Chilton, then the four-star Commander of Air Force Space Command and now Commander of United States Strategic Command. The latter noted, "The small-diameter bomb, which was a dream just a few years ago, now is actually out in the field used in combat, flying off F15Es. To bring that small-yield weapon, you've got to be really precise. It's linked very tightly to our GPS constellation. We've got folks who have figured out a way to make sure when that bomb comes off the [F-15E], it has the best signal possible through a system called Talon NAMATH."

Yet on the commercial side, matters have been different. After successfully completing Phase I contract with AFRL, the Air Force TENCAP Command awarded NAVSYS a Phase III in 2005. The work proceeded rapidly and AF TENCAP declared the system "provisionally operational in December 2006." In fact, the program was accelerated to meet the needs of war fighters. In 2008, NAVSYS became the first small company to receive the Association for Enterprise Integration (AFEI) award for Excellence in Enterprise Integration.

Normal procedure at that point would be for the Air Force either to award a contract for further development to NAVSYS or to include the company in a larger team developing and applying the system. Instead, Air Force awarded the contract to Boeing, as part of the Zero Age Message & Data Service

[45]Speech to the National Defense Industrial Association (NDIA), February 2007.

(ZMDS) contract in April 2007. NAVSYS was not included on the Boeing team, and SMC failed to notify the SBA of this departure from normal procedures as required by law. NAVSYS appealed through both the Air Force and eventually to SBA, which issued a stop work order with which Air Force complied. A year later, Air Force provided a formal response to the order and work restarted.

Air Force Space Command finally notified Air Force Air Combat Command (ACC) that flies the F-15E and uses the Small Diameter Bomb that it needed to take responsibility for the Talon NAMATH program. However, the GPS funding remained as part of the SMC budget, according to Dr. Brown, so operational progress has been limited.

SBIR Awards

NAVSYS won its first SBIR award from the Air Force in 1989. Since then, it has won a total of 119 awards, primarily from DoD but also from NSF, NASA, the Department of Transportation, and the Department of Commerce. On average, NAVSYS received about $1.5 million in SBIR awards annually. Over the past 5 years, SBIR funding as a percentage of contract revenue has held steady, averaging just less than 30 percent.

IP and Knowledge Effects

NAVSYS has published widely on GPS-related technologies. As of mid-2011, more than 165 technical papers were available on the NAVSYS web site.

SBIR Issues and Recommendations

Dr. Brown emphasized that the problems NAVSYS experienced with Talon Namath have implications far beyond the immediate issue. Not only is DoD at risk of failing to acquire the best technologies, but also there are long-term implications for small high-tech companies who are a key part of the military supply base. Effectively, if there is no path into procurement or if the path is considerably higher risk than necessary, then, in Dr. Brown's view, there is no long-term business model for NAVSYS or companies like it in serving the military. In particular, it makes it more difficult if not impossible for companies to become less dependent on SBIR funding.

Dr. Brown also noted that Phase III funding has become more difficult to acquire. In the past, NAVSYS has used Congressional plus-ups to fund further development, but these are now very rare.

In addition, Dr. Brown has observed wide variations even within the Services with regard to their use of small business in general and SBIR in particular. She believes for example that less than 2 percent of SMC contracts by value are with small business.

Dr. Brown was a lead on an industry study that reviewed the DoD acquisition process. The study determined that the vertically integrated model for the primes developed during the Cold War has led to significant dysfunctions, and primes continue to compete with suppliers. For example, subcontractors are almost always prohibited from making any contact with the final DoD customer.

Vertical integration, according to Dr. Brown, leads to obvious conflicts of interests throughout the procurement process, because prime contractors are effectively in the position of making decisions about whether to fund their own projects and research or those of smaller competitors. In areas where the SBIR program was especially successful—notably some parts of Navy—a more competitive support base had been encouraged.

Dr. Brown also noted that there are significant problems related to intellectual property and data rights, which are the life blood of small firms—the value that can be used to generate ongoing revenue. Yet despite clear evidence that problems are growing—notably through violations by agency staff—there has never been a prosecution on this basis. In effect, although the nominal data rights are well designed, in practice they are not sufficiently protected by the agencies, especially at DoD.

Overall, Dr. Brown strongly supports the SBIR program and believes that the problems identified above are much broader than the SBIR program, which could in fact play a leading role in solving them.

NIELSEN ENGINEERING & RESEARCH: SBIR CASE STUDY

Based on interview with
Mr. Michael Mendenhall, President and CEO
February 13, 2012
Santa Clara, CA

Nielsen Engineering & Research (NEAR) was founded in 1966. According to Mr. Mendenhall, NEAR was at the time one of five to six similar companies focused on aerodynamics R&D and problem solving. That niche, however, was too small to permit much growth, and during the 1970s NEAR expanded its areas of competence (and staffing) to provide much wider ranging technical solutions.

In the late 1960s through the early 1980s the company successfully acquired a number of sole source contracts from NASA and DoD, focused on solving problems identified by the staff at NASA Centers and DoD agencies. This strategic focus ended during the 1980s when NASA and DoD became increasingly reluctant to offer sole source contracts. The company contracted and refocused on more commercial work.

The company made a comfortable living providing aerospace R&D and technical services to a wide range of clients (see below) throughout the 1990s up until the financial crisis in 2007.

Since 2008, the company has been going through a challenging time. Not only have traditional commercial clients faced the need to scale back some activities, but also SBIR success has become much less consistent. Mr. Mendenhall observed that this was partly because appropriate topics appear to come up less often and partly because the nature of the SBIR program is changing in ways that do not suit companies such as NEAR.

Today, NEAR is fundamentally a technology service provider in the broad field of fluid mechanics, primarily for aerospace. NEAR states that "the basic philosophy has been to attempt to solve relevant technical problems using the best technology available in the fluid mechanics world, whether or not it has been developed by NEAR." It currently has six full-time and three part-time engineers and scientists specializing in fluid mechanics and computational methods.

Key Capabilities

NEAR's mission is to develop and acquire knowledge of fluid mechanics and to transfer this knowledge to the aerodynamics industry by consulting and software licensing. Analytical services are available to customers who require data for evaluating new ideas, for supporting wind tunnel and flight tests, and for FAA certification efforts. In addition, NEAR's R&D and resources can support customers who need help with creating new products or enhancing systems/processes.

NEAR has over the years developed or acquired a range of analysis tools for aerodynamics and hydrodynamics, including computational fluid dynamics, engineering-level numerical methods, custom-designed analytical software, laboratory and wind tunnel testing, and hardware development and evaluation. These services cover the following technical areas:

- Aerodynamic Design and Analysis
- Advanced Computational Fluid Dynamics
- Knowledge Management Systems
- Reduced-Order Modeling
- Flow-Related Sensors
- Aerodynamic Hardware Solutions

Awards and Recognition

Since 1980, NEAR engineers have received nine NASA awards for "the creative development of a technical innovation." NEAR staff members have served on more than 20 technical committees and government-organized review boards, such as the American Institute of Aeronautics and Astronautics, the Naval Aeroballistic Advisory Committee, and NASA Peer Review Committees. NEAR has received several recent leadership and achievement awards from the NASA Engineering and Safety Center for work on special projects.

Clients

NEAR has been in business for more than 45 years and has collected a formidable collection of clients in the United States (both commercial and government) as well as internationally. Domestic clients include almost all of the prime contractors working in aerospace, including the following:

- ATK
- Space Exploration Technologies (Space X)
- United Technologies Aerospace Systems
- Bell Helicopter
- Boeing Military Airplane
- General Dynamics, Electric Boat Division
- Goodyear Aerospace Company
- Integrated Systems, Inc.
- Lockheed Georgia Company and Lockheed-Martin, Missiles and Fire Control
- Loral Vought Systems
- Martin Marietta
- McDonnell-Douglas Aircraft Corporation
- Orbital Sciences Corporation
- Raytheon Missile Systems
- Rockwell International
- United Technologies Research Center
- Westinghouse Electric Corporation

U.S. government clients include the following:

- Air Force Office of Scientific Research
- Air Force Systems Command
- Air Force, Wright Aeronautical Laboratories
- Army Redstone Arsenal
- Army Research Office
- Army Research and Development Command
- Department of Energy
- NAWC Weapons Division, China Lake
- NASA Ames Research Center
- NASA Armstrong Flight Research Center
- NASA Langley Research Center

- NASA Marshall Space Flight Center
- NASA Glenn Research Center
- National Science Foundation
- Naval Air Systems Command
- Naval Sea Systems Command
- Naval Coastal Systems Center
- Office of Naval Research

NEAR has worked for universities, including Johns Hopkins University Applied Physics Laboratory and the Massachusetts Institute of Technology Lincoln Laboratory. NEAR also serves a wide range of international clients, in countries including Korea, Germany, the UK, Brazil, the Netherlands, Spain, Japan, Norway, France, Turkey, India, and Singapore

NEAR and SBIR

NEAR has received approximately 75 Phase I and 39 Phase II awards totaling approximately $26 million. The company has served almost all branches and components of DoD that issue SBIR awards.

Mr. Mendenhall observed that one of the biggest challenges for SBIR companies has been the DoD contracting and auditing systems. In recent years, DCAA appeared to respond to a recent critical report from GAO by failing large numbers of small businesses—an approach that Mr. Mendenhall described as being a drastic over-reaction. He believes that NEAR's experience with DCCA was not untypical. Because DCAA refused to explain specifically why NEAR failed an audit, the company had to guess at corrective actions until approval could be obtained. In his view, this effort to maintain a completely arm's length relationship was little short of ridiculous—and had enormous negative consequences for the company. While NEAR was in failed audit status it was not able to receive new contracts. This situation was corrected without serious financial implications.

Moreover, communications with DCAA were extremely slow—it took the agency 18 months to complete routine audits that a CPA could complete for a normal small business in a few weeks at most. For NEAR, this meant an 8-month delay in the receipt of Phase II funding, during which NEAR would have had to lay off staff had two engineers not moved on to other opportunities. Currently, DCAA is more than five years behind in their audits of NEAR accounts.

Mr. Mendenhall also observed that contracting can generate problems. In part, SBIR funding can be too back-loaded to support the kind of front-end activities required for a successful project. In addition, Phase II awards can generate uncertainty because they could be canceled midcourse, which is more likely if the TPOC changes.

Mr. Mendenhall recommended that all SBIR awards be treated as fixed price contracts to address the difficulties involved in pricing labor and to reduce uncertainty for recipients. In effect most SBIR Phase II awards are treated as fixed cost, without the concurrent benefits.

The SBIR program has changed in Mr. Mendenhall's view. It is increasingly focused on product development as a form of commercialization, which means that companies focused on solving problems for agencies are increasingly frozen out. This change has substantially affected DoD, sharply reducing the number of applications open to NEAR, somewhat less so at NASA. NEAR used to identify around 20 possible topics for a proposal in each solicitation and would then work to reduce the final number to 3-4; today the company is fortunate if it can find even one topic to which it can respond.

Mr. Mendenhall also observed that the Company Commercialization Report (CCR) scores generated for DoD applicants do not account for the fact that almost all of the work undertaken by companies such as NEAR are covered by ITAR, which severely limits commercialization to the civilian sector. Consequently, a small business who has had a number of SBIR contracts, but has been limited in commercialization opportunities, receives a low CCR score which incurs a penalty in the proposal rating system.

The TPOC's role can be critical, Mr. Mendenhall noted. In his considerable Phase II experience, the company has encountered only one unsatisfactory TPOC—a staffer close to retirement. However, TPOCs can stand between the company and the ultimate customer, which NEAR experienced with Navy a number of years ago, for example. This can make it difficult to pursue Phase III effectively.

Mr. Mendenhall believes that the quality of Phase I reviews in particular has declined in recent years, possibly because staff has less time to conduct them. He has noticed a rise in what he considers to be random or not-relevant comments, some of which clearly affect the success of the proposal.

Finally, Mr. Mendenhall recommended that all SBIR agencies consider the approaches adopted for other programs at DARPA and DoE, where companies are encouraged to submit a short white paper, after which they are notified whether a full proposal is warranted. SBIR's low success rate overall imposes substantial costs on small businesses. He also noted that any opportunity to review preliminary comments during the selection process would probably improve outcomes for both the company and the agency.

Update from the Company

At this update in mid 2014, NEAR is working on one Navy Phase II SBIR contract which has good commercialization potential even though it is under ITAR control. NASA is still providing a reasonable level of funding to the company, and a number of commercial companies have come to NEAR for assistance on specific aerodynamic problems, a sign that the overall economy in the aerospace industry is improving. NEAR has added several retired NASA engineers to its staff for work on aerospace problems which can benefit from the "greybeard" expertise and corporate memory generated during more than one-hundred years of technical experience. The DCAA audit for calendar year 2008 is still ongoing, but there is hope it may be completed before the end of this year.

OPTEMAX: SBIR CASE STUDY

Based on interview with
Shirley Collier, CEO
August 31, 2010
Columbia, MD

Optemax aims to solve increasingly pressing technical problems that face the military and in some cases non-military users of communications technology. For aerial surveillance, where sensors and hyper spectral imaging generates massive bandwidth requirements for high-definition real-time video, military requirements are for highly secure communications that provide extremely high bandwidth—on the order of 10-100 gigabits per second. These requirements are far beyond the capacity of standard radio frequency (RF) services. RF—with substantial enhancements on existing capabilities—may reach 1 G/ps. In addition, RF is inherently a broadcast mechanism and cannot be tuned to shield signals. Optemax is developing optical laser-based technology to address these needs. It has developed the BeamNet® mobile wireless optical networking system.

History

Founded in 2004, Optemax has licensed wireless optical networking technologies from world-class research institutions including Johns Hopkins University (JHU). Through collaborative research and development, Optemax believes that it will be able to deploy 40+ Gbps secure communications to mobile entities within a network, over a range of 100 Km or greater.

Optemax was founded by Shirley Collier and her husband Thomas Collier after they sold a previous venture, Paragon Computer Services. Optemax was founded to commercialize university technologies, and it focused on laser-based communications in part because of high-level research capabilities at local universities.

Technologies were licensed from the Applied Physics Laboratory at JHU and formed the basis for the approach funded through NAVAIR SBIR (see below). However, the relationship with JHU eventually dissolved. According to Ms. Collier, JHU staff could not understand the requirements of commercial R&D, especially the need for secrecy, and insisted on publishing results before they could be commercially protected. These drivers of standard university activity could not be constrained even by the existence of standard nondisclosure clauses in the licensing and research agreement. Moreover, JHU is a large recipient of federal R&D funding. It appears that over time JHU determined that participation in commercial ventures—in which government agencies would likely end up paying commercial rates for technology acquisition—might endanger their primary R&D funding streams. Ms. Collier also noted that, although JHU scientists were very capable of specifying technical *problems*, they appeared less ready to develop commercially viable *solutions*. This clash of cultures eventually led Optemax to relinquish its $250,000 investment and dissolve the partnership.

Since then, Optemax has developed a network of engineers and technicians, using a dispersed work rather than a physically based central office. This has allowed Optemax to minimize overhead.

Currently, Optemax seeks funding to move further toward a deployable technology suitable for military or civilian use. Ms. Collier noted that the optical technologies at the core of BeamNet™ are extremely expensive to develop and that her original estimate called for investment of approximately $10 million to reach commercialization for this technology.

Technology

Because there are inherent limitations in laser-based technology, Ms. Collier has positioned BeamNet as a complementary technology—providing strong advantages when it is available, but acknowledging that weather conditions sometimes make laser-based technologies inoperable. Anticipated 90 percent availability would not be acceptable for backbone communications services (where 99.999 percent availability is required) but would provide sufficient access for such a complementary role, according to Ms. Collier. She also noted that areas of the globe where the technology would likely be used are also areas where cloud coverage is at a minimum.

BeamNet integrates a number of different cutting-edge technologies, including networking, forward error correction, advanced optics, and routing algorithms. The BeanNet system has three components:

- An appliance, which provides the primary computing platform, including optical modem, storage, and processing power
- A software suite, which controls the hardware, provides continuous monitoring, and manages processes such as weather mitigation
- A gimbal-mounted FSO terminal, which includes a telescope, camera, and media conversion technology

The technology is currently at approximately TRL 4-5, at the pre-prototype stage. Optemax is seeking funds to move the technology to TRL 6.

Optemax and SBIR

Optemax won one Phase I, Phase II, and initial Phase III funding from the Naval Air Systems Command (NAVAIR) in 2005 and 2006. Optemax was awarded a Phase II research contract to demonstrate a BeamNet prototype to satisfy NAVAIR requirements for an aerial LPI/LPD communications network as part of the EPX program, aimed at developing a future SIGINT program for Navy.[46]

Phase III Experience

Optemax has had mixed experiences with Phase III. The company found support and a sponsor in a program that targeted high-level manned surveillance. Optemax was in line for further support when the program was canceled at the end of 2009.

Prior to that, Optemax successfully acquired a Congressional earmark for further research. Since then, Optemax has been working to find connections to other possible funding sources, including prime contracts (especially Lockheed Martin) and other DoD acquisition programs, notably Navy unmanned surveillance programs. Unfortunately, the primary sponsor for Optemax research at Navy has since left federal employment. There have, however, been some successful contacts at the engineering level, but not with PEOs or other potential funding supporters.

Indeed, Ms. Collier explained that she has identified a very likely fit with the E6 program at Pax River but has been completely frustrated by the refusal of Navy staff to share contact information for relevant staff within the program. It appears as though all contacts have to be made second- or third-hand via press and public relations officers.

Optemax experienced a similar lack of success via the Navy Commercialization Assistance Program. Ms. Collier described the program as being primarily designed for scientists and engineers with minimal understanding of markets and marketing, which, given her extensive marketing background, provides her with minimal new information. Optemax also participated in the Navy Opportunity Forum, but it discovered that these events attract large numbers of marketing staff from primes, rather than acquisitions and operations staff. Therefore, Optemax generated no additional contacts beyond the company's existing network. Ms. Collier noted that, in her experience, primes are not especially interested in encouraging or supporting early-stage research, being much more focused on later stages of the TRL readiness spectrum.

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[46]Planned as a replacement for the EP-3 Aries aircraft, the EPX will be a manned multi-mission, multi-intelligence, surveillance, reconnaissance and targeting (ISR&T) platform. *Defense Update,* EPX—Studying a Future SIGINT Platform for the US Navy, February 8, 2008, <*http://defense-update.com/newscast/0208/news/news_080208_epx.htm*>.

These experiences led Ms. Collier to formulate a number of possible improvements to DoD SBIR programs. Ms. Collier believes that NAVAIR SBIR staff is focused on spreading SBIR money to a large number of companies and have adopted a highly linear view of technology development and the role of SBIR awards. In this model, a single Phase II award is sufficient to move a company's technology past the prototype stage to TRL 6 or better, which Ms. Collier noted rarely exists in the real world. However, its dominance at NAVAIR makes it difficult for companies to acquire the multiple awards needed to build a substantial platform for an advanced and complex technology such as optics-based wireless communications.

Ms. Collier was also highly critical of what she considers to be lack of transparency regarding upcoming DoD platforms and technology requirements. She believes the decision to discontinue the Advanced Technology Review Board was a mistake, eliminating an important medium through which companies could find TPOC sponsors and supporters.

Ms. Collier also observed that large primes exert too much influence, which results in over-reliance on incremental improvement of existing technologies instead of support for truly disruptive innovations. In addition, despite efforts to improve funding flows, gaps between Phases are still significant and cause difficulties for small firms.

Overall, Ms. Collier is a strong supporter of the SBIR program, but believes that it should be reorganized to provide larger amounts of funding for highly promising projects, rather than distributing funding widely across a broad array of recipient companies.

OPTO-KNOWLEDGE SYSTEMS INC. (OKSI): SBIR CASE STUDY

Based on interview with
Dr. Nahum Gat, Founder and President
February 8, 2012
Torrance, CA

OKSI specializes in the development of turn-key electro-optical sensor systems, especially those that combine imaging and spectroscopy, including the mechanical assembly, electronics, optics, computer interface and signal acquisition, algorithms for signal and data processing. OKSI focuses on R&D projects where off-the-shelf solutions are unavailable.

The company was founded by Dr. Gat in 1991, on the basis of successful Phase I award (which had the positive side effect of proving to the Internal Revenue Services (IRS) that the company was in fact a going concern).

The company has tried several times to move beyond small batch production and prototypes into manufacturing, but has not yet been successful. Recently the company has been exploring the DoD program for Low Initial Rate Production (LRIP).

Technology and Products

OKSI has developed a number of technologies related to its mission of "converting light into knowledge." These have included an intelligent fire detection system (in the late 1990s), a number of hyperspectral systems, multispectral imaging systems for use in particular in aircraft (e.g., the Airborne Multispectral/Thermal imager, which is used for plant stress and vigor analysis, ground thermal mapping, and ground imaging), and a range of other imaging technologies such as infrared imaging, software for spectral analysis, and technologies integrated into surveillance systems and platforms.

True Color Night Vision

Among the most interesting current technologies are those developed for true color night vision. With the wars in Iraq and Afghanistan, DoD demand for high-quality night vision technology has expanded rapidly. OKSI's approach has been to develop a true color technology, which is contrasted with existing false color and monochromatic technologies.

The prototype produces a true-color night imagery camera system, using a visible/near infra-red color EMCCD camera fused with output from a thermal long wave infra-red (LWIR) camera. The fusion draws complimentary information from both images while retaining true color information. The system can work to produce true-color images in light down to about the level of quarter moon, after which it switches to fused monochrome and thermal. At lower light level the system reverts to thermal only. The system works in real time to generate both digital and analog-video outputs at 30 frames per second.

According to Dr. Gat, Army has shown very strong interest in the technology. The True Color Night Vision—Fusion system did not move forward because the Army decided that the EMCCD technology was too expensive, had high power consumption, and had high noise level. So the Army decided to invest in a new technology to replace the EMCCD.

IP

According to the publications page of the OKSI web site,[47] OKSI staff has authored more than 100 papers in the broad field of opto-electronics. In addition, the company has received 12 patents based on its work funded by SBIR.[48]in the field of infra-red cameras.

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[47]*<http://www.optoknowledge.com/publications.html accessed March 15 2012>*.
[48]<http://www.optoknowledge.com/patents.html>.

OKSI and SBIR

OKSI has received more than 50 Phase I and 25 Phase II awards since 1991, totaling about $20 million. Most of the awards have been from DoD, with the remainder from NASA and DoE/NNSA. Within DoD, OKSI has received awards from all the major service branches and several others.

Overall, about one-half of OKSI's revenues are currently from SBIR awards, a share which has not changed much in recent years. This funding was especially important in early years, helping the company to "get on the map," according to Dr. Gat. Although the company can now get non-SBIR contracts, the SBIR program is still invaluable for entering technical areas that are otherwise dominated by either large prime contractors or universities. For example, OKSI has undertaken a number of non-SBIR contracts with the Missile Defense Agency (MDA), for whom it has developed sensors for many different kinds of missions, in most cases acting as its own prime contractor. Without the SBIR program, OKSI would not have been able to build sensors and demonstrate its technology directly to MDA.

Dr. Gat noted a continuing and substantial gap between the Phase I and Phase II funding streams at DoD. In fact, for a recent SBIR award, OKSI received a Phase I option at the same time as its Phase II award, which meant that 3 to 4 months of work schedule was lost.

These awards have, according to Dr. Gat, been the basis for essentially all of the-cutting edge technology developed at OKSI. And the technology clearly has been valued by the agencies. In addition to multiple SBIR awards, OKSI has received quality awards. In 2011, OKSI received a Tibbetts award, which followed a 2006 Army Quality Award for its Continuously Variable Aperture/Cold Stop technology, which is used for automated target recognition in the Future Combat Systems platform as well as other applications.[49] OKSI partnered with Raytheon and L-3, DRS Communications, and Cincinnati Electronics to implement this technology. OKSI received a Phase III from Army for this project, plus additional funding from its partners to adapt the technology to their own cameras. Following successful prototyping, the Army opened a solicitation for systems development and demonstration.

However, according to Dr. Gat, Army eventually decided to work directly with the primes. Despite the facts that the partners signed highly restrictive nondisclosure agreements (NDAs) and that SBA sent a letter to Army requiring it to cease violating the governing SBIR policy directive, Army continued to freeze out OKSI. As a result, OKSI has been very careful in its dealings with the primes.

However, as Dr. Gat observed, a technology company working in the defense sector has few options for commercializing its products beyond the primes, given DoD's strong preferences for working with its established contractors. In fact, OKSI is working with other primes on a system to enhance

[49] Army SBIR Quality Awards, 2006.

driving vision with infra-red technology. OKSI is helping to convert the currently all-analog system to provide digital outputs. OKSI is designing and building electronic boards that will replace the existing technology. . More recently, Dr. Gat noted that the customer program has been eliminated following budget cuts, so this project is now on hold. OKSI is now working with yet another prime on the True Color Night Vision, and has submitted a joint proposal to the DoD.

SBIR Problems and Recommendations

Overall, Dr. Gat strongly supports the SBIR program, which he believes provides a key innovation platform for DoD. However, he noted a number of significant and in some cases growing problems.

- **Many topics came from the research side, especially for the Army but also Air Force.** This tends to create significant gaps between topic authors and acquisitions programs.
- **There is a particular problem aligning SBIR awards with acquisitions**. For example, OKSI demonstrated its night vision technology for DoD and found an enthusiastic audience—but no clear path toward a requisition that would allow purchase of the technology.
- **Small companies are essentially on their own to find acquisitions partners.** The night vision technology may in the end be picked up by DoD. There was, however, no marked path or guidance to help OKSI find this potential buyer.
- **There are difficulties in working with universities**. SBIR contracts require that publication has to be approved by the agency, which presents a problem for universities, since they have rules for unrestricted publications in for peer review journals. While the collaborating faculty may agree (on a "hand-shake basis") to restrict their publishing in case of SBIR collaborative efforts, the university administrator would not accept any restricting clauses in the subcontract. In addition, almost all of the work undertaken by OKSI is covered by ITAR, which place too many restrictions on the flow of knowledge for most universities to accept.
- **There are problems with contracting and auditing**. Like other SBIR firms in southern California, OKSI experienced serious problems with DCAA, the DoD audit organization. Dr. Gat noted that DCAA prides itself on using a single standard for audits, regardless of the company size, which in his view imposes significant costs on small business. In addition, DCAA does not provide the information needed to correct any possible errors and takes far too long to complete its work. At OKSI, DCAA took 7 months to complete an audit for a 15-person company. OKSI failed because of inadequate written procedures—which had the

effect of holding up a number of critical contracts, some of which were critical for the agency as well as the company. He believed that DCAA was 3 years behind in auditing indirect rates for his company.

POWDERMET INC. AND MESOCOAT INC.: SBIR CASE STUDY

Based on interview with
Dr. Andrew Sherman—Founder, Powdermet and MesoCoat; CEO, MesoCoat
September 24, 2012
By telephone

Powdermet is a privately held nanotechnology and advanced materials research and development organization, headquartered in Euclid, Ohio. The company was founded by Mr. Andrew Sherman as a spinout of Ultramet, Inc., in 1996, with a mission to "mature and transition clean, sustainable, energy and life-saving advanced materials solutions to the marketplace."[50] Powdermet focuses on the commercial development of advanced nanoengineered composite powders, using its technologies to develop materials that reduce weight, resource consumption, environmental footprint, and life-cycle costs, while increasing energy efficiency.

Powdermet technology was initially based on the extensive research and resulting intellectual property developed by Ultramet Inc. (another SBIR recipient company). This IP was licensed to Powdermet in 1997, and the operating group that developed them at Ultramet moved to Powdermet. In 1997-2005, Powdermet acquired the exclusive worldwide rights to the proprietary Chemical Vapor Deposition (CVD) technology developed at Ultramet over the prior three decades (limited to particulate coating), and successfully completed the development and commercial scale-up of a powder encapsulation and vapor-conversion nanoparticle production process. Technologies were developed for scalably depositing numerous metals and ceramics onto particle sizes ranging from submicrometer to 100 mils.

In 2003, the company relocated from California, where it operated a 7,000 sq. ft. R&D facility, to Ohio, where the company currently operates a 54,000 square foot manufacturing facility enabled through a minority interest corporate VC investment. From 2002-2005, Powdermet was listed twice in the INC 5000 with a roughly 80 percent annual growth rate, completed ISO9001 quality system development and implementation, completed a brownfield cleanup and environmental restoration of an EPA listed, unutilized and non-productive urban industrial site in a labor surplus area, and increased capacity in its initial 18,000 sq. ft. high bay manufacturing building to more than 10 R&D, pilot, and production reactors capable of producing 100,000 lb/year of

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[50]Powdermet Inc., "About Powdermet," <*http://www.powdermetinc.com/company_overview.html*>. Accessed September 24, 2012.

nanoengineered particulates, and with plans, approvals, infrastructure, and permits for 2-3,000,000 lb nanocomposite and microencapsulated powder production capacity.

Powdermet's commercial success and continued SBIR support allowed it to substantially expand its research facilities. In 20067-2008, the company renovated the 36,000 sq. ft. former TRW Caldwell Research Center, a three-floor R&D Center with more than 26 individual labs, and opened the "Nanomaterials Research Center" in summer 2008 including a high-temperature thermal analysis and XRD lab, a furnace/sintering lab, a mechanical, friction, and wear characterization lab, a foam processing lab, a refractory metals lab, and a coating development/thermal spray laboratory.

In 2008, Powdermet spun-out its life of asset wear and corrosion control solutions (surface engineering) group into Mesocoat Inc., which went public as Abakan Inc and is listed under the ticket symbol ABKI. In 2013, a second spin-out, Terves Inc (Hungarian for "to Plan") was formed to pursue commercial introduction of "environmentally responsive metals", structural nanocomposite materials that sense and respond to the environment. A third spin-out, Cratos Energy, was formed in 2014 to commercialize nanocomposite thin film capacitors, currently demonstrating 20X state of the art energy storage capabilities with record-breaking 20-30 J/cc film capacity.

Origins and Development Trajectory

At Ultramet, Mr. Sherman was the principal investigator on SBIR awards from 1987-1996, and was the company's chief metallurgist and business development manager. It was his original vision of "nanoengineered powder metallurgy", or building in nanostructural features to micron-mm sized particle "repeating microstructural units" which led to the spinout from Ultramet. The company licensed the relevant technology from Ultramet and hired several Ultramet staff (a spinout that was amicable on both sides—Ultramet did not wish to dilute its core focus to enter the areas in which Powdermet focused).

From the beginning, Powdermet was premised on the belief that success would require the ability to scale—that simply being an R&D house was not the objective. Even a pilot plant was, however, too expensive and hence risky for Ultramet, as it required a significant investment and permitting change. So initial funding came from Mr. Sherman, friends, and family, and then from SBIR and a series of private investors (as well as a loan/contribution from Ultramet). Mr. Sherman observed that "the role of the entrepreneur is to provide early vision—passionate knowledge and drive—prior to the time where sound financial metrics can be used to drive the business."

Overall, the initial startup of the company attracted about $1 million in capital, with about 75 percent being debt. A key early support came from the National Institute of Standards and Technology (NIST) in the form of an ATP award, which essentially matched the initial investments with a further $1 million, funding the company during its first 2 years of operations.

Initially, the company was based in southern California in Pacoima and then San Fernando California. It received technical support from LARTA (a Los Angeles area nonprofit that supports innovation[51]), which helped attract angel funding and also helped with capital structuring. The decision to move to Ohio was driven by a number of factors, notably:

- **The high cost of land in California.** The company sought land to build what was in essence a chemical plant. Dr. Sherman noted that land costs were on the order of 95 percent cheaper in Ohio.
- **Regulatory concerns.** Because California has very strict environmental regulations, and was not supportive of the specialty chemical industry, Powdermet might not have been able to build the plant, even if it had the land. In contrast, he believed that regulatory and permitting problems could be worked out efficiently in Ohio—as they were.
- **Encouragement from Kennametal.** This strategic partner wanted Powdermet close to its own operations, especially its largest cutting tool facility, which was in Ohio.
- **The Third Frontier Program.[52]** Through this program, Ohio offered a substantial amount of business planning support on a cost share basis (a program that has since been eliminated).[53]

Once in Ohio, Powdermet developed in two directions. First, it built a $300,000-$500,000 annual revenue "toll production" business through which it provided customized materials (mainly coatings) for use by large companies (typically Fortune 100/500). Second, it began to explore partnership options for developing a business that would go further downstream, producing the coatings themselves as well as the specialized materials that are used to produce coatings.

In 2002, the company formed a strategic alliance with Kennametal Inc., a large producer of components and products for the aerospace, auto, mining, machining industries as well as agriculture. The partnership was based in part on the idea that Powdermet—in which Kennametal took a minority equity stake with a view to eventual purchase—would become the cutting-edge research arm, providing new technologies that would provide Kennametal with a competitive edge. Powdermet in turn would utilize SBIR awards to generate the technology and fund the company's ongoing operations. The first connection with Kennametal was forged via the ATP award from NIST, focused on the market for cutting tools, and eventually led to the building of a nano-engineered carbide powder production plant in Cleveland

[51]See <*http://www.larta.org*>.
[52]A technology-based innovation support program and fund based in the Ohio State Development Services Agency, <*http://development.ohio.gov/bs_thirdfrontier/default.htm*>.
[53]According to Dr. Sherman, Third Frontier now focuses on much larger partnerships and projects.

Ohio seemed like a good location in other ways. Powdermet's dealings with the state were productive. The state offered significant tax incentives and leverage for the Kennametal investment in the form of a 166-direct loan. Finally, because Powdermet bought a renovated a brownfield site, it was eligible for additional financing for land acquisition and cleanup. Overall, the new facility cost about $6 million to acquire, clean-up hazards from prior industrial operations, renovate, and purchase and install the nanoengineered powder production equipment.

The transition from California to Ohio was not without cost: Powdermet lost key employees among its 15 total employees. Still, the new facility offered Powdermet with an opportunity to scale up production. Kennametal was ready to use its output and its strategy—to utilize the Kennametal brand, market knowledge, and management expertise to leverage Powdermet's ability to develop technologies and processing capabilities—appeared to be working. Global market shifts intervened, however. In 2002-2003, Chinese intervention in the global tungsten market led to a fall in price of 50-70 percent. As a result, Kennametal radically shifted its strategy, from focusing on technology (and particularly nanotechnology) to focusing on tungsten sourcing, pricing, and market consolidation—tungsten being a large part of Kennametal's overall business.

By 2004, Kennametal's commitment to new technology and to Powdermet had essentially vanished. Furthermore, a new CEO had new ideas. Eventually, the partnership unwound (amicably) with Powdermet providing Kennametal with a license to cutting tools technology as well as some of the equipment used for joint projects. Mr. Sherman bought out Kennametal's preferred positions and options to invest further to buy a controlling interest in Powdermet. The agreement to unwind was concluded in 2004, although the unwinding itself took some time longer.

From 2002 to 2005, Powdermet experimented with a number of markets. It worked on penetrators and warheads with DoD (largely through SBIR). For a while it was a significant player in the battery industry, because it had the production infrastructure and the capacity to build nanocomposite cathodes, and its R&D100 (2000) award winning fluidized bed production technology could overcome mass and heat transfer limitations enabling production of high quality nanoengineered C-LiFePO4 composite cathodes at tonnage quantities needed for commercial use.

In 2005-6, with the primary market of hard materials and tooling exclusively licensed to Kennametal, the company made some more strategic shifts, and refocused its commercial main focus on chrome replacement and coating applications of its nanomaterials, using much of the same technology but for a new set of applications. This was helped by a new federal executive order in 2005 which required the elimination of chrome—which requires highly toxic manufacturing processes—in government applications. This opened new markets for the company's technology.[54]

The chrome replacement technology was based on Phase I/II SBIR technology, derived for an Army SBIR award for wear resistant, thermally insulating coatings to improve efficiency and reduce emissions and heat rejection in diesel engines using nano-engineered thermal spray coatings. This program turn led to 2 order of magnitude improvement in wear resistance over state-of-the-art coatings. Based on these SBIR results, the Ohio Third Frontier program provided business plan development funding under an SBIR commercialization matching grant program.

Spinout of MesoCoat, Inc.

By 2007, the business planning was complete, and Powdermet was ready to spin out a new company, MesoCoat Inc, to address the new opportunities in coatings. Powdermet retained its core processes and still had solid revenues of $500 thousand to $1 million from toll processing work. It also continued to win highly competitive SBIR awards to continue to improve the technology and customizing nanomaterials for DoD and other agency needs.

The spinout was driven not only by the need for distinct strategies for the two parts of the business, but also because earlier efforts to raise external funding for Powdermet had left the capital structure too complicated to attract the funding needed for rapid growth. In addition, Powdermet could not take on significant additional corporate or venture capital without losing SBIR eligibility, which remains part of its core strategy as the primary, and largely the only source of non-dilutive financing for high risk technology development. MesoCoat was formed as a wholly owned subsidiary, which licensed technology from Powdermet in the surface engineering field of use as well as some physical assets. The spin-out structure was designed with Powdermet as a service provider/support, and with an equity position to align its interests and return mechanisms directly with equity investors to facilitate financing.

The new company was initially monetized and brought into existence via Congressional earmark (based on the need to find a chrome alternative and eliminate use of hex chrome) as the route to financing the Phase III. Funding came from the House Appropriations Committee, Air Force, and prime contractors, with $1.6M spread over the 2008 and 2009 appropriations cycles (the third year was unfunded due to elimination of earmarks and the untimely death of Congresswoman Stephanie Tubbs-Jones in 2010. This earmark was leveraged with a Jumpstart (regional economic development corporation) loan for $350,000, and in 2009, MesoCoat closed an additional $1.4 million seed investment round that includes milestone-based options for an additional $18.8 million.

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[54]Executive Order 13423, 2007.

By the time MesoCoat was up and running and seeking serious capital in late 2008 to continue growth, the window for venture capital (VC) investments had effectively closed with the market crash of 2008. In fact, the company was is due diligence for an investment with a corporate partner in the oil and gas industry at the time of the financial crash- the corporate partner was wiped out with the loss of a $500M line of credit and ultimately went bankrupt in early 2009. Due to the strength of the technology platform, SBIR and industry validation, MesoCoat able to find a corporate venture partner in Abakan Inc., whose principles had roots in the mining industrial sector. Abakan principles believed that the proven financial valuation models based on prospecting, proving reserves, and then exploiting an opportunity could be applied in technology-driven industries like coatings as well as in mining and oil and gas in order to capitalize technology based businesses using the small cap public marketplace. This same financial model has also been applied by Abakan principles to solar and superconductor technologies (Tape Solar), and several other (mainly DOE/national-lab) technology spin-outs/start-ups as well

Most recently, Mesocoat has become a wholly-owned subsidiary of Abakan, completing the "creeping take-over" agreement, and has completed construction and bringing to initial operational status an 11,000 sq. ft,, 5.4 acre new clad pipe manufacturing demonstration facility located next to Powdermet's facilities.

With management transition complete at Mesocoat, Mr. Sherman is now focused on monetizing and transitioning the environmentally responsive and light metals technologies through a new spin-out Terves Inc following the mesocoat (and originally Powdermet-Ultramet) license model. Terves has recently raised nearly $1M in seed capital which was used to develop and qualify high strength "triggered" (disintegrates upon a chemical triggering event) disintegrating magnesium completion tools, and is in the process of raising its series A to meet growing market demand for this and related products for reducing the cost and environmental impact of oil and gas operations.

Mesocoat Technologies

Powdermet and MesoCoat together have developed technologies to underpin two broad lines of future applications: coatings and claddings.

Coatings

Thermal-sprayed coatings can be very effective in increasing component life and value, decreasing machinery down-time, and improving performance. They have a wide range of potential applications in numerous industry sectors. Thermal spraying processes coat a surface by spraying melted (or heated) materials onto it. They can provide thick coatings over a large surface area at high deposition rate as compared to other coating processes, and they can use metals, alloys, ceramics, plastics, and composites.

Feedstocks are fed in as powder or wire, heated to a molten or semi-molten state, and accelerated toward substrates as micrometer-size particles. Because the sprayed surface does not necessarily heat up significantly, the coating can be made from flammable substances. Coating quality is measured by assessing porosity, oxide content, macro and micro-hardness, bond strength, and surface roughness. Generally, the coating quality increases with increasing particle velocities.

MesoCoat's technology constitutes a substantial improvement on state of the art, according to Mr. Sherman. MesoCoat claims that its coatings can extend the life of components by 3-20 times and are cheaper, lighter, and involve minimize use of toxic materials.

PComP's (MesoCoat's coatings) are cermets (ceramic-metal composites) fabricated into a hierarchical structure, using a patented process to engineer down to the nanoscale. The result is a microcomposite cermet coating that the company claims offers revolutionary performance and cost breakthroughs. The technology for this application was based on the Army SBIR Phase II award, and further developed and perfected using the congressional earmark funding, and a related SBIR from the department of energy on nuclear criticality control for waste and fuel packages that taught Powdermet how to design with a wide range of materials in the structure. PComP Materials are now in commercial use, primarily for replacing chrome plating and extending too, pump, and valve life in the oil and gas industry. The primary advantages are 3-7X the toughness of traditional cermets (due to the hierarchical structure), combined with improved wear, excellent machinability, and extremely low friction performance derived from the engineered nanostructured features.

Mesocoat has developed new compositions under a Phase I/II DOE (ARRA) award, and is launching a PComP version which is virtually immune to wear, corrosion, and thermal shock in metal processing operations (zinc coating), where it expects a successful commercial launch and major industry cost and energy savings to be achieved in 2014-2015.

Cladding

MesoCoat also has a cutting-edge cladding technology, CermaClad™. This is a high-speed high-energy-density fusion cladding process for large areas that the company claims can clad materials 15-100 times faster, is cost competitive, and offers better metallurgical properties than the competitive weld or laser cladding processes. Traditional thermal spraying delivers only 5 lbs of material per hour—which were insufficient for Navy ship-scale needs which were a target application of the materials technology. To solve this problem, a research partnership with Oak Ridge National Laboratory generated a technology that can deliver 500 lbs/hr of coating, which is 80-100 times higher productivity, simply enabling for Large area applications such as preventing corrosion of infrastructure

CermaClad™, fusion cladding, utilizes a high-intensity light source to rapidly fuse metal and ceramic coatings onto steel pipes, plates, and bars. Process speed is sufficient to match the line speed of steel mills and hence reduce lead times for clad pipes, plates, and bars by 75-80 percent. The same technology can be used to protect large surface areas in highly caustic and corrosive environments. Mr. Sherman describes the long term-vision as "paint the world with stainless steel", and has aspirations for the technology to augment or replace organic coatings with metallic coatings that have 10-100 times greater durability.

Other Awards

MesoCoat was recently recognized by Forbes as one of "The Most Promising American Companies" and was the highest ranked material science and nanotechnology company on the list. Powdermet has won approximately 100 federal and state awards (including SBIR awards) over its 18 year history. It has been the recipient of four R&D 100 awards, three NorTech Innovation Awards, a wall street journal "manufacturing technology of the year" award, the pipeline innovation guilds "subsea technology award", and numerous other industry accolades and recognitions. The companies have made the INC 5000 list of fastest growing companies 4 times.

Future Strategy and Prospects

MesoCoat's revenues have tripled annually since 2008, and the number of employees increased from 3 to 30 during the same period. FY2011 revenues equaled $3.5 million; FY2012 revenues are projected to be about $8 million, and 2014 $40 million. As new plants come on line, this growth rate is expected to continue, according to Mr. Sherman.

MesoCoat/Abakan are raising about $20 million to support expansion in Brazil and Canada, as well as a third target site in the Middle East or Asia. All three are primarily focused on the oil and gas industry. Existing partners in Houston are also growing rapidly. Abakan Inc., MesoCoat's largest shareholder and a publicly traded company, is providing growth capital (perhaps better understood as late stage venture funding).

Since forming Mesocoat in 2008, Powdermet has been under new management. It remains a primary supplier of raw materials to MesoCoat, and it continues working with the SBIR program to advance the next technology platform. With recent maturity and transition of Mesocoat more fully under Abakan (now 90 percent owner), Mr Sherman is working to successfully monetize and transition light and reactive metals (Terves), and Energy storage (Cratos Energy) technologies which have reached sufficient validation and maturity to be of interest to the financial (venture) markets using SBIR and other (primarily ATP/TIP, and previously congressional directed funding).

Powdermet, MesoCoat, and SBIR

As Table F-5 indicates, Powdermet successfully pursued awards from five agencies, although DoD predominates and accounts for 75 percent of Phase II awards. It should be noted that Powdermet is less successful than the average company in transitioning from Phase I to Phase II—particularly at DoE and NSF, but also true to a lesser degree at DoD. The average transition rates at all three agencies range from 40-50 percent.

According to Dr. Sherman, the SBIR program has been essential to the long-term success of Powdermet (and hence MesoCoat, and Terves). SBIR funding has been used as non-diluting funding to build core competencies and capabilities, and to incubate technologies (and the company) and survive long enough to become commercially viable in a materials marketplace where development, maturation, and commercialization cycles are typically between 10 and 20 years (or longer). It has been absolutely critical for building technical capabilities, supporting PhD scientists before market revenues developed, and maintaining a critical mass for R&D, without which there would be no substantial technology platform at Powdermet. Without the SBIR program, the company would likely have remained a small scale job shop materials contractor with maybe $1 million in revenues and a dozen employees.

More generally, Mr. Sherman noted that outside of the SBIR program there a very few funding sources for entrepreneurs to develop and support the science, team, and tools needed to commercialize emerging technologies. He

TABLE F-5 Mesocoat SBIR Awards

Agency	Phase I Awards	Phase I Amounts	Phase II Awards	Phase II Amounts
DoD	38	3,069,824	12	7,622,370
DOE	10	899,865	1	578,592
EPA	1	70,000		
NASA	9	679,545	2	1,049,994
NSF	9	796,998	1	499,998
Total	67	5,516,232	16	9,750,954

SOURCE: SBA TechNet Awards database, accessed September 24, 2012.

believes that venture funding is not an alternative to SBIR funding because it fills a different space in the value chain, and is mainly aimed at technologies that can deliver substantial market share in 3-5 years (at most, meaning 7-10 years into the development cycle for materials and manufacturing technologies). He also believes that small businesses do not have access to many of the mainstream development funding sources supporting larger businesses (grants, contracts, and retained warnings), universities, and non-profits.

SBIR Concerns

Mr. Sherman is very concerned about recent changes to what he considers to be a highly successful program. In particular, he believes that the growing pressure to ensure that SBIR funding generates commercial returns is profoundly misplaced: it is driving selection of projects that are shorter term and lower risk. Such projects are better suited to other funding streams—either acquisitions within DoD or venture funding in the private sector. In his view, SBIR is shifting toward a role as substitute for other sources of capital, for example, 6.3 and EMD funding at DoD and venture capital in the private sector. It is becoming an alternative to large company R&D and is being used to lower the cost of capital for venture firms. In short, it is becoming more of a corporate welfare program than a technology investment and high risk exploratory program.

The net effect is to kill the technology innovation seed corn by starving innovative projects and companies, according to Mr. Sherman. Perhaps as a result, new companies are finding it harder to access SBIR funding. SBIR awards are now being made to established larger companies, which can provide more and better data and offer the lowest risk, rather than to the most creative and innovative companies. It is notable that although Powdermet continues to win awards to apply its technology to DoD projects, MesoCoat has not been able to break in and receive DoD support, even though its products has more commercial and cost-savings potential in the long-run, and was originally created to serve DoD needs.

According to Dr. Sherman, this shift has occurred at most agencies. He believes that PEO's in DoD have recognized the shift (and program offices want low technology and execution risk and rapid insertion/benefits), and that NSF has moved away from its previous portfolio investing approach to one that requires each project to be successful. The emphasis is on making sure that one-half of all projects can in some way be described as successful, rather than finding the 1 in 20 or 1 in 50 big disruptive technologies.

As a result, Mr. Sherman is concerned that the original mission of the SBIR program is being lost. He discussed data that indicate that only about 5 percent of all federal R&D funding goes to small business, and that SBIR accounts for more than two-thirds of that funding. Hence a significant shift in the SBIR program could mean a catastrophic effect on overall R&D by small businesses—which generate a disproportionate share of cutting-edge technologies and employee the majority of scientists and engineers, not to mention entrepreneurs like Mr. Sherman.

QUALCOMM CASE STUDY [55]

Based on interview with
Dr. Irwin Jacobs, Founder
April 26, 2011
By telephone

Qualcomm Inc. (Qualcomm) is a publicly traded company headquartered in San Diego. It was founded in 1985 by a small group of researchers, some of whom had previously founded Linkabit, a precursor company. Since then, Qualcomm has grown to become one of the preeminent companies in the wireless technology business and the largest fabless semiconductor manufacturer in the world. Qualcomm intellectual property provides the technical base for most of the 3G networks that now dominate wireless markets worldwide.

Qualcomm is a case study in the development, implementation, and widespread adoption of a highly disruptive technology[56]—code division multiple access (CDMA). This technology revolutionized the wireless industry by dramatically increasing the capacity of wireless networks, permitting the adoption of wireless technology by millions of users and the subsequent emergence of smart Internet-enabled mobile phones.

In order to establish its credibility, Qualcomm had to prove the feasibility of this new and unproven technology. It took the company more than 6 years to firmly establish the feasibility of the technology, and it was during this period that the SBIR awards proved influential.

Background

Qualcomm's first important contract was to build the OmniTRACs messaging and location system for the trucking industry, starting in its first year of operations in 1985. According to Dr. Jacobs, the contract was a "bet the company" risk for Qualcomm: It needed the OmniTRACs revenues to survive, but was not sure at the time that it could deliver the agreed technologies and services. The contract generated about $6 million in development revenues in 1987, and Qualcomm then signed an important commercial contact for OmniTRACs with Schneider National in 1988.

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[55]This section is based on the testimony of Dr. Irwin Jacobs before the Senate Small Business Committee on February 21, 2011, and on an interview conducted with Dr. Jacobs on April 26, 2011.
[56]A term used to describe technologies that disrupt existing markets, originally coined by Clayton Christensen in J.L. Bower and C.M. Christensen, Disruptive technologies: Catching the wave, *Harvard Business Review*, January-February 1995.

By 1989, Qualcomm's technology was in a sufficiently advanced position for the company to acquire $1 million in funding from Pactel and, perhaps more importantly, sell $20 million in Series B preferred shares in April and further Series C shares for $8/share in September. The year culminated with the critically important first-ever CDMA (Code division multiple access) field trial for Pactel in San Diego—a trial which provided critical evidence that CDMA technology could be applied successfully.

The timing of the trial suggests that SBIR funding indeed played an important role. Much of the revenue generated in 1986 was used to support development of the OmniTRACs system, with little left for finalizing the research needed to implement cellular CDMA for the first time. To complete technology development of an entirely new networking technology to the point of field trials in the course of 2 years required the limited resources from SBIR, which arrived right at the critical time.

Timing in the development and deployment of CDMA technology was absolutely central to its success. By March 1990 the telecommunications Industry Association (TIA) had approved a competing technology—TDMA—for use in the United States, which was quickly adopted through the GSM standard as the primary technology for the emerging European cellular market. There was therefore strong support for TDMA from existing cellular carriers, many of whom were not convinced that CDMA could ever be implemented in the field, even though the theory underpinning the technology had been initially patented during WWII.

Anticipated rapid growth in the U.S. market, and pressure to address capacity constraints in existing networks, meant that network providers would soon be forced to decide which technology they would use to make the critical transitions from analog AMPS technology to the new digital age. Once made, that decision would determine the future of the industry through the first generation of digital deployment. Accordingly, the timing of the San Diego field trial was absolutely central to Qualcomm. Had the trial been unsuccessful, or had it been a year later, key decisions would likely have been made and the window of opportunity for CDMA would have closed.

It should also be understood that once TIA had endorsed standards based on TDMA, there was very strong industry resistance to what was called a split standard, because that would involve expensive development of two technologies: "No one is overjoyed about the split in the cellular standard — least of all manufacturers who together shelled out $200 million to $300 million developing TDMA and now face a similar expenditure on CDMA."[57]

The fact that Qualcomm's trial was timely and was successful is in part due to the key funding provided through the SBIR program, which as Dr. Jacobs noted, helped the company to crack certain key technical problems on its way to building a successful solution.

[57]*Business Week*, April 27, 1992.

BOX F-3
Competing Wireless Standards: FDMA, TDMA, CDMA

The initial analog wireless networks implemented in the United States (AMP) utilized frequency-division multiple access standards (FDMA). Essentially, FDMA reserves part of the spectrum for each call. The result is high quality—but very limited capacity.

As it became clear that new digital networks would be required, a new standard emerged—time division multiple access (TDMA). Under TDMA, networks resources are allocated to callers sequentially—first to one pair, then to another. This approach increased capacity, but only up to a limited point. Further expansion would require very expensive additional infrastructure, which would slow or prevent the subsequent rapid decline in the costs of cellular service, which in turn would limit market growth.

Code division multiple access (CDMA) allows multiple users to share network resources simultaneously, as bits are coded for delivery to the appropriate conversation and user. CDMA offered the possibility of enormous capacity gains and reduced costs—but was in the late 1980s untested and faced some formidable technical obstacles. Many respected people in the wireless industry and academics did not believe that CDMA could ever be implemented on a large scale.

The effect of the San Diego trial and a second in New York 3 months later was immediate: six leading operators and equipment manufacturers signed up to develop and implement CDMA-based solutions. These companies committed more than $30 million to development over 2 years.[58] In 1991 Qualcomm made its first large international deal when South Korea's ETRI agreed to a partnership to develop a CDMA-based industry in South Korea.[59]

The timing of this breakthrough is also indicated by the extremely rapid diffusion of CDMA technology thereafter.

What was the role of the SBIR program in Qualcomm's technical success and business breakthroughs? This has to be understood in the context of the technical challenges facing Qualcomm at the time.

Key Technical Challenges in the Early Years of Qualcomm—The Road to CDMA

Rapidly accelerating demand for mobile services drove the need for a massive increase in mobile capacity, which clearly would require a switch to

[58]Dave Mock, The Qualcomm Equation: How a Fledgling Telecommunications Company Forged a New Path to Big Profits and Market Dominance, AMACON, 2005. p. 91.
[59]Mock, op.cit., p. 48.

digital technology. However, although CDMA theoretically offered far larger gains in capacity and potentially reduced costs, formidable technical barriers had to be overcome. Indeed, some respected experts in the industry and in academia argued that CDMA was simply too complex and faced too many technical difficulties to be implemented effectively. Four technical challenges had to be addressed.

The Near-Far Field Effect

Because all users would operate on the same spread spectrum, interference from other users—and in particular signals from other users closer to the base station—would drown out others who were further away. This problem required a new focus on *minimizing* the power of the user signal rather than maximizing it, as was customary under AMPS, FDMA, and TDMA, where users did not share the same spectrum at the same time. Qualcomm solved the problem by using existing automatic gain control circuits in the handset, which became the basis for what it called the open loop power control method.[60]

At the same time, Qualcomm used new technology at the base station to deliver closed loop feedback to handsets hundreds of times a second, which required the handset to increase or reduce power based on needs of the cell. This technology was patented in November 1989 and provided a solution to a subtly different problem, that of outside interference (e.g., phones in motion).[61]

Soft Handoffs

Existing systems for transferring calls between cells were hardware based and used "make and break" to hand off. Essentially, the call was connected to a second cell tower before it was disconnected from the first one. Hence calls were maintained on two towers at the same time.

Qualcomm opted instead for what became known as a "soft handoff," in which the call is transferred via software coordination between the towers. This required precise synchronization between the towers, and Qualcomm used GPS to synchronize, drawing on its experience with the OmniTRACs satellite-based system. Again, it was not clear at the time that this more complex and challenging solution could be implemented.

Voice Coding

Qualcomm was among the first to realize that major gains in capacity could be driven by more efficient ways to digitally encode voices advances. The company developed a variable rate coder (VRC) that could process information at four different levels of accuracy, depending on the bit rate employed. The

[60]Mock, op.cit., p. 63.
[61]Mock, op.cit., p. 64.

VRC was able to identify dead time between words and to reduce the bit rate to a minimum, without any loss of quality. As Qualcomm found that a considerable percentage of conversation time is in fact silent, which dramatically expanded the system's capacity without reducing voice quality. Dave Mock, Qualcomm's biographer, says that this tripled the system's capacity.[62]

In addition, VRC allowed the system to simply reduce quality in the face of congestion. FDMA and TDMA could only drop calls in response. Degraded but still functional connections provided a substantial market advantage for CDMA systems.

Custom ASICs (application-specific integrated circuits)

Many of the core technologies developed by Qualcomm had to be implemented via development of an ASIC—off-the-shelf processors at the time were not well suited to CDMA needs.

The original ASICs division team developed the ASICs for the OmniTRACs system and for the Viterbi decoder, but only the rapid expansion that Dr. Jacobs says was partly fueled by SBIR permitted Qualcomm to provide chips at the scale required for network deployment.[63] Qualcomm produced its first custom ASIC in May 1991.[64]

Qualcomm and SBIR

Qualcomm has long since graduated from the SBIR program. It now employs more than 31,000 staff worldwide[11] and has annual revenues on the order of $25 billion, up 30 percent year over year. It is highly profitable, earning near $7 billion in profits in fiscal 2013, increased 12 percent year over year. It sold about 190 million MSM chipsets in the last quarter of 2013.[65]

Qualcomm is therefore one of the largest companies ever to participate in the SBIR program. But in 1988 and 1989, its position was very different. During its first 5 years of operation, Qualcomm received eight Phase I and four Phase II awards, amounting to about $1.4 million. Critically, SBIR funding provided a crucial influx of funding in 1988 and 1989, providing about $700,000 in 1988 award cycle funds.

According to Dr. Jacobs, "This funding allowed us to pursue several innovative programs that otherwise would not have been possible." In his Senate testimony, Dr. Jacobs noted that SBIR funding had a particularly direct and powerful effect on the company's ability to develop ASICs and a core competency in this area. Although those ASICs have long since left the market,

[62]Mock, op. cit., p. 70.
[63]Jacobs interview.
[64]Qualcomm, private communication.
[65]Qualcomm Announces Fourth Quarter and Fiscal 2013 Results.

the competency has remained. Approximately two-thirds of Qualcomm's current revenues are derived from ASICs. [66]

In the interview, Dr. Jacobs specifically identified three areas in which SBIR funding made a central difference:

- A project involving bandwidth-efficient coding techniques
- A method and hardware to test error detecting codes
- Development of an application-specific integrated circuit (a first step in a business that now brings in about two-thirds of company revenue).

The role of SBIR funding is usually best captured by the views of executives involved at the time. In his testimony and interview, Dr. Jacobs highlighted the importance of SBIR funding to Qualcomm at a very early and critical stage of its development. Beyond the immediate funding impact, he SBIR provided a critical "stamp of approval" that allowed the company to successfully pursue sources of private capital.[67] The NRC and others have identified this validation effect as an important although difficult to quantify contribution of the SBIR program to the U.S. innovation ecology.

Finally, it is worth noting that SBIR funding for the technology was largely provided by DoD and in particular by Navy. Although it does not appear that Navy directly acquired Qualcomm technology in advance of its private-sector success, the continuation of funding suggests that Navy found positive outcomes from its SBIR awards with Qualcomm.

Qualcomm After 1991

Building an industry coalition was not the end of the game for Qualcomm. The eventual success of CDMA technology in the United States required many more years of effort, as well as the inevitable setbacks and successes. Even 4 years later, in 1994, the *Wall Street Journal* was still not convinced: "It's a good idea. But in technology, ideas alone won't cut it. Speed in rolling out a product is vital ... Qualcomm's whiz-bang digital technology is losing ground, some experts believe, to older digital methods already adopted."[68]

During 1997 and 1998, Qualcomm rolled out the world's first commercial CDMA smartphone (the pdQ™), and in 1999 most major network vendors agreed to use CDMA for the rollout of 3G networks, which for the first time brought the Internet to millions of smartphones and ushered in the transition from a voice-driven to a data-driven mobile network.

Jumping forward, Qualcomm has remained an industry leader. For example, in 2008 a Qualcomm chipset drove the G1, the first Android phone.[69]

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[66]Jacobs testimony, op.cit., and Interview, April 26.
[67]Jacobs testimony, op.cit.
[68]*Wall Street Journal*, October 11, 1994.
[69]Qualcomm, private communication.

The company now has more than 31,000 employees, up from 428 in 1990, 6,300 in 2000, 9,300 in 2005, and 17,000 in 2010. MSM chip shipments continue to grow rapidly.

The Qualcomm business model is worth noting. Once Qualcomm provided CDMA technology and supported initial implementation by providing a complete package of software and hardware, including both handsets and base stations, it quickly adjusted to re-focus on the IP side of its operations, developing partnership relations with telecoms manufacturers and operators.

Today Qualcomm has a market cap of more than \$123 billion[70], and its technology is in use in more than 2 billion 3G connections worldwide.[71]

Qualcomm has also continued to fund research and development at a very high level. R&D funding grew to \$5 billion in fiscal year 2013, about 20 percent of revenues.[17] Cumulatively, Qualcomm has invested more than \$31 billion in R&D investments over its lifetime.[72]

Paying Back for the Nation's SBIR Investment

Qualcomm's success has led to substantial dividends for the taxpayer. In FY2010, the company paid federal income tax of \$1.3 billion,[73] not including the personal federal income taxes paid by the thousands of Qualcomm employees.

Qualcomm has had significant regional impacts in the San Diego area. According to a San Diego Workforce Partnership & San Diego Regional Economic Development Corporation study released in 2013, Qualcomm contributes \$4.53 billion in direct and indirect economic activity annually.[74] The same study found that Qualcomm employed more than 11,000 people directly in San Diego and that money spent by Qualcomm and its employees created and supported more than 26,000 jobs touching a variety of goods and services in San Diego County. According to the study, Qualcomm is responsible for economic output equal to approximately 3 percent of the Gross Regional Product of San Diego County in 2010 and is the county's largest private sector employer.

Today, the San Diego region hosts hundreds of telecommunications companies, from startups to leading R&D facilities of global telecom companies, which is in sharp contrast to what existed in 1985. The telecom industry supports the region's economy with thousands of high-paying jobs. Qualcomm has contributed to the creation of this industry cluster through spin-offs and partnerships with other companies.

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[70]As of July 31, 2014.
[71]Qualcomm's Fiscal 2013 Annual Report on Form 10-K filed with the SEC.
[72]Qualcomm, private communication as of third quarter fiscal 2014.
[73]Qualcomm's Fiscal 2010 Annual Report on Form 10-K filed with the SEC.
[74]*The Economic Impact of Qualcomm*, January 2013

Finally, Qualcomm continues to pour funding in R&D. Qualcomm reported at the end of the fourth quarter of 2013 that it continues to fund R&D at more than $5 billion annually, approximately 20 percent of revenues.[75]

TEXAS RESEARCH INTERNATIONAL: SBIR CASE STUDY

Based on interview with
Dr. Michael Dingus, Vice President and Technical Director
October 21, 2011
By telephone

Texas Research International (TRI) is a privately held company headquartered in Austin, Texas. Founded in 1975 by Dr. J. Scott Thornton, the company specializes in addressing the materials-related needs of defense and government clients, and its mission is to "develop, characterize and transition innovative materials and material health monitoring systems that address the critical needs of the Armed Forces." TRI currently has more than 125 employees.

TRI is organized into three subsidiaries or divisions:

- TRI/Air Testing Inc. focuses on compressed air testing, medical gas testing, and indoor air testing
- TRI/Austin, Inc., TRI's flagship company, conducts materials research and development projects

TRI/Environmental, Inc. (TRI) is an independent, third party, geosynthetics firm providing geosynthetics testing and research services to the international community. The SBIR awards were acquired by TRI/Austin, and this case study focuses on that division.

TRI/Austin's areas of technical expertise include materials science, composite materials and products, environmentally compliant alternative material development, adhesives, polymer science, coatings, nondestructive testing, accelerated life testing, reliability engineering, and specialized instrument development.

Technologies and Capabilities

Advanced materials are at the core of TRI capabilities and cover a broad range of polymer chemistries. More specific capabilities include the following:

[75]Qualcomm Announces Fourth Quarter and Fiscal 2013 results.

- **Composites Engineering,** especially for marine use. TRI uses materials selection, solid modeling, finite element analysis, and structural analysis to optimize composite components, as well as a variety of composite manufacturing techniques to produce prototypes and preproduction components.
- **Experience with extreme environments.** TRI develops high-performance products to meet demanding environments for military aircraft, land vehicles, ships, and submarines. For example, TRI's Proteckt^{R} High Temperature Coating provides a new, high temperature resistant abrasion coating for the Joint Strike Fighter, directly improving the reliability and maintainability of the weapons system.
- **Meeting environmental and safety regulations.** TRI has developed 100 percent lead-free solids and volatile organic compound (VOC)-free materials that meet or exceed the performance of incumbent materials. For example, ThermaSafe™ composite resins meet fire, smoke, and toxicity restrictions aboard submarines.
- **Materials Testing.** TRI has extensive materials testing facilities to support R&D projects and also develops customized protocols for specialized testing requirements.
- **Diagnostics/Prognostics/NDE/NDT.** TRI holds patents on structural health monitoring systems and nondestructive testing technologies, and it ran DoD's Nondestructive Testing Information Analysis Center for over 15 years.
- **Materials Qualification and Transition.** Part of the transition process for using materials in the military is testing and qualification. TRI has developed, tested, and qualified numerous materials for military use, for example Bond-Coat^{R}, which was developed under a Navy Phase II SBIR and significantly extends the life of submarine and other underwater electrical connectors and is mandated for use by the Navy.[76]

Business Strategy and Commercialization

TRI began as a contract research house, and it used SBIR award funding to supply the armed forces with specific research required to address technical problems. It still performs contract research and development and product development for DoD and other government agencies as well as private industry. It also performs contract technical support services. For example, for over 15 years TRI ran DoD's Nondestructive Testing Information Analysis Center, which contained the world's largest library on NDE/T technologies.

TRI has worked hard at SBIR transition and has made significant investments to commercialize its technology both within and outside DoD.

[76]NAVSEA S9320-AM-PRO-030/MLDG, REV 03.

Aside from direct commercialization discussed below, it has developed a spinout in partnership with another organization called Ideas to Market LP. This partnership has successfully launched the Ecomass^{R} products under the spinoff company Ecomass Technologies (<*www.ecomass.com*>) (see Box F-4), which have generated more than $43 million in sales.[77] The limited partnership raised more than $1 million in an initial offering for market research, intellectual property protection, and additional product development efforts for selected SBIR technologies.

Today, TRI sees itself as a company providing "cradle-to-grave" advanced materials for advanced applications, not only within DoD where the company has four primary customers, but also in the oil industry around its home base in Austin, Texas.

This focus on commercialization has led the company into relationships with a number of prime contractors (discussed in the TRI and the Primes section below).

According to Dr. Dingus, several of the company's products have completely transitioned to commercial production. These notably include the following:

- **Bond-Coat**, a method of extending the life of underwater electrical connections. According to the Quad-Chart describing project progress and provided by TRI, Bond-Coat has saved the Navy $814,400 per submarine over the life of the connectors, even before considering savings due to improved combat readiness. The federal government now requires Bond-Coat NCC on Navy underwater connectors and other outboard equipment.[78]
  Bond-Coat—which costs about $50 per connector—potentially extends the useful life of underwater electrical connectors up to 6-fold—from 2.5 to 15 years. Dr. Dingus notes that sales are more than $10 million, of which over $7 million were made by TRI.
- **Submarine flex hose,** which has generated sales of more than $2.7 million to date. TRI has partnered with a cable production company—Cortland Cable—on this project. The TRI technology addresses a significant problem with lead exposure to workers and sailors related to the production of control hoses for certain torpedoes.

Following Bond-Coat, TRI has aimed to move from a licensing-based strategy toward one focused on manufacturing and implementing solutions that contain its technology. This transition has been supported by SBIR.

TRI is working to commercialize other products.

[77]See Ecomass description at <*http://www.ecomass.com/*>.
[78]Phase II SBIR Final Technical Report "Non-Conductive Coatings for Underwater Connector Backshells", May, 1995, Contract Number N00024-93-C-4124.

BOX F-4
Ecomass® Compounds

Ecomass Compounds (Ecomass) is a non-toxic thermoplastic material with a density equal to lead that can potentially be used for many applications. Compared to lead, Ecomass offer a greater yield strength, can be injection molded, is nontoxic, and can be very flexible or very stiff depending on the application. According to Dr. Dingus, Ecomass emerged directly from an Army Phase I SBIR funding.

The Army has successfully tested the product for use as nontoxic training projectiles in an effort to reduce or eliminate additional lead contamination problems at its firing ranges, where more than 700 million rounds are fired each year.

Other applications for Ecomass include shot for shotgun shells, radiation shielding in nuclear reactors, vibration dampening, soundproofing, flywheels, inertia brakes, counter weights, fishing weights, golf clubs, and many other applications where a nontoxic, high-density, high-strength material is required.

TRI developed this technology and subsequently contributed it to a start-up company, Ideas to Market, LLC, in exchange for a significant ownership in the company. Ecomass has since generated more than $43 million in revenues.

TRI and the Primes

TRI has teamed with an array of technology leaders, primes, and commercialization partners. These include Boeing, Lockheed Martin, Northrop Grumman, Johnson & Johnson, Hazeltine, Sigma Coatings Inc. USA, Ameron, PolyOne, W. W. Henry, Gilson, Conoco, 3M, Dell, CTI Alaska, API, MTI, Hughes, Fuel Systems—Textron, and Newport News.

According to Dr. Dingus, these partnerships are possible because primes are generally not interested in entering small markets for materials products. In most cases, work on materials for DoD is focused on niche applications with small potential markets and few non-military applications, and hence of little interest to the primes.

Overall, TRI has had strongly positive experiences with teaming:

- **Lockheed Martin.** In an effort partly funded by Lockheed Martin, aircraft appliqués were developed as paint replacement materials to minimize the costs associated with paint application and waste disposal.
- **Boeing.** Corrosion costs the Air Force alone more than $100 million per year in total direct costs. Boeing has now integrated TRI's

monitoring technology into its MAUS system, which helps to address this problem.

- **Johnson & Johnson.** With funding from Johnson & Johnson (J&J) Medical, TRI developed powder-free natural latex and neoprene surgical gloves. The patented coating system allows surgeons to don the gloves either wet or dry. TRI also assisted J&J with the transition to production of these new gloves.
- **NASA, Boeing, and Lockheed Martin.** In response to the Columbia accident, NASA established a new office, the NASA Engineering and Safety Center (NESC), to provide independent (outside NASA) assessment of potential safety issues. TRI was part of the team working on these issues, and conducted studies on the reliability of aging Space Shuttle composite overwrapped pressure vessels (COPVs).

In general, Dr. Dingus observed that working with primes is more difficult on transition and commercialization projects that on contract research projects, which have fewer potential conflicts of interest and strategy.

TRI and SBIR

SBIR has been a central plank of TRI's business strategy almost since the inception of the program. It received its first SBIR award from the first round of NSF awards in 1983 and overall has received more than 150 Phase I and 60 Phase II awards, totaling approximately $50 million (as of 2010).[79] TRI has expanded its use of the SBIR program in recent years. Starting around 1995, TRI experienced a sharp increase in the number of Phase I and II SBIR awards at TRI. Its conversion rate to Phase 2 increased significantly in 2000, but has declined somewhat since 2006. More recently, SBIR awards at TRI appear to be declining, with non-SBIR work increasing, although it is perhaps too soon to tell whether this is a trend.

According to Dr. Dingus, TRI has been interested in participating in commercialization efforts within the DoD. For example, TRI has repeatedly participated in the Navy Transition Assistance Program (TAP). TRI submitted a proposal for a Phase II enhancement covering new technology to deploy camouflage face paints that are less expensive and have properties that reduce facial burns. A Phase II enhancement second project concerns a high-temperature coating that effectively retains color, to avoid coating burn off in high temperature areas of Air Force aircraft.

Dr. Dingus believes that the new Rapid Innovation Force RIF program will be very popular, perhaps resulting in more than 5,000 white papers at DoD. However, he notes that the first $25 million has already been allocated, and if

[79]SBA TechNet SBIR Awards database, accessed October 21, 2011.

BOX F-5
Air Force Phase II Award

In 2007, Air Force awarded TRI a Phase II SBIR for development of a handheld radome inspection tool. After repair, aircraft radomes are installed and then tested at a different facility for radar transparency. If it fails the test, then the entire radome is rejected and must be repaired again. Currently, there is no simple small tool that can be used at a radome repair facility to determine whether it has proper radar performance. .

TRI partnered with the University of Missouri, Rolla to develop a handheld, low-power microwave probe that captures a variety of flaws that cause radar performance problems. The system reliably detected anomalies.

funding is approximately $3 million per project as expected, then funding will be available for only 25-50 projects. This suggests a considerably lower success rate than for regular Phase II SBIR awards.[80]

SBIR and Data Rights

Data rights are an extremely important part of the SBIR program, according to Dr. Dingus. Indeed, had current rules been in operation at the time of Bond-Coat's development, the company would have been able to substantially accelerate and expand commercialization (the project predates the current data rights rules introduced in 1994).[81]

More generally, Dr. Dingus said that contracting officers need substantially more education about SBIR data rights because knowledge varies widely between officers. Moreover, there are no penalties for violating data rights—in effect, companies are helpless if agencies do not play by the rules. He said that it would be useful if penalties could be enumerated and disseminated.

Finally, Dr. Dingus noted that, although he appreciates the sole source provisions of SBIR data rights, they have never been used by TRI and he does not anticipate their use in the future.

SBIR Recommendations

Many of TRI's most pressing concerns with SBIR center around the role of the TPOC, which Dr. Dingus believes is central to a project's success.

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[80]In an email update, dr. Dingus noted that TRI-Austin has received 2 RIF awards and is a subcontractor on a third.
[81]See RIGHTS IN DATA--SBIR PROGRAM (52.227-20) (MAR 1994), *<http://code210.gsfc.nasa.gov/autoc/html/subE27-33/F27-20.html>*.

Although recent improvements in the award cycle mean that there should be fewer instances of TPOCs changing in the course of the project, this remains a major concern.

Dr. Dingus supports all efforts to provide ways for agencies and companies to connect prior to submission of the formal application. He endorsed the Air Force introduction of a pre-solicitation publication of areas of possible interest as "tremendously beneficial," because it provides adequate time to investigate an area and talk to potential sponsors.

TPOC connections are so important that, whenever possible, TRI tries to meet face to face with potential sponsors. The reduced timeline for proposals from 12 to 8 weeks, however, makes that more difficult.

Dr. Dingus appreciates the increase in the award size, especially for Phase I, but is concerned that this will lead to fewer awards, a trade-off that TRI would not favor.

Dr. Dingus expressed concerned that at some of the Services—notably Army—priorities can shift quickly even after award of a Phase I, leaving worthwhile projects stranded. For example, the Ecomass project was highly successful, but Army funding for Phase II disappeared despite highly favorable reviews. He believed that a commitment to fund at least one Phase II per topic (provided that solutions were technically successful at Phase I) would be appropriate.

Company Update:

Under Phase II SBIR and internal IRAD funding, TRI/Austin has developed and recently transitioned a lightweight, low cost, energy dissipating vehicle floor mat material called **Proteckt**^R^ that substantially mitigates the risk of serious leg and lower body injury in the event of IED detonation under military tactical vehicles. **Proteckt**^R^ (U.S. Patent No. 8790776) is a novel hybrid material that can be readily adapted to the Joint Light Tactical Vehicle (JLTV) and any other new or existing vehicles to prevent injuries. **Proteckt**^R^ energy absorbing floor mats can be rapidly designed for and integrated into ground vehicles as an insertion floor mat kit - no changes to the vehicle are required. In addition to superior performance, **Proteckt**^R^ weighs and costs less than currently used blast energy dissipating floor mats. The **Proteckt**^R^ technology development, design, and testing were initially performed under an Army TARDEC SBIR Phase II (SBIR Topic number ARMY 06-192, Contract Number W56HZV-08-C-0047). TRI/Austin recently produced 55 floor mat kits for the HET A0 vehicle and delivered 5 blast mats kits for the LVSR that passed full vehicle blast tests. TRI delivered and installed 5 **Proteckt**^R^ interior occupant impact attenuation vehicle kits for the A1P2-FMTV via Army TACOM (contract number W912CH-09-C-L512). TRI has also internally funded IR&D efforts for initial production scale up, design modifications, and IED floor blast simulated tests. TRI has established a 3000 sq. ft. **Proteckt**^R^ production facility that includes all necessary equipment and storage space to support low rate initial production. The facility is currently ISO 9001 compliant and is ISO 9001:2008 certified.

TRX SYSTEMS: SBIR CASE STUDY

Based on interview with
Carol Politi, CEO
February 2, 2013
Greenbelt, MD

TRX Systems is a privately held company headquartered in Greenbelt, Maryland. Founded by Carole Teolis, Gilmer Blankenship, and Ben Fun, TRX established a focus on indoor location in part because of its success in winning an SBIR award from NSF in 2007, which provided critical seed capital.

The company focuses on developing new tools for geo-locating personnel in locations where existing technologies (such as GPS) do not work or work poorly—for example, indoors or other areas where there is considerable signal interference.

Business Model

TRX is the developer of NEON®, an indoor location system that delivers precise, infrastructure-free tracking of personnel inside buildings where GPS is not available and in outdoor urban centers where GPS is unreliable. NEON greatly improves situational awareness and command effectiveness through the use of advanced sensor fusion, time of flight ranging, and mapping algorithms that deliver precise, real-time location of personnel in GPS-denied locations.

The TRX business model focuses on selling NEON, including a TRX developed accountability system, to federal and public safety markets as well as in licensing the NEON technology on an OEM basis for integration into third-party products.

Core Technologies

GPS, Wi-Fi, and ultra wideband technologies are all used for geo-locating, but they have significant shortcomings. They work less effectively in certain environments, particularly indoors where GPS and compasses are unreliable, and in circumstances where building maps are not available.

TRX NEON is a software suite that integrates data from numerous and disparate sources to create accurate 2D and 3D maps and to track personnel across them. These patent-pending sensor fusion and mapping algorithms integrate data from a broad range of sensors including compasses, GPS, ranging, inertial, light, and pressure sensors to deliver accurate tracking of personnel paths.

NEON determines when a degraded sensor (e.g., compass or GPS) is providing accurate estimates and when it is not. Poorly functioning or degraded sensors are isolated and de-emphasized or eliminated in the navigation solution. As a result, NEON works well even when a sensor's data is more than 50 percent erroneous.

NEON uses received sensor information to build site maps, building features, and other landmarks dynamically as people move about an area or building. Information from multiple people is merged to deliver "team-wide" location estimates. Essentially, by managing the data flow from multiple sensors NEON can determine the likelihood that any one data stream is erroneous, and act accordingly.

Ranging information, if available, can also be used to constrain location results. Examples include people operating within 50 meters of each other or working within range of a fixed RF node.

Accuracy is further increased where there are known features or floor plan information, because NEON can also match location estimates and inferred maps to known features and floor plans. User corrections can also be incorporated into NEON's data stream.

Products

NEON Location Services

The NEON Location Services are the core product for TRX. NEON uses an open architecture that is easily implemented with sensors from partner-provided hardware systems. The NEON Engine software includes application programming interfaces APIs for integrating input or constraints from partner systems and for providing indoor location data to third-party applications.

System Components

In addition to delivering location information in an API, TRX delivers an application into the public safety market (called NEON Tracker Command Software) that supports rapid and easy 3D building mapping, clear 2D and 3D views of personnel operating in and around buildings, and a record/history of personnel activities for after action review. System configuration can be performed in advance or immediately prior to an event or training session. Personnel equipped with NEON tracking units, or devices running NEON software, are automatically detected and monitored. NEON's Tracker Software allows commanders to visualize the location of personnel outfitted with NEON Tracking Units in both 2D and 3D as they operate indoors.

NEON Tracking Units are waist-worn devices (about the size of a deck of cards). They include a number of sensors: temperature compensated triaxial accelerometers and gyroscopes, triaxial magnetic sensors, barometric pressure, light sensor, Time of Flight (TOF) RF ranging, and GPS. These Tracking Units interface to radios or smartphones to transmit location information back to the NEON Tracker Command software. TRX is also now implementing its location algorithms on Android smartphones which now have many of the same sensors that exist in the NEON Tracking Units.

NEON Multi-Sensor Anchor Nodes can be used in fixed site applications to enhance precision. Anchor Nodes do not require networking and can be added during operations. It's also possible to use both Bluetooth and Near-Field Communications to support location initialization using cellular devices.

Markets

There are numerous potential markets that require an efficient means to geo-locate people in circumstances where standard GPS does not work effectively. TRX has focused on three core areas: first responders, defense, and security

First Responders

First responders often work inside buildings, in dangerous circumstances, where GPS is unavailable and where the location of personnel is a critical need for commanding officers.

NEON's key feature is that it can work in areas that are currently unmapped and that are not equipped with networked beacons: it does not require a building plan or pre-installed infrastructure to constraining the routes through which people move. This differentiates NEON sharply from many competing approaches, which rely in part on existing building maps and often require installation of beacons to deliver location indoors.

Defense

Dismounted war fighters increasingly rely on location for navigation and to deliver the situational awareness required for optimal command effectiveness. In some cases, GPS may be either unavailable or insufficiently precise. NEON is currently being adapted for use specifically for training, where trainers benefit from immediate review of exact personnel movements in near real time, as well as information on personnel orientation and proximity to other personnel or entities to enhance training realism.

Security

Security applications require easily deployed systems to support monitoring and tracking of essential security personnel. Event security requires highly portable systems that can be rapidly deployed with a minimum of facility integration, reliance, or impact. Many fixed facilities need to incorporate monitoring and tracking of security personnel in harsh environments, where infrastructure cannot be relied upon, or where networking of infrastructure is difficult or expensive.

NEON greatly improves situational awareness and command effectiveness for these applications, delivering real-time 2D and 3D locations for personnel operating in and around buildings. Key features include:

- Real-time 2D and 3D location of personnel
- Clear situational awareness, indoors and out
- Effective after action review
- Portable, lightweight, and rapidly deployed.

Partners and Business Model

TRX has focused primarily on infrastructure-free applications for which it has a substantial competitive advantage and on government applications in particular. It is now expanding to include mobile applications. Primarily, sales are made through partner organizations, which include Motorola, Globe Manufacturing, and ST Electronics.

In general, partners integrate TRX's NEON geo-tracking system into their own solutions, thus becoming in effect a distribution channel for TRX, which can then focus on R&D and partner management. Partners often bring an extensive suite of tools in the form of a fully integrated solution, such as Motorola's radio systems or Globe Manufacturing's fire suit, and may also have expandable existing contracts and a sales and support organization already in place.

In addition, TRX has deployed some systems directly both in the United States and internationally. Such sales typically involve sale of a system for evaluation, followed by customization to integrate the system with existing radio networks or other situational awareness tools. This has allowed TRX to deploy very rapidly, providing a further competitive advantage.

Finally, sometimes TRX directly licenses its algorithms for use on other hardware, which provides greater form factor flexibility for the partner.

Over the long term, the management team at TRX foresees a much wider range of potential uses. According to Carole Teolis, CTO, "While TRX Systems started with a focus on firefighters, it has become clear that there are a many situations that would benefit from precise indoor location without relying on pre-installed infrastructure for support. In places like malls and office buildings, this technology would allow a person to navigate to the exact restaurant where a friend is waiting, to a store with a favorite item is on sale or to an office cubicle to meet a colleague."[82]

R&D

TRX R&D programs include the deployment of NEON location services in a "software as a service" or SAAS environment, and on mobile devices. Current research projects include the following:

National Science Foundation: Collaborative Indoor Mapping Technologies

TRX is developing a smart phone application that creates indoor maps through sensor fusion and crowd-sourcing. The resulting indoor map database changes dynamically as individuals move about indoor spaces, using data gathered from sensors in Android smartphones. Building features and navigable passageways are detected and displayed, while accuracy increases as the number of users increases.

Federal Highway Administration: Navigation Aid for the Blind and Visually Impaired

TRX is developing a navigation aid for the blind and visually impaired, to track the location of a blind person anywhere, including areas where GPS is not available or reliable (for example, indoors or in urban areas with tall buildings). The application also aims to plan and adaptively update a route based on recognized obstacles to be avoided (for example, people or construction within the path). A third objective is to take gestural input and provide natural route guidance based on tactile stimulus instead of relying solely on auditory or visual instructions.

Army: Distributed Navigation

The goal of high accuracy and robust navigation for mobile soldiers requires a flexible system design that uses all available information. A network of soldiers must be able to move seamlessly from operating individually to navigating as a team. TRX is building a soldier-worn device that shares location information and leverages available communications (to other squad members and optionally to ground sensors and vehicle-based navigation systems and command), generating dynamic and timely information for improving navigation.

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[82]A. Rote, TRX Systems, Inc., Taking a new Perspective, researchers develop new locating tech, *NSF Livescience* online magazine, December 12, 2012.

BOX F-6
Army Contract Enhancement to Develop Urban Training

TRX was awarded an enhancement contract with the U.S. Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED), Simulation and Training Technology Center (STTC). The contract is to enhance and deliver a flexible, low-cost training system to support real-time location and tracking of war fighters during urban training operations.

TRX will deliver a small, Android-based application that war fighters can use to the view location of themselves and their team-mates, as well as maps of the surrounding environment. A software application provides visualization of the urban terrain and allows for rapid creation of 3D urban environments. By implementing the system STTC aims to deliver flexible training any time and in any geographic location; effective after-action review will support real-time assessment of individual and team learning.

Department of Homeland Security

The Department of Homeland Security Science and Technology Directorate has sponsored Honeywell, with team members Argon ST and TRX Systems, to develop the Geo-spatial Location, Accountability and Navigation System for Emergency Responders (GLANSER). GLANSER provides accurate and reliable location of emergency responders (ERs) in all types of environments. It aims to provide indoor/outdoor precision navigation, robust communications, and real-time position updates for commanders.

Private Investment

In 2012, TRX received a $2 million A round of venture funding from Motorola Solutions Inc. (NYSE: MSI), New Dominion Angels, the Maryland Department of Economic Development, and inside investors. It is using the investment to fund integration of NEON with Motorola Solutions' radios and to expand sales and marketing operations more generally.[83] (Since that time, NEON was approved for use with the Motorola APX radio and is now available to Motorola customers through its catalog).

"The ability to locate personnel operating indoors and often in hazardous situations improves command effectiveness, increases personnel safety and ultimately saves lives," said Mel Gaceta, investment manager, Motorola Solutions Venture Capital. "The TRX NEON Indoor Location System

[83] J. Clabaugh, TRX Systems gets $2M in VC funding, *Washington Business Journal,* November 13, 2012.

clearly complements Motorola Solutions' capabilities to improve safety for mission-critical users."[84]

TRX and SBIR

TRX can already be viewed as an SBIR success story. Only 5 years after its founding, received a Tibbetts award in 2012. TRX founder Carole Teolis was well aware of the SBIR program; Teolis had previously been a PI at TSI, another successful SBIR recipient in the Maryland suburbs of Washington, DC.

The company's focus on indoor location was critically enabled by its first SBIR award from NSF. It has since received several awards from DoD, including a recently expanded award from DoD's Army training command. Three of TRX's four Phase I awards have been selected for Phase II, providing total committed SBIR funding as of yearend 2012 of about $3 million.

Important early support was also provided by a TEDCO grant from the state of Maryland, which together with the SBIR program provided critical early funding to deliver proof of concept. Carol Politi notes that this early support was very important to the company's success and allowed it to file its first patents in 2007 and 2008. (Since that time, TRX has had 7 patents awarded, four of these in the US).

TRX worked with Army's Simulation and Training Technology Center (STTC) on group training and simulation technologies, focused on developing an application to help train soldiers in urban areas. Army is required to develop effective urban training and particularly needed a tool for after-exercise review in near real time. Existing solutions required expensive networking technologies such as ultra wide band or the introduction of numerous cameras for video review. A better approach would be lightweight and rapidly deployable, and it would require no pre-existing infrastructure or network, while still providing a means to track the location and path of all soldiers during an exercise. The Army also sought integration of interior maps where available.

TRX received substantial support from a program manager, Tim Roberts, at SSTC, who linked the company to staff conducting live training exercises. This provided important feedback for improving NEON, as well as access to testing venues.

Eventual take-up in DoD, according to Politi, must be based on end-user support and establishment of the right partners. TRX has recently partnered with General Dynamics to integrate NEON within the Army CTIA training architecture, and to extend the NEON capabilities to further enhance training realism.

[84] Motorola Solutions invests in TRX Systems Inc., *PRWeb,* November 12, 2013.

For TRX, key competitive advantages include the following:

- low costs (no infrastructure required, which means that training organizations can simply buy the technology without any significant prior planning or authorization, or need for integration with current systems)
- easy interface with programs of record, but no requirement for integration
- multiple sales options (more than 100 military training organizations are potential buyers)
- light weight both physically and technically (which means high degree of portability, so systems can be deployed for training within theater)

TRX primarily markets its product by looking for partners. Ms. Politi notes that in many cases, "TRX is an important piece of a much larger program." As a result, partnership is inherent to TRX's business strategy.

Similar solutions and approaches are used to address the training needs of other organizations, notably law enforcement, first responders, and others in the wider field of security. Here partnerships such as that with Motorola and Globe, and the development and potential licensing relationship with Honeywell, are the primary conduits for sales.

TRX has a flexible business model. Although Ms. Politi expects to make most sales through partners, TRX is set up to make direct sales where necessary or to offer OEM services where it provides the product but not fulfillment.

Ms. Politi observed some angel and VC funders are concerned that companies will become dependent upon SBIR funding, and apply for programs that become distractions from developing a product business. TRX frequently rejects opportunities to pursue SBIR funding in order to stay focused on its core business of location and mapping.

SBIR Matching Funds and Enhancements

TRX has found enhancement programs within SBIR to be of considerable value and would recommend expanding them, particularly at DoD where they can be used to help fund company efforts to traverse the difficult and demanding DoD validation process. Developing hardened products is expensive, and enhancement programs can provide key funding in that area.

DoD funding in this case required matching funds, which TRX was able to raise from a strategic partner (Motorola) as well as other investors.

TRX was also the recipient of an NSF Phase IIB award, which provided another important contribution. NSF support was central in helping the company raise its first angel funding: the ability to point to a federal contribution that effectively doubled the money of investors was "a huge benefit in raising outside money."

More generally, Ms. Politi observed that "matching programs give you a reason to reach out to people, and the double-your-money offer is very well received."

Recommendations

TRX is not woman-owned but it is woman controlled. Both the CEO and CTO are women. Because TRX was successful in raising outside funds, its time as a woman-owned business, according to SBA's definition, was limited. So, although the company is still well below 50 percent venture owned, it is more than 50 percent owned by outside funders—and therefore is no longer woman-owned. This change suggests a significant weakness in efforts to track the engagement of women (and minorities) within the SBIR program: successful companies quickly fail to meet the standard SBA definition of woman-owned.

Ms. Politi observed that through NSF, TRX had received commercialization support from LARTA, whose process was especially helpful in relation to a new collaborative mapping initiative. LARTA's method focuses on business planning and partnerships from the start of Phase I, which could also help to support a new initiative within an existing company. TRX has also used the method to train new PIs.

In addition, through NSF, TRX has received invaluable marketing support. This support included the development of publicly available spotlights of TRX founders and technology, as well as videos showcasing TRX developments.

Appendix G

Comparison Group Analysis

The 2011 large-scale survey of SBIR recipients at the Department of Defense (DoD) was sent to two distinct populations: all principal investigators who received DoD Phase II SBIR awards between fiscal year (FY) 1999 and FY2008 inclusive; and all principal investigators who received a Phase I SBIR award and whose company did not receive a Phase II award during the same period.

We sought to develop a useful comparison group for the data collected through the 2011 NRC Survey, but encountered substantial difficulties in finding matching firms – similar in their demographics, market orientation, industry sector, age, size etc.—that have not received SBIR funding.

We then 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, the National Science Foundation, and NASA) during the award period covered by the survey (1999-2008). After considerable review, we concluded that the Phase I-only group was also not appropriate for use as a statistical comparison group.

In the interests of providing researchers with a full view of the data collected, this appendix includes tables showing both the Phase I and Phase II survey responses for questions where both groups were surveyed. Some questions that addressed only Phase II respondents are excluded from this Appendix. These tables can be found in the body of the report, especially in Chapter 6.

TABLE APP G-1 Sales (percent of respondents)

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
No sales to date, no sales expected	44.6	28.1
No sales to date, but sales expected	27.7	26.4
Any sales to date	27.7	45.5
	100.0	100.0
N=	390	765

NOTE: Data collected 2011. Data covers awards 1998-2007 inclusive.
SOURCE: 2011 NRC Survey, Question 35.

TABLE APP G-2 Distribution of Total Sales, by Range and Phase

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Under $100,000	34.4	23.4
$100,000-$499,999	38.7	33.2
$500,000-$999,999	12.9	13.2
$1,000,000 or more	14.0	30.2
	100.0	100.0
N=	93	325

SOURCE: 2011 NRC Survey, Question 36, B1.

TABLE APP G-3 Markets for DoD SBIR Products and Services (percentage of total sales)

	Phase I Only (Percent)	Phase II (Percent)
DoD	33.7	37.3
Domestic private sector	31.9	21.4
Primes for DoD	15.5	21.6
Export markets	5.2	4.5
Other federal agencies	3.5	4.1
NASA	1.6	2.4
State or local governments	0.5	1.6
Prime contractor for NASA	0.6	1.3
Agency that awarded the Phase II (if not NASA or DoD)	0.0	0.9
Other (specify)	7.5	5.0
	100.0	100.0
N=	108	348

NOTE: For this question, each respondent reported a percentage distribution. Values above were calculated by deriving the mean value for all the responses received for each category. N=firms reporting sales >$0.
SOURCE: 2011 NRC Survey, Question 37.

TABLE APP G-4 Employment at Time of Award

Number of Employees	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Under 5	28.1	19.0
5 to 9	16.9	17.6
10 to 19	15.9	16.8
20 to 49	16.1	23.7
50 to 99	10.7	11.4
100 or more	12.2	11.5
	100.0	100.0
Mean	40	41
Median	12	17
BASE: TOTAL RESPONDENTS ANSWERING	378	727

SOURCE: 2011 NRC Survey, Question 18A.

TABLE APP G-5 Employment at Time of Reporting

Number of Employees	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Under 5	23.1	16.0
5 to 9	16.5	14.5
10 to 19	13.6	15.2
20 to 49	22.0	25.1
50 to 99	10.5	13.4
100 or more	14.2	15.8
Mean	63	66
Median	15	24
N=	366	739

SOURCE: 2011 NRC Survey, Question 18B.

TABLE APP G-6 Additional Investment after SBIR Award

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Yes	48.5	61.0
No	51.5	39.0
	100.0	100.0
N=	390	765

SOURCE: 2011 NRC Survey, Question 33.

TABLE APP G-7 Additional Investments by Non-SBIR Federal Sources by Phase and Amount

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Under $100,000	19.5	17.8
$100,000-$499,999	31.2	31.2
$500,000-$999,999	27.3	15.0
$1,000,000 or more	22.1	36.0
	100.0	100.0
N=	77	253

NOTE: N=Those reporting additional funds >$0.
SOURCE: 2011 NRC Survey, Question 34.1.

TABLE APP G-8 Sources of Additional Funding

	Phase I Only (Percent)	Phase II (Percent)
Own company	49.7	54.6
Federal non-SBIR funding	40.7	54.2
Other companies	11.6	16.3
Personal funds	15.9	10.7
State/local government	6.9	6.4
Private equity/angels	5.3	3.6
Venture capital	4.2	2.8
Foreign private	2.1	3.0
Universities/colleges	2.6	2.4
N=	189	467

NOTE: Responses do not sum to 100 percent because respondents could select more than one response.
SOURCE: 2011 NRC Survey, Question 34.

TABLE APP G-9 Company-Level Changes as a Result of the SBIR Funding

	Phase I Only (Percent)	Phase II (Percent)
Established one or more spin-off companies	11.5	16.1
Been acquired by/merged with another company	6.5	3.5
Made an IPO	1.3	1.4
Planning to make an IPO in 2011-2012	0.5	0.9
None of the above	81.3	80.1
N (unique companies) =	250	386
N (unique respondents) =	359	659

NOTE: Responses do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 NRC Survey, Question 10.

TABLE APP G-10 Market-Oriented Activities—Finalized Agreements with U.S. Companies and Investors

	Phase I Only (Percent)	Phase II (Percent)
R&D agreement(s)	58.5	49.2
Customer alliance(s)	25.6	27.0
Licensing agreement(s)	22.0	24.2
Manufacturing agreement(s)	18.3	18.9
Marketing/distribution agreement(s)	13.4	16.8
Joint venture agreement	7.3	7.4
Sale of technology rights	6.1	6.6
Sale of company	4.9	2.9
Company merger	3.7	3.3
Partial sale of company	1.2	2.9
Other	8.5	4.9
N=	82	244

NOTE: Responses do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2011 NRC Survey, Question 38.1.

TABLE APP G-11 Participation in Commercialization Training, by Phase

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Yes	21.4	30.2
No	78.6	69.8
	100.0	100.0
N=	388	761

SOURCE: 2011 NRC Survey, Question 17.

TABLE APP G-12 Full-Time Marketing Staff (one or more)

	Phase I Only (Percent)	Phase II (Percent)
Yes	35.4	39.0
No	64.6	61.0
Total	100.0	100.0
N (unique respondents) =	361	670

SOURCE: 2011 NRC Survey, Question 12.

TABLE APP G-13 Number of Patents Related to All Company SBIR Awards

	Phase I Only (Percent)	Phase II (Percent)
0	47.3	42.0
1 or 2	21.4	24.7
3 or 4	12.4	12.1
5 to 9	12.1	11.3
10 or more	6.9	10.0
Total	100.0	100.0
At least 1	52.7	58.0
N (unique companies) =	245	374
N (unique respondents) =	348	643

NOTE: N=348 statistical tests were run on responses weighted by company.
SOURCE: 2011 NRC Survey, Question 11.

TABLE APP G-14 Number of Patents Related to Surveyed Project

	Phase I Only (Percent)	Phase II (Percent)
0	72.9	68.2
1	17.1	17.3
2	4.3	9.2
3	3.3	2.6
More than 3	2.4	2.6
Total	100.0	100.0
At least 1	27.1	31.8
N=	210	422

SOURCE: 2011 NRC Survey, Question 39.1.2.

TABLE APP G-15 Number of Scientific Publications Related to the Surveyed Project

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
0	48.6	25.6
1	21.4	18.0
2	14.5	17.8
3	6.4	12.7
More than 3	9.1	25.8
Total	100.0	100.0
At least 1	51.4	74.4
N=	220	488

SOURCE: 2011 NRC Survey, Question 39.4.2.

TABLE APP G-16 Links to Universities

	Phase I Only (Percent)	Phase II (Percent)
Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI	16.0	18.8
A university or college was a subcontractor on this project	13.4	19.7
Graduate students worked on this project	10.2	17.7
The technology for this project was originally developed at a university or college by one of the participants in this project	8.9	7.7
The PI for this project was an adjunct faculty member	5.2	3.3
The technology for this project was licensed from a university or college	4.2	3.1
The PI for this project was a faculty member	3.4	1.7
Any of the above	30.4	34.8
N=	381	750

SOURCE: 2011 NRC Survey, Question 59.

TABLE APP G-17 Long-Term Impacts of SBIR Funding on Recipient Companies

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Had a transformative effect	20.2	20.2
Had a substantial positive long-term effect	44.6	56.8
Had a small positive effect	27.2	17.2
Had no long-term effect	7.0	3.8
Had a negative long-term effect	1.1	1.9
Total	100.0	100.0
N (unique companies) =	263	416
N (unique respondents) =	387	762

SOURCE: 2011 NRC Survey, Question 45.

TABLE APP G-18 Number of Founders

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
1	37.6	41.8
2	33.2	30.8
3	14.5	16.1
4	7.6	7.7
5 or more	7.2	3.5
	100.0	100.0
N (unique companies) =	244	382
N (unique respondents) =	350	660

NOTE: The NRC survey received responses from multiple respondents per company. For company-level questions, these responses were weighted equally, so that, taken collectively, the responses from each company had equal impact on statistical analysis. This approach was used for tables based on Questions 3-12 inclusive in the survey questionnaire (see Appendix D).
SOURCE: 2011 NRC Survey, Question 4A.

TABLE APP G-19 Number of Previous Companies Started by Founders

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
0	56.4	62.0
1	21.1	17.8
2	11.1	12.9
3	6.9	4.2
4	1.4	1.3
5 or more	3.0	1.8
	100.0 percent	100.0 percent
N (unique companies) =	244	382
N (unique respondents) =	350	660

SOURCE: 2011 NRC Survey, Question 4B.

TABLE APP G-20 Number of Founders with Business Backgrounds

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
None	48.6	51.7
1	37.0	32.2
2	9.2	11.0
3	2.3	2.9
4	2.5	1.4
5 or more	0.4	0.7
Total	100.0	100.0
At least 1	51.4	48.2
N (unique companies) =	246	382
N (unique respondents) =	352	660

NOTE: Statistical tests were run on responses weighted by company.
SOURCE: 2011 NRC Survey, Question 4C.

TABLE APP G-21 Number of Founders with Academic Backgrounds

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
None	31.4	38.8
1	42.5	39.9
2	14.9	12.2
3	6.5	4.2
4	3.9	3.6
5 or more	0.9	1.4
Total	100.0	100.0
At least 1	67.8	61.3
N (unique companies) =	246	382
N (unique respondents) =	351	660

SOURCE: 2011 NRC Survey, Question 4D.

TABLE APP G-22 Prior Employment of Founders

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Other private company	67.8	73.1
College or university	29.8	27.6
Government	12.2	9.2
Other	7.2	4.8
N (unique companies) =	250	391
N (unique respondents) =	358	671

SOURCE: 2011 NRC Survey, Question 5.

TABLE APP G-23 Company Founded Because of SBIR Program

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Yes	15.5	17.9
In part	16.5	17.5
No	68.1	64.7
Total	100.0	100.0

SOURCE: 2011 NRC Survey, Question 6.

TABLE APP G-24 Distribution of Responses by Sector and Phase

Technology sector	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Aerospace	31.6	46.3
Defense-specific products and services	68.1	71.6
Energy and the environment	11.8	10.7
- Sustainable energy production (solar, wind, geothermal, bio-energy, wave)	2.8	2.2
- Energy storage and distribution	2.8	2.0
- Energy saving	2.1	2.5
- Other energy or environmental products and services	2.3	3.0
Engineering	39.1	51.9
- Engineering services	10.3	14.3
- Scientific instruments and measuring equipment	7.5	12.6
- Robotics	4.1	5.5
- Sensors	15.7	24.0
- Other engineering	7.5	10.6
Information technology (IT)	19.3	18.2
- Computers and peripheral equipment	3.6	4.2
- Telecommunications equipment and services	4.1	3.8
- Business and productivity software	4.1	3.3
- Data processing and database software and services	4.6	5.9
- Media products (including web-, print- and wireless-delivered content)	1.5	1.3
- Other IT	2.8	5.4
Materials (including nanotechnology for materials)	26.2	23.1
- Medical technologies	2.6	2.1
- Pharmaceuticals	-	0.7
- Medical devices	5.4	5.9
- Other biotechnology products	2.6	2.2
- Other medical products and services	2.8	1.6
Other (please describe)	7.5	12.6

NOTE: Answers do not sum to 100 percent because respondents could select more than one response.
SOURCE: 2011 NRC Survey, Question 20.

TABLE APP G-25 Current Status of Surveyed Projects

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Project has not yet completed [SBIR] funded research	8.5	2.4
Efforts at this company have been discontinued	43.6	30.7
Discontinued because no sales or additional funding resulted from this project	36.4	20.8
Discontinued—The project did result in sales, licensing of technology, or additional funding	7.2	9.9
Project is continuing post-award technology development	22.1	26.9
Commercialization is under way	12.1	12.4
Products/Processes/Services are in use	13.8	27.6
In use by target customers	9.0 percent	21.7 percent
In use by customers not anticipated at the time of the award	4.9 percent	5.9 percent
Total (primary categories)	100.0	100.0
N=	390	765

SOURCE: 2011 NRC Survey, Question 30.

TABLE APP G-26 Primary Reason for Project Discontinuation

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Not enough funding	61.2	24.8
Project goal was achieved (e.g. prototype delivered for federal agency use)	8.8	16.5
Market demand too small	4.7	13.0
Company shifted priorities	5.9	2.6
Level of technical risk too high	3.5	2.6
Other reason mentioned:	15.9	40.4
	100.0	100.0
N=	170	230

NOTE: N = Respondents with awards no longer active.
SOURCE: 2011 NRC Survey, Question 32.

TABLE APP G-27 Company Annual Revenues by Phase (most recent fiscal year)

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Less than $100,000	12.1	10.0
$100,000-$499,999	19.1	13.9
$500,000-$999,999	13.8	12.2
$1,000,000-$4,999,999	30.6	37.6
$5,000,000-$19,999,999	15.0	18.3
$20,000,000-$99,999,999	7.1	6.7
$100,000,000 or more	2.3	1.4
	100.0	100.0
N (unique companies) =	243	385
N (unique respondents) =	350	659

SOURCE: 2011 NRC Survey, Question 8.

TABLE APP G-28 Percentage of R&D Effort expended on SBIR projects (most recent fiscal year)

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
0%	26.5	17.3
1%-10%	10.8	14.5
11%-25%	14.6	15.9
26%-50%	13.5	19.5
51%-75%	19.2	17.6
76%-100%	15.4	15.2
	100.0	100.0
N (unique companies) =	249	387
N (unique respondents) =	357	660

SOURCE: 2011 NRC Survey, Question 7.

TABLE APP G-29 Percentage of Company Revenues Related to SBIR Project (most recent fiscal year)

	Phase I Only (Percent)	Phase II (Percent)
0%	30.8	21.3
1%-10%	10.8	16.3
11%-25%	16.5	16.9
26%-50%	14.3	16.8
51%-75%	12.2	15.3
76%-99%	9.6	10.3
100%	5.6	3.1
Total	100.0	100.0
N (unique companies) =	247	385
N (unique respondents) =	355	654

NOTE: Companies reporting $0 have completed their previous awards and do not have current awards.
SOURCE: 2011 NRC Survey, Question 9.

TABLE APP G-30 Number of Prior SBIR or STTR Phase I Awards Related to the Surveyed Project

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
0	26.1	20.0
1	35.6	34.4
2	18.7	17.3
3	8.3	11.5
4	5.2	6.5
5 or more	6.0 percent	10.2 percent
Total	100.0	100.0
1 or more	73.9	80.0
N=	348	704

SOURCE: 2011 NRC Survey, Question 40.1.1.

TABLE APP G-31 Sources of Funding, Prior to SBIR Award, for Related Technology

	DoD SBIR Phase I Only (Percent)	DoD SBIR Phase II (Percent)
Internal company investment (including borrowed money)	45.4	52.7
Prior [SBIR] (excluding the Phase I that preceded this Phase II) (a)	NA	53.3
Prior non-[SBIR] federal R&D	27.3	30.0
Prior SBIR Phase I funding (b)	45.8	NA
Other private company	8.8	14.0
Private investor (including angel funding)	15.4	9.5
State or local government	8.5	7.7
Venture capital	3.5	5.7
College or university	3.8	3.7
Other (please specify)	8.5 percent	6.1
N=	260	493

NOTES: (a) Only asked for Phase II awards. (b) Only asked for SBIR Phase 1 awards. Totals do not sum to 100 percent because respondents could select more than one funding source.
SOURCE: 2011 NRC Survey, Question 21.

Appendix H

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