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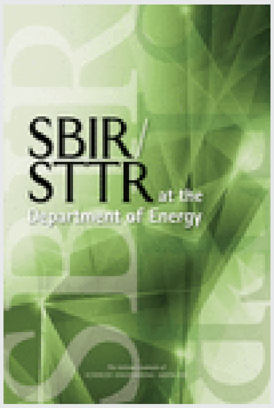

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Committee on Capitalizing on Science, Technology, and Innovation:
An Assessment of the Small Business Innovation Research Program—Phase II

Board on Science, Technology, and Economic Policy

Policy and Global Affairs

A Report of

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

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Preface

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

The Small Business Innovation Research (SBIR) program is one of the largest examples of U.S. public-private partnerships. An underlying tenet of the program is that small businesses are a strong source of new ideas, and therefore economic growth, but that it is difficult to find financial support for these ideas in the early stages of their development and market implementation. The SBIR program was established in 1982 to encourage small businesses to develop new processes and products and to provide quality research and development in support of the U.S. government's many missions. By involving qualified small businesses in the nation's research and development (R&D) effort, SBIR grants stimulate innovative technologies to help federal agencies meet their specific functional needs in many areas, including energy, health, the environment, and national defense. The Small Business Technology Transfer (STTR) Program was created in 1992 by the Small Business Research and Development Enhancement Act to expand joint venture opportunities for small businesses and

[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.

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nonprofit research institutions by requiring small business recipients to collaborate formally with a research institution. This report provides an analysis of how well the SBIR and STTR programs at the Department of Energy are fulfilling their congressionally mandated goals.

When reauthorizing the programs in 2000, the U.S. Congress tasked the National Research Council (NRC)[2] with undertaking a "comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet federal research and development needs" and with recommending further improvements to the program.[3] In the first-round study, an expert committee prepared a series of reports from 2004 to 2009 on the Small Business Innovation Research program at the Department of Defense (DoD), the National Institutes of Health (NIH), the National Aeronautics and Space Administration (NASA), the Department of Energy (DoE), and the National Science Foundation (NSF)—the five agencies responsible for 96 percent of the program's operations.[4]

When reauthorizing the SBIR and STTR programs in 2011, Congress expanded the study mandate to include a review of the STTR program.[5]

Building on the outcomes from the first round, this second-round assessment, led by a new committee, examines topics of general policy interest that emerged during the first round as well as topics of specific interest to the individual agencies. The results have been published in reports of agency-specific and program-wide findings on the SBIR and STTR programs and were submitted to the contracting agencies and Congress. In partial fulfillment of these objectives, this volume presents the committee's review of the SBIR and STTR programs' operations at the Department of Energy (DoE).[6]

ACKNOWLEDGMENTS

On behalf of The National Academies of Sciences, Engineering, and Medicine, we express our appreciation for and recognition of the valuable insights and close cooperation extended by Department of Energy staff, the survey respondents, and case study interviewees, among others. The committee gives particular thanks to its lead researcher, Robin Gaster of Innovation Competitions LLC, to Rosalie Ruegg of TIA Consulting, and to Peter Grunwald

[2]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council are used in an historic context identifying programs prior to July 1, 2015.
[3]See the SBIR Reauthorization Act of 2000 (H.R. 5667, Section 108).
[4]For a list of publications from the first round review, see Chapter 1, Box 1-1. For the overview report, see National Research Council, *An Assessment of the SBIR Program,* Washington, DC: The National Academies Press, 2008. See also National Research Council, *An Assessment of the SBIR Program at the National Aeronautics and Space Administration,* Washington, DC: The National Academies Press, 2009. The committee also prepared reports on the SBIR program at DoD, DoE, NIH, and NSF.
[5]SBIR/STTR Reauthorization Act of 2011, P.L. 112-81, December 31, 2011.
[6]The formal Statement of Task is presented in Chapter 1 of this report.

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of Grunwald Associates LLC, which conducted the surveys and described the results presented in this volume. David Dierksheide of the STEP staff is especially recognized for his important contributions to operation of this study and the preparation of this report.

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies of Sciences, Engineering, and Medicine's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study 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: Paul Grimmer, Eltron Research and Development; Sabrina Howell, New York University; Philip Neches, Teradata Corporation; Phillip Phan, Johns Hopkins University; Marcia Reike, University of Arizona; Troy Scott, RTI International; Colm O'Muircheartaigh, University of Chicago; Gwendolyn Thames, Connecticut Innovations; William Valdez, The Consultants International Group, Inc.; and Lorel Wisniewski, Independent Consultant.

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.

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Summary

Created in 1982 through the Small Business Innovation Development Act, the Small Business Innovation Research (SBIR) program remains the nation's 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.

Seeking to bridge the gap between basic science and commercialization of resulting innovations, the Small Business Technology Transfer (STTR) program, created in 1992 by the Small Business Research and Development Enhancement Act of 1992, seeks to expand joint venture opportunities for small businesses and nonprofit research institutions. Under STTR, a small business receiving an award must collaborate formally with a research institution.

Adopting several recommendations from a 2008 National Research Council (NRC) study of the SBIR Program, Congress reauthorized the SBIR/STTR programs in December 2011 for an additional 6 years. As a part of this reauthorization, Congress called for further studies by the National Academies of Sciences, Engineering and Medicine. In turn, the Department of Energy (DoE) requested the National Academies to provide a subsequent round of analysis, focused on operational questions with a view to identifying further improvements to the program.

FOCUS ON LEGISLATIVE OBJECTIVES

This report assesses the performance of the DoE SBIR and STTR programs against the broad congressional objectives for the programs.

For SBIR, these objectives were reiterated in the 2011 program reauthorization and elaborated in the subsequent policy directive of the Small Business Administration (SBA). Section 1c of the SBA SBIR Directive states program goals as follows:

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The statutory purpose of the SBIR Program is to strengthen the role of innovative small business concerns (SBCs) in Federally funded research or research and development (R-R&D). Specific goals are to:

(1) Stimulate technological innovation;
(2) use small business to meet Federal R-R&D needs;
(3) foster and encourage participation by socially and economically disadvantaged small businesses (SDBs; [also called minority-owned small businesses—MOSBs—elsewhere in the report]*, and by women-owned small businesses (WOSBs), in technological innovation; and*
(4) Increase private sector commercialization of innovations derived from Federal R-R&D, thereby increasing competition, productivity and economic growth.

The parallel language from the SBA's STTR Policy Directive is as follows:

(c) The statutory purpose of the STTR Program is to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and Research Institutions through Federally funded research or research and development (R-R&D). By providing awards to SBCs for cooperative R-R&D efforts with Research Institutions, the STTR Program assists the small business and research communities by commercializing innovative technologies.

SCOPE OF THE ASSESSMENT

The SBIR/STTR programs are unique in terms of scale and mission focus. In addition, the evidence suggests that there are no truly comparable programs in the United States, and those in other countries operate in such different ways that their relevance is limited. Further, as in the 2008 NRC study, the objective of this second-round study is "*not* to consider if SBIR should exist or not." Rather, this study is charged with "providing assessment-based findings of the benefits and costs of SBIR [and STTR] . . . to improve public understanding of the program, as well as recommendations to improve the program's effectiveness."

It is important to note at the outset that this volume—and this study—do not seek to provide a comprehensive review of the value of the SBIR/STTR programs, in particular measured against other possible alternative uses of federal funding. Such a review is beyond the committee's scope. Rather, the committee's work is focused on assessing the extent to which the DoE SBIR/STTR programs have met the congressional objectives set for the programs, in particular whether recent initiatives have improved program

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outcomes, and to provide recommendations for further improvements to the program.

STUDY METHODOLOGY AND LIMITATIONS

The committee's findings are based on a complement of quantitative and qualitative tools including a survey, case studies of award recipients, agency data, public workshops, and agency meetings. The methodology is described in Chapter 1 and Appendix A of this report. In reviewing the findings, it is important to note that the National Academies' 2014 Survey—hereafter referred to as the 2014 Survey—was sent to every principal investigator (PI) who won a Phase II award from DoE, FY 2001-2010 (not the registered company points of contact [POC] for each company.) Each PI was asked to complete a maximum of two questionnaires, which as a result excludes some awards from the survey. The preliminary population was developed by taking the original set of SBIR and STTR Phase II awards made by DoE during the study period and eliminating on a random basis awards in excess of two to PIs who received more than two awards (to limit the burden on respondents). The resulting preliminary population was 1,077 awards. PIs for 583 of these awards were determined to be not contactable at the SBIR/STTR company listed in the DoE awards database. The remaining 494 awards constitute the effective population for this study. From the effective population, we received 269 responses. As a result, the response rate in relation to the preliminary population was 25.0 percent and in relation to the effective population was 54.5 percent.

The committee acknowledges that the study lacks an experimental or quasi-experiment study design that allows a randomly based comparison of the outcomes of companies that applied and did not apply and of those that received SBIR/STTR awards and those that did not—a design that would allow testing of the award's impact and the effect of gender and ethnicity on applications, awards, and success rates. As is typically the case in studies of competitively based grant programs, study designs that allowed comparisons only of the application or grant effect was impossible because the populations of applications and non-applications and of award recipient and non-recipients differ in many more ways than whether or not they applied and in whether or not they received an award; also, the program has criteria for making awards that are not randomly based.

The committee acknowledges that because information from non-respondent PIs was lacking, and because the agencies also have minimal information about PIs which could be used to track potential non-respondent biases, we can conclude only that the data are likely to be biased. Two potential biases are expected with regard to PIs participating in the survey: A bias toward PIs who are working at companies that are still in business as corporate entities (i.e. have not failed or been acquired), and a bias toward PIs who have received multiple awards because they are in the system multiple times and they may tend to have a greater reliance on the SBIR program, a more favorable view of

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it, and a greater willingness to complete the survey; furthermore, they may have greater recall about the program from working with it multiple times. Another potential bias results from the fact that the body of data is skewed, such that companies showing successful commercialization are rarer than companies having less commercial success. A random draw from the database would be less likely to produce a commercial success than not. Box A-1 in Appendix A presents a more complete discussion of the potential sources of biases that can skew the results in different directions.

The committee chose to focus the survey on Phase II awards rather than Phase I awards because Phase II-funded projects are expected to have business plans and to have progress toward commercialization. Thus, it is reasonable to expect a survey based on Phase II to show more evidence of commercial activity than one based on Phase I or a combination of both phases. The focus on Phase II awards reflects the effects of a "weeding out" of projects which were either not pursued by the companies for further SBIR/STTR funding or which were deemed not worthy of additional funding by the SBIR/STTR funding process. The focus on Phase II seems reasonable given the interest in commercialization.

In addition to information from this survey, the committee has drawn on company case studies, discussions with agency staff, and other documentation. In interpreting the findings and recommendations set out below, the reader needs to keep in mind the size of the survey population and response rates, and the overall potential sources of bias.

KEY FINDINGS

The SBIR program at the DoE is having a positive overall impact. It is meeting three of the four legislative objectives of the program with regard to stimulating technological innovation, using small businesses to meet federal research and development (R&D) needs, and increasing private-sector commercialization of innovations derived from federal R&D. However, the committee finds that more needs to be done to "foster and encourage participation by socially and economically disadvantaged small businesses (SDBs), and by woman-owned small businesses (WOSBs), in technological innovation." The STTR program at DoE is also meeting the program's statutory objectives, defined above, in that it is encouraging and supporting linkages between small business corporations (SBCs) and research institutions (RIs).

The findings are organized according to the legislative goals for SBIR/STTR plus findings on the management of the program.

Program Management

- DoE has substantially improved its SBIR/STTR programs since 2008 (the publication year of the previous National Academies report on the

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DoE SBIR program). A number of recommendations from the 2008 report have been adopted. (Finding I-A)

- DoE has adopted a number of other initiatives and pilot programs, which collectively have improved the program. (Finding I-A)
- DoE is seeking ways to improve its data collection and tracking. (Finding I-E)

Commercialization

- Nearly half of the respondents to the National Academies' 2014 Survey reported some sales, and a further 23 percent reported anticipating future sales. Of those respondents reporting some sales, 25 percent had sales less than $100,000. Six percent had sales over $10 million, and an additional 26 percent had sales over $1 million. The large number of companies with small-scale revenues suggests that although many companies reach the market, few can be described as successful in commercial terms. This finding reflects a deeper understanding of the limitations of the available data on successful commercialization. (Finding II-A)
- Subsequent investment in DoE SBIR/STTR projects is an indicator that they are seen as having the potential for commercial value even if they have not yet reached the market. The 2014 Survey shows that seventy-eight percent of 2014 Survey respondents reported receiving additional investment funding in the technology related to the surveyed project. (Finding II-C)
- SBIR/STTR funding makes a substantial difference in determining project limitation, scope, and timing. The 2014 Survey data show that seventy-one percent of respondents reported that the project probably or definitely would not have proceeded without SBIR/STTR funding. (Finding II-E)

Fostering the Participation of Women and Other Underserved Groups in the SBIR/STTR Programs

- Current data show that the objective of fostering the participation of women and underserved minorities has not been met by the DoE SBIR/STTR programs. (Finding III-A)
- Woman-owned firms accounted for less than 9 percent of Phase I SBIR and STTR awards in FY 2005-2015. The average success rates for Phase I applications by firms owned by woman and white males were 15.7 percent and 18.9 percent, respectively, during this period. (Finding III-A)
- Minority-owned firms accounted for less than 7 percent of Phase I SBIR and STTR awards during FY 2005-2015. (Finding III-A)

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- Among respondents to the 2014 Survey, the vast majority of "minority" firms were in fact owned by Asians. Firms owned by Blacks, Hispanics, and American Indians accounted for 2 percent of all responses (including zero Black-owned and American-Indian owned firms). (Finding III-A)
- DoE is making efforts to understand the patterns of woman and minority participation in the SBIR program, but more is needed. (Finding III-C)

Stimulating Technological Innovation and Meeting Agency Mission Needs

- The DoE SBIR/STTR programs support the development and adoption of technological innovations that advance the agency's mission. (Finding IV-A)
- The DoE SBIR/STTR programs connect companies to universities and research institutions. Among SBIR awardees responding to the 2014 Survey, 43 percent reported a link to a research institution related to the surveyed project; 26 percent reported that faculty worked on the project (not as a PI); 21 percent employed graduate students for the project; and 29 percent used universities and research institutions as subcontractors for the surveyed project. (Finding IV-B)

Fostering Innovative Companies

- The DoE SBIR/STTR programs encourage new firm start-up. Forty-five percent of companies responding to the 2014 Survey indicated that the company was founded entirely or in part because of the SBIR/STTR programs. (Finding V-A)
- Sixty-one percent of respondents to the 2014 Survey indicated that the DoE SBIR/STTR programs "had a highly positive or transformative effect" on their company. Another 35 percent said that it "had a positive effect." (Finding V-C)

STTR

- STTR is meeting the program objectives defined in the Small Business Administration's Policy Guidance for STTR. (Finding VI-A)
- Analysis of STTR in particular suggests that National Laboratories generally do not make good formal partners for small business concerns: their administrators do not prioritize SBIR/STTR because the funding amounts are small; and small businesses have limited leverage if the Laboratories fail to meet their obligations. (Finding VI-E)
- The DoE SBIR and STTR programs have not made sufficient efforts to enhance collaborations between the National Laboratories and small innovative firms. (Finding VI-E)

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KEY RECOMMENDATIONS

Although the DoE SBIR/STTR programs generate substantially positive outcomes, the committee has identified a series of recommendations to improve their processes and outcomes. The order of these recommendations reflects the relative emphasis of the committee.

Improving Monitoring, Evaluation, and Assessment

- Although DoE recognizes the need for better data and is working to improve tracking mechanisms, more remains to be done in this area. (Recommendation I)
- DoE should improve current data collection approaches and methodologies. (Recommendation I-A)
- DoE should ensure that the outcomes data it now collects are systematically employed to guide program management. (Recommendation I-B)
- DoE should prepare a comprehensive SBIR/STTR Annual Report that replaces current reporting requirements and provides a clear picture of program operations to the Secretary of Energy, Congress, and the public. (Recommendation I-C)

Addressing Underserved Populations

- DoE should immediately extend past and current efforts to foster the participation of underserved populations in the SBIR/STTR programs, develop an outreach and education program focusing on these populations, and create benchmarks and metrics to relate the impact of such activities. (Recommendation II)
- While DoE should strive to increase participation of under-represented populations in the SBIR/STTR programs, it should not develop quotas for that purpose. (Recommendation II-A)
- DoE should accelerate its efforts to develop new benchmarks and metrics. (Recommendation II-B)
- DoE should develop an outreach and education program focused on expanding participation of underserved populations. DoE should provide significant management resources, because these outreach efforts are likely to be difficult and long term, and should consider designating a senior staff member to work exclusively on outreach to women and minorities to improve reporting and deployment of the new initiatives. (Recommendation II-C)
- DoE should review selection procedures and remove any identified biases in the selection process. DoE should ensure that patterns of

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applications, awards, and success rates are monitored and reported out annually. (Recommendation II-D)

Improving Commercialization Outcomes

- DoE should support the commercialization of SBIR and STTR supported technologies beyond the completion of Phase II. (Recommendation III-A)
- DoE should review the effectiveness of its commercialization support and training initiatives. (Recommendation III-B)

Improving Linkages to National Laboratories

- DoE should seek to develop programs linking Laboratories' procurement actions with relevant SBIR/STTR projects. (Recommendation IV-A)
- DoE should seek ways to ensure that Laboratories fully understand and respect the intellectual property (IP) provisions of SBIR/STTR. (Recommendation IV-B)
- DoE should examine from a strategic perspective how the relationship of SBIR/STTR with the National Laboratories works today. (Recommendation IV-C)

Improving Program Management

- DoE should improve its topic development process. (Recommendation V-A)
- DoE should change the balance of funding to better reflect innovation and commercialization opportunities in the private sector. (Recommendation V-B)
- DoE should review and possibly rethink the relationship between the National Laboratories and SBIR/STTR. (Recommendation V-D)
- DoE should improve its application review system and monitor the profile of applicants. (Recommendation V-E)
- DoE should consider whether its current requirements for Phase I commercialization plans are appropriate. (Recommendation V-E)
- DoE should ensure that the selection criteria are fully transparent. (Recommendation V-E)
- DoE should monitor the percentage of multiple awards and the composite age of company applicants (e.g., ratio of startups to mature companies) who are applying for and receiving awards. Careful monitoring and study should inform the question of whether "small" or "young" companies are more effective in generating state-of-the-art technology and innovation in the context of SBIR. This evidence can

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be used by Congress to determine if encouraging participation by younger firms furthers the missions of the SBIR program. (Recommendation V-E)

- DoE should further address the funding gap between Phase I and II awards. (Recommendation V-F)

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1

Introduction

Small businesses are an important driver of innovation and economic growth in the United States.[1] Despite the challenges of changing global environments and the impacts of the 2008 financial crisis and subsequent recession, innovative small businesses continue to develop and commercialize new products for the market, improving the health and welfare of Americans while strengthening the nation's security and competitiveness.[2]

Created in 1982 through the Small Business Innovation Development Act,[3] the Small Business Innovation Research (SBIR) program remains the nation's 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.[4] 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 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]Small Business Innovation Development Act of 1982, P.L. 97-219, July 22, 1982.

[4]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 demanding from the small business perspective. Historically, all Department of Defense (DoD) and NASA awards have been contracts, all National Science Foundation (NSF) and most National Institutes of Health (NIH) awards have been grants, and the Department of Energy (DoE) has used both vehicles.

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

Seeking to bridge the gap between basic science and commercialization of resulting innovations, the Small Business Technology Transfer (STTR) program, created in 1992 by the Small Business Research and Development Enhancement Act of 1992[5] seeks to expand joint venture opportunities for small businesses and nonprofit research institutions. Under STTR, a small business receiving an award must collaborate formally with a research institution.

Both the SBIR and STTR programs consist of three phases:

- Phase I provides limited funding (up to $100,000 prior to the 2011 reauthorization and up to $150,000 thereafter) for feasibility studies.
- Phase II provides more substantial funding for further research and development (typically up to $750,000 prior to 2012 and $1 million after the 2011 reauthorization).[6]
- Phase III reflects commercialization without providing access to any additional SBIR/STTR funding, although funding from other federal government accounts is permitted.

The SBIR program has four congressionally mandated goals: (1) to stimulate technological innovation, (2) to use small business to meet federal research and development (R&D) 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.[7] The goals for the STTR program are to (1) stimulate technological innovation, (2) foster technology transfer through cooperative R&D between small businesses and research institutions, and (3) increase private-sector commercialization of innovations derived from federal R&D.[8] Each of the research agencies has sought to pursue these goals in administering their SBIR and STTR programs, utilizing the administrative flexibility built into the general program to address their unique mission needs.[9] Agencies with SBIR programs include the Department of Agriculture,

[5]Small Business Research and Development Enhancement Act, P.L. 102-564, Sec. 2941, Oct. 28, 1992.

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

[7]Small Business Innovation Development Act of 1982, P.L. 97-219, Sec. 881, July 22, 1982.

[8]Small Business Administration, "About STTR," https://www.sbir.gov/about/about-sttr, accessed July 9, 2015. Only the first two objectives are embedded in the authorizing legislation, although there is little controversy about the importance of the third, which appears to have been added by the Small Business Administration (SBA) in drafting its governing Policy Guidance for the program.

[9]The committee commended this flexibility in its 2008 assessment of the SBIR program. See Finding C, National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, p. 59.

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Department of Commerce, Department of Defense (DoD), Department of Education, Department of Energy (DoE), Department of Health and Human Services (DHHS), Department of Homeland Security, Department of Transportation, Environmental Protection Agency, NASA, and the National Science Foundation (NSF). Of these, DoD, NSF, DoE, DHHS, and NASA also have STTR programs.

At DoE, differences between the SBIR and STTR programs are summarized in the guidance document provided for potential applicants:

- STTR requires a formal collaboration between the small business concern (SBC) and a research institution (RI). The latter include colleges, universities, federal R&D laboratories, and other nonprofit research organizations.
- SBIR requires that the Principal Investigator (PI) be primarily employed by the SBC; STTR permits the PI to work only part time at the SBC, which, in turn, permits university faculty members to retain their faculty positions while acting as PI.
- SBIR requires that at least two-thirds of the Phase I and at least one-half of the Phase II R&D be conducted by the SBC; for both Phase I and II, STTR requires the SBC to perform at least 40 percent of the research and the RI at least 30 percent.[10]

As discussed in Chapter 2, DoE effectively operates SBIR and STTR as a unified program: it releases a unified solicitation, and companies can apply simultaneously for SBIR and STTR funding.

In fiscal year (FY) 2015, across DoE, 18 percent of Phase I SBIR/STTR applications resulted in an award, making it a highly competitive program. Also in FY 2015, 60 percent of Phase II applications were successful.[11] As a result, about 11 percent of DoE Phase I applications can be expected to result in a Phase II award. Before the 2011 reauthorization, Phase II awards could be awarded only to projects that had successfully completed Phase I, but after the reauthorization, Phase II awards could be awarded without meeting that requirement.

Over time, through a series of reauthorizations described in the pages that follow, SBIR/STTR legislation has required those federal agencies with extramural R&D budgets in excess of $100 million to set aside a growing percentage of their budgets for the SBIR program, and those with extramural R&D budgets in excess of $1 billion to set aside a growing percentage of their budgets for the STTR program (see Table 1-2). By FY 2012, the 11 federal agencies administering the SBIR/STTR programs were disbursing $2.4 billion

[10]Manny Oliver, "DOE's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs," DoE Webinar, December 4, 2015, p. 6.
[11]Data provided by DoE SBIR/STTR Program Office.

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TABLE 1-1 Agencies Currently Participating in the SBIR and STTR Programs

Agency	SBIR Participant	STTR Participant
Department of Agriculture	X	
Department of Commerce	X	
Department of Defense	X	X
Department of Education	X	
Department of Energy	X	X
Department of Health and Human Services[a]	X	X
Department of Homeland Security	X	
Department of Transportation	X	
Environmental Protection Agency	X	
National Aeronautics and Space Administration	X	X
National Science Foundation	X	X

[a] The Institutes and Centers at the National Institutes of Health; the Centers for Disease Control and Prevention (CDC); Food and Drug Administration (FDA); and the Administration for Children and Families (ACF) each operates its own SBIR and STTR programs.
SOURCE: Small Business Administration.

a year.[12] As shown in Figure 1-1, 5 agencies administer greater than 96 percent of SBIR/STTR funds: Department of Defense (DoD), Department of Health and Human Services (HHS) particularly the National Institutes of Health [NIH]), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), and Department of Energy (DoE). Aggregate award amounts for the five largest agencies for FY 2012 are provided in Table 1-2.

In December 2011, Congress reauthorized the SBIR/STTR programs for an additional 6 years,[13] with a number of important modifications. Many of these modifications—for example, changes in standard award size—were consistent with or followed recommendations made in a 2008 National Research Council (NRC)[14] report on the SBIR program, a study mandated as part of the program's 2000 reauthorization.[15] The 2011 reauthorization also called for further studies by the National Academies of Sciences, Engineering, and Medicine.[16]

[12]Small Business Association, SBIR/STTR annual report, http://www.sbir.gov/, accessed July 2015. FY2012 is the most recent year for which SBA publishes comparative data across agencies.
[13]Sec. 5137 of P.L. 112-81.
[14]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1, 2015.
[15]National Research Council, *An Assessment of the SBIR Program*. The National Research Council's first-round assessment of the SBIR program was mandated in the SBIR Reauthorization Act of 2000, P.L. Law 106-554, Appendix I-H.R. 5667, Sec. 108.
[16]The National Defense Reauthorization Act for Fiscal Year 2012, P.L. 112-81, Sec. 5137.

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TABLE 1-2 SBIR/STTR Funding by the Five Principal Funding Agencies, FY 2012

Agency	Sum of Award Amounts (Dollars)
Department of Defense	1,013,041,252
Department of Energy	201,954,290
Department of Health and Human Services[a]	774,065,517
National Aeronautics and Space Administration	159,122,575
National Science Foundation	130,236,977
Total	2,278,420,611

[a] The Institutes and Centers at the National Institutes of Health; the Centers for Disease Control and Prevention (CDC); Food and Drug Administration (FDA); and the Administration for Children and Families (ACF) each operates its own SBIR and STTR programs.
SOURCE: SBA awards database, https://www.sbir.gov/sbirsearch/award/all, accessed January 6, 2016.[17]

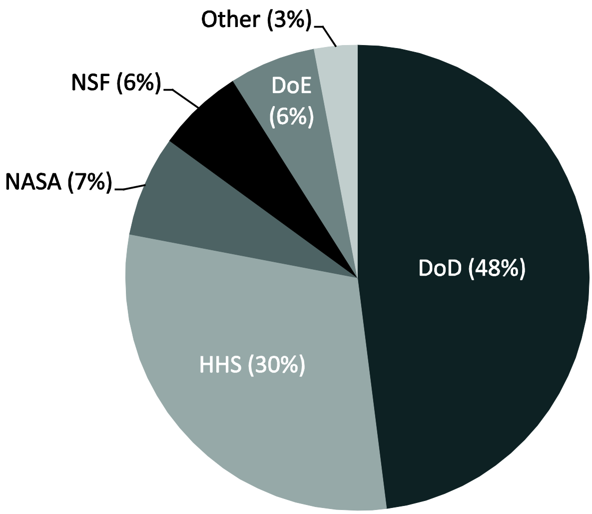

FIGURE 1-1 Percentage of total SBIR/STTR funding by agency, FY 2012.
NOTE: The Institutes and Centers at the National Institutes of Health; the Centers for Disease Control and Prevention (CDC); Food and Drug Administration (FDA); and the Administration for Children and Families (ACF) each operates its own SBIR and STTR programs.
SOURCE: Small Business Administration, FY 2012 SBIR/STTR annual report, http://www.sbir.gov, accessed January 4, 2016.

[17]It is a matter of some concern that SBA has not updated the SBIR/STTR annual reports available to the public. All of the agencies have reported FY 2015 data, and it is unclear why SBA has not provided what are relatively simple reports in a timely manner.

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The National Academies' first-round assessment resulted in 11 publications including the 2008 report referenced above. (See Box 1-1 for a listing of the 11 publications).

This introduction provides general context for analysis of the program developments and transitions described in the remainder of the report. The first section of the introduction provides an overview of the history and structure of the SBIR and STTR programs across the federal government. This is followed

BOX 1-1
The 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, National Aeronautics and Space Administration, Department of Energy, and National Science Foundation. In addition to published reports on the SBIR program at each agency and on the study methodology, the study resulted in a summary of a symposium focused on the diversity of the program and challenges to its assessment, a summary of a symposium focused on the challenges in commercializing SBIR-funded technologies, two reports on special topics, and the committee's summary report, *An Assessment of the SBIR Program*. In all, 11 study volumes were published by The National Academies Press:[a]

- *An Assessment of the Small Business Innovation Research Program: Project Methodology* (2004)
- *SBIR—Program Diversity and Assessment Challenges: Report of a Symposium* (2004)
- *SBIR and the Phase III Challenge of Commercialization: Report of a Symposium* (2007)
- *An Assessment of the SBIR Program at the National Science Foundation* (2007)
- *An Assessment of the SBIR Program at the Department of 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] Compete citations are provided in Appendix H.

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by a summary of the major changes mandated through the 2011 reauthorization and the subsequent Small Business Administration (SBA) Policy Directive; a review of the program's advantages and limitations, in particular the challenges faced by entrepreneurs using (and seeking to use) the program and by agency officials running the program; and a summary of the technical challenges facing this assessment and our recommended solutions to those challenges.

PROGRAM HISTORY AND STRUCTURE[18]

A review of the programs' origins and legislative history provides context to its place in the U.S innovation landscape. During the 1980s, the perceived decline in U.S. competitiveness due to Japanese industrial growth in sectors traditionally dominated by U.S. firms—autos, steel, and semiconductors—led to concerns about future economic growth in the United States.[19] A key concern was the perceived failure of American industry "to translate its research prowess into commercial advantage."[20] 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 remained a challenge. As the great corporate laboratories of the post-war period were buffeted by change, new models such as the cooperative model utilized by Japanese keiretsu seemed to offer greater sources of dynamism and more competitive firms.

At the same time, new evidence emerged to indicate that small businesses were an increasingly important source of both innovation and job creation.[21] This evidence reinforced recommendations from federal commissions dating back to the 1960s; that is, federal R&D funding should

[18]Parts of this section are based on the National Academies' previous report on the NIH SBIR program: National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Washington, DC: The National Academies Press, 2009.
[19]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.
[20]D.C. Mowery, "America's industrial resurgence (?): An overview," in D.C. Mowery, ed., *U.S. Industry in 2000: Studies in Competitive Performance*, Washington, DC: National Academy Press, 1999, p. 1. Other studies highlighting poor economic performance in the 1980s include M.L. Dertouzos et al., *Made in America: The MIT Commission on Industrial Productivity*, Cambridge, MA: The MIT Press, 1989; and O. Eckstein, *DRI Report on U.S. Manufacturing Industries*, New York: McGraw Hill, 1984.
[21]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.

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provide more support for innovative small businesses (which was opposed by traditional recipients of government R&D funding).[22]

Early-stage financial support for high-risk technologies with commercial promise was first advanced within an agency by Roland Tibbetts at NSF. In 1976, Mr. Tibbetts advocated for shifting some NSF funding to innovative technology-based small businesses. NSF adopted this initiative 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[23] 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.[24]

The SBIR Reauthorizations of 1992 and 2000

The SBIR program approached reauthorization in 1992 amid continued worries about the ability of U.S. firms to commercialize inventions (see Box 1-2). Finding that "U.S. technological performance is challenged less in the creation of new technologies than in their commercialization and adoption," the National Academies recommended an increase in SBIR funding as a means to improve the economy's ability to adopt and commercialize new technologies.[25]

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.[26] Legislative language explicitly highlighted commercial potential as a criterion for awarding SBIR contracts and grants.

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[22]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.

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

[24]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.

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

[26]Small Business Research and Development Enhancement Act, P.L. 102-564, Sec. 2941, Oct. 28, 1992. See also R. Archibald and D. Finifter, "Evaluation of the Department of Defense Small Business Innovation Research program and the Fast Track Initiative: A balanced approach," in National Research Council, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative,* Washington, DC: National Academy Press, 2000, pp. 211-250.

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BOX 1-2
Commercialization Language from 1992 SBIR Reauthorization

Phase II "awards shall be made based on the scientific and technical merit and feasibility of the proposals, as evidenced by the first phase, considering, among other things, the proposal's commercial potential, as evidenced by—

(i) the small business concern's record of successfully commercializing SBIR or other research;
(ii) the existence of second phase funding commitments from private sector or non-SBIR funding sources;
(iii) the existence of third phase, follow-on commitments for the subject of the research; and
(iv) the presence of other indicators of the commercial potential of the idea."

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

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."[27]

Established by the Small Business Technology Transfer Act of 1992 (P.L. 102-564, Title II), the STTR program was reauthorized until 2001 by the Small Business Reauthorization Act of 1997 (P.L. 105-135) and reauthorized again until September 30, 2009, by the Small Business Technology Transfer Program Reauthorization Act of 2001 (P.L. 107-50).

As explained below, the SBIR/STTR Reauthorization Act of 2011 included a number of changes to the SBIR/STTR programs, including increases in the set-asides over the next 6 years and expanded eligibility for STTR awardees to take part in technical assistance programs.

The 2011 SBIR/STTR 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

[27]Small Business Research and Development Enhancement Act, P.L. 102-564, Sec. 2941, Oct. 28, 1992.

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standard path to commercial success includes venture funding at some point.[28] Other issues were also difficult to resolve, but the conflict over participation of venture-backed companies dominated the process[29] following an administrative decision to exclude these firms more systematically.[30]

After a much extended discussion, passage of the National Defense Act of December 2011 reauthorized the SBIR and STTR programs through FY 2017.[31] 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.[32]

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

The reauthorization made changes in the SBIR program that were recommended in prior National Academies reports.[33] These included the following:

- Increased award size limits
- Expanded program size
- Enhanced agency flexibility—for example for Phase I awardees from other agencies to be eligible for Phase II awards or to add a second Phase II
- Improved incentives for the utilization of SBIR technologies in agency acquisition programs
- Explicit requirements for better connecting prime contractors with SBIR awardees
- Substantial emphasis on developing a more data-driven culture, which has led to several major reforms, including the following:
    - adding numerous areas of expanded reporting
    - extending the National Academies' evaluation program

[28]D.C. Specht, "Recent SBIR extension debate reveals venture capital influence," *Procurement Law,* 45:1, 2009.
[29]W.H. Schacht, "The Small Business Innovation Research (SBIR) program: Reauthorization efforts," Congressional Research Service, Library of Congress, 2008.
[30]A. Bouchie, "Increasing number of companies found ineligible for SBIR funding," *Nature Biotechnology,* 21(10):1121-1122, 2003.
[31]SBIR/STTR Reauthorization Act of 2011, P.L. 112-81, Dec. 31, 2011.
[32]See SBA post, S. Greene, "Implementing the SBIR and STTR Reauthorizations: Our Plan of Attack," February 21, 2012, http://www.sbir.gov/news/implementing-sbir-and-sttr-reauthorization-our-plan-attack.
[33]See Appendix B for a list of the major changes to the SBIR program resulting from the 2011 Reauthorization Act. For a report from the first-round assessment focused specifically on venture funding, see National Research Council, *Venture Funding and the NIH SBIR Program,* Washington, DC: The National Academies Press, 2009.

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  - adding further evaluation, such as by the Government Accountability Office and Comptroller General
  - tasking the SBA with creating a unified platform for the collection of data

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

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

- Expansion of the STTR program
- Limitations on agency flexibility—particularly in the provision of larger awards
- 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 National Academies, mandated reports from the Comptroller General on combating fraud and abuse within the program, and protection of small firms' intellectual property within the program.

PREVIOUS RESEARCH ON SBIR

Prior to the National Academies' first-round assessment, there had been few internal assessments of the agency programs, and external studies, most notably by the General Accounting Office and the SBA, focused on specific aspects or components of the SBIR and STTR programs.[34] The academic

[34]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,

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literature on SBIR was also limited,[35] except for an assessment in the 1990s by Joshua Lerner of the Harvard Business School who found "that SBIR awardees grew significantly faster than a matched set of firms over a ten-year period."[36]

To help fill this assessment gap and to learn about a large, relatively under-evaluated program, the NRC's Committee for Government-Industry Partnerships for the Development of New Technologies (GIP, which preceded the NRC's first-round congressionally mandated study of the SBIR) convened a workshop to discuss the SBIR program's history and rationale, review existing research, and identify areas for further research and program improvements.[37] In addition, in its report on the SBIR Fast Track Program at the Department of Defense, the GIP committee found that the SBIR program contributed to mission goals by funding "valuable innovative projects."[38] It concluded that a significant number of these projects would not have been undertaken absent SBIR funding[39] and that DoD's Fast Track program encouraged the commercialization of new technologies[40] and the entry of new firms into the program.[41] The GIP committee also found that the SBIR program improved both the development and utilization of human capital and the diffusion of technological knowledge.[42] Case studies provided some evidence that the knowledge and human capital generated by the SBIR program have positive economic value, which spills over into other firms through the movement of people and ideas.[43] Furthermore, by acting as a "certifier" of promising new technologies, SBIR awards encourage further private-sector investment in an award-winning firm's technology.[44]

It may be suggested that private sources of financing, such as early-stage seed capital firms and venture capital firms, can meet the need that is met by SBIR/STTR. However, both theoretical and empirical work on the process of innovation suggests that the private sector alone tends to underinvest in early-stage, high-risk innovation. Venture capital firms, early-stage seed companies

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1999. There is also a 1999 unpublished SBA study on the commercialization of SBIR that surveys Phase II awards from 1983 to 1993 among non-DoD agencies.

[35]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.

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

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

[38]National Research Council, *An Assessment of the DoD SBIR Fast Track Initiative*. See Chapter III: Recommendations and Findings, p. 32.

[39]Ibid, p. 32.

[40]Ibid, p. 33.

[41]Ibid, p. 34.

[42]Ibid, p. 33.

[43]Ibid, p. 33.

[44]Ibid, p. 33.

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and other private financing sources tend to delay their investments until technical and business risks have been reduced. Venture capital funding waxes and wanes, and none of these are substitutes for SBIR/STTR.[45] The fact that SBIR/STTR programs are the subject of multiple congressional objectives beyond commercialization only increases the likelihood that private funding sources are not analogous to SBIR and STTR.

THE ROUND-ONE STUDY OF SBIR

The 2000 SBIR reauthorization mandated that the NRC complete a comprehensive assessment of the SBIR program.[46] This assessment of the SBIR programs at DoD, NIH, NASA, NSF, and DoE began in 2002 and was conducted in three steps. As a first step, the committee authoring this study developed a research methodology[47] and gathered information about the program by convening workshops where officials at the relevant federal agencies described their program operations, challenges, and accomplishments. These meetings 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.[48]

The committee implemented the research methodology during the second step. As set out in the methodology, multiple data collection modalities were deployed. These included the first large-scale survey of SBIR recipients. Case studies of a wide variety of SBIR firms were also developed. The committee then evaluated the results and developed the findings and recommendations presented in this report for improving the effectiveness of the SBIR program. It is important to stress that the respondents to the survey represented a subset of all awardees, and is biased towards the opinions of those who did respond.[49]

During the third step, the committee reported on the program through a series of publications in 2004-2009: five individual volumes on the five major funding agencies and an additional overview volume titled *An Assessment of the SBIR Program*.[50] Together, these reports provided the first detailed and comprehensive review of the SBIR program and, as noted above, served as an important input into SBIR reauthorization prior to December 2011 (see Box 1-1).

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[45]Lewis Branscomb, Kenneth Morse, and Michael Roberts, *Managing Technical Risk and Understanding Private Sector Decision Making on Early Stage Technology-based Projects*, NIST GCR 00-787, April 2000.

[46]SBIR Reauthorization Act of 2000, P.L. 106-554, Appendix I-H.R. 5667, Sec. 108.

[47]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.

[48]Adapted from National Research Council, *SBIR: Program Diversity and Assessment Challenges*, Washington, DC: National Academies Press, 2004.

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

[50]National Research Council, *An Assessment of the SBIR Program*.

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THE CURRENT, SECOND-ROUND STUDY: CHALLENGES AND OPPORTUNITIES

The set of reports from the National Academies' first-round study of the SBIR program found that the program was, overall, "sound in concept and effective in practice."[51] Furthermore, in its review of the DoE SBIR program, the committee concluded, "The DoE SBIR program is making significant progress in achieving the congressional goals for the program."[52] The current study, described in the Statement of Task in Box 1-3, provides a second snapshot to measure the program's progress against its legislative goals.

This volume partially addresses the Statement of Task. It is supplemented by a number of workshops and other publications (See Box 1-4). For example, the committee convened workshops on the participation of women and minorities in SBIR/STTR (February 2013), the evolving role of university participation in the program (February 2014), the relationship between state innovation programs and SBIR (October 2014—see Box 1-5), the STTR program (May 2015), the economics of entrepreneurship in relation to SBIR (June 2015), and the challenge of commercialization of SBIR and STTR technologies (April 2016). The National Academies also published a report on *Innovation, Diversity, and Success in the SBIR/STTR Programs*, based on the 2013 workshop.

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

- Are there initiatives and programs within DoE that have made a significant difference to outcomes and in particular to the commercialization of SBIR-/STTR-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 of the SBIR and STTR by woman- and minority-owned firms and participation by female and minority principal investigators?
- Can links with universities be improved? In what ways and to what effect?
- Are there aspects of the program that make it less attractive to small firms? Could they be addressed?

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[51]Ibid., p. 54.
[52]National Research Council, *An Assessment of the Small Business Innovation Research Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008, p. 4.

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BOX 1-3
Statement of Task

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

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

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

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

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

In partial fulfillment of this Statement of Task, this volume presents the committee's review of the operation of the SBIR/STTR programs at DoE.

[a] The Phase I study refers to the National Academies' round-one assessments discussed above.

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BOX 1-4
Publications from the Second-Round Assessment of SBIR and STTR Programs

The National Academies of Sciences, Engineering, and Medicine's second-round assessment of the SBIR and STTR Programs at the Department of Defense, National Institutes of Health, National Aeronautics and Space Administration, Department of Energy, and National Science Foundation has resulted in six reports in addition to this report, each published by The National Academies Press:[a]

- *SBIR at the Department of Defense* (2014)
- *SBIR at the National Science Foundation* (2015)
- *Innovation, Diversity, and the SBIR/STTR Programs* (2015)
- *SBIR/STTR at the National Institutes of Health* (2015)
- *STTR: An Assessment of the Small Business Technology Transfer Program* (2016)
- *SBIR at NASA* (2016)

[a] Compete citations are provided in Appendix H.

- 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?

STUDY METHODOLOGY

The SBIR/STTR programs are unique in terms of scale and mission focus. In addition, the evidence suggests that there are no truly comparable programs in the United States, and those in other countries operate in such different ways that their relevance is limited.[53] Thus, it is difficult to identify comparable programs to SBIR/STTR against which to benchmark their results.

Assessing the DoE SBIR/STTR programs is challenging for other reasons as well. Unlike DoD and NASA, SBIR/STTR awards at DoE—although they may help to generate tools and capabilities for agency use—have their primary function as supporting technologies that will be adopted outside the

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

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agency, largely in the private sector. Thus success cannot be measured by internal sales of product to the agency alone.

The DoE SBIR/STTR programs are highly centralized in terms of management, but it is highly decentralized in terms of agency uses of the program and the kinds of topics that are funded. Although the SBIR/STTR Program Office sets policy, closely manages the topic development, solicitation, application, and award processes, and provides ongoing support for contracts and commercialization, each program area determines award funding separately. Program areas may have different views of the program and different approaches to their responsibilities. Therefore, generalizations about the DoE SBIR/STTR programs must be made with care.

Focus on Legislative Objectives

It is important to note at the outset that this volume—and this study—do not seek to provide a comprehensive review of the value of the SBIR/STTR programs, in particular measured against other possible alternative uses of federal funding. Such a review is beyond the committee's scope. Rather, the committee's work is focused on assessing the extent to which the DoE SBIR/STTR programs have met the congressional objectives set for the programs, in particular whether recent initiatives have improved program outcomes, and to provide recommendations for further improvements to the programs.[54]

Therefore, as in the first-round study, the objective of this second-round study is "*not* to consider if SBIR should exist or not"—Congress and the President have already decided affirmatively on this question, most recently in the 2011 reauthorization of the program.[55] Rather, this study is charged with "providing assessment-based findings of the benefits and costs of SBIR [and STTR]. . . to improve public understanding of the program, as well as recommendations to improve the program's effectiveness." As with the first-round committee, this committee "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."[56]

Defining Commercialization

Among the varied congressional objectives for the SBIR/STTR programs described above, measuring commercialization offers practical and

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[54]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.*

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

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

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BOX 1-5
SBIR/STTR & the Role of Complementary State and Federal Programs

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

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

State and local efforts that complement SBIR/STTR vary by state and locality. SBA maintains an annually updated listing of state and local economic development agencies, small business development centers, and colleges and universities that have received grants from the Federal & State Technology (FAST) Partnership Program specially aimed at helping firms compete in the SBIR/STTR program.[b] A directory of state services is also maintained by SBA for applicants to use in finding local assistance with business planning, matching

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funds programs, and other startup activities—with contact information, Web links, brief descriptions, and an interactive map—and is accessible via the home page of the SBIR-STTR website.[c] Many states are evolving a suite of services ranging from Phase 0 support to firms that might apply for SBIRs, to grants that match Phase I awards to some extent, to programs that help firms bridge the gap between Phase I and Phase II, to programs that match to various degrees a Phase II award, to programs that encourage firms to commercialize as a part of a Phase III. Not all states provide the full suite, but programs offered state and regional organizations focus on different features of support.

An earlier two-volume study[d] examined the relationship between state and federal programs in support of technology development by firms. The study found that the state programs augmented and were complementary to the federal program. While the federal program played the larger direct funding role, state and university programs were found to provides seed funding, intellectual property transfer, technology incubation, and researchers.

[a] National Academies of Sciences, Engineering, and Medicine, Workshop on *SBIR/STTR & the Role of State Programs*, Washington, DC, October 7, 2014. An archived copy of the webcast and a copy of the workshop agenda are available on the website of the National Academies of Sciences, Engineering, and Medicine at http://sites.nationalacademies.org/PGA/step/PGA_152137.
[b] FAST provides funding to state and local economic development agencies, Small Business Development Centers, and colleges and universities for providing outreach and technical assistance to science and technology-driven small businesses, particularly in helping socially and economically disadvantaged firms compete in SBIR/STTR. A listing of FAST grants for 22 states from FY 2012-2014 is provided in an EXCEL spreadsheet; lists by year from FY 2012 through FY 2016 are available by clicking on the year at the FAST website (http://www.sbir.gov/about-fast).
[c] To access the directory of local assistance for small businesses, go to http://sbir.gov/.
[d] See Schachtel and Feldman, *Reinforcing Interactions between the Advanced Technology Program and the States*, Vol. 1: *Reinforcing Interactions between the Advanced Technology Program and State Programs*, National Institute of Standards and Technology, NIST GCR 00-788, April 2000; and Feldman, Kelley, Schaff, and Farkas, *Reinforcing Interactions between the Advanced Technology Program and the States*, Vol. 2: *Case Studies of Technology Pioneering Start-up Companies and Their Use of State and Federal Programs*, National Institute of Standards and Technology, NISTIR 6523, December 2000.

definitional challenges. As described in Chapter 5, several different definitions of commercialization can be used to discuss the SBIR/STTR programs. The committee concluded that it is important to use more than one definition. For example, a simple measure of the percentage of funded projects that reach the marketplace is not a conclusive indicator of commercial success.

In the private sector, commercial success over the long term requires profitability. However, in the short term, the path to successful 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

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report the committee uses multiple metrics to measure commercial activity (see Chapter 5).

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 workshop described in a 2004 report.[57] In addition, as noted above, a peer-reviewed report on study methodology completed by the first-round committee provided the baseline for the initial study and for follow-on studies—including this one.[58]

Survey Development

For the current study, a survey of SBIR and STTR award recipients was developed and deployed in 2014, a necessity given DoE's decision to not provide quantitative outcomes data on privacy grounds. This survey was based closely on previous surveys, particularly the 2005 survey that focused exclusively on SBIR, but nonetheless it included significant improvements.[59] The description of the survey and improvements, including a discussion of the survey outreach and response, are documented in Appendix A of this report. Most notably, the committee made an ambitious but ultimately unsuccessful effort to develop a comparison group to provide context and a benchmark for analyzing results (this effort is also discussed in Appendix A).

The 2014 Survey developed for this assessment delves more deeply into the demographics of the program. It also includes questions about the role of agency liaisons, who deal with contract operations and thereby provide a link between individual projects and DoE. Furthermore, it provides unique opportunities to collect qualitative views on the program and recommendations for improvement from recipients. The survey was deployed from December 2014 to April 2015 and generated 269 responses from DoE Phase II SBIR/STTR award recipients. It is an important component of the research conducted for this volume.

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[57]National Research Council, *The Small Business Innovation Research Program: Program Diversity and Assessment Challenges*.

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

[59]The survey carried out as part of this study was administered in 2014, and the survey completed as part of the National Academies' first-round assessment of SBIR was administered in 2005. In this volume, all survey references are to the 2014 survey unless noted otherwise.

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The committee chose to focus the survey on Phase II awards rather than Phase I awards because Phase II-funded projects are expected to have business plans and to have progress toward commercialization. Thus, it is reasonable to expect a survey based on Phase II to show more evidence of commercial activity than one based on Phase I or a combination of both phases.[60] The focus on Phase II awards reflects the effects of a "weeding out" of projects which were not pursued by the companies for further SBIR/STTR funding. It also reflects the effects of a "weeding out" of projects which were deemed not worthy of additional funding by the SBIR/STTR funding process in cases where the Phase I work provided the answer being sought by the agency. The focus on Phase II seems reasonable given the interest in commercialization.

Appendix A provides a detailed discussion of the issues related to quantitative methodologies, a review of potential biases, and a list of the challenges of tracking commercial outcomes.[61] The committee recognizes that there are significant limitations on the conclusions that can be drawn from this quantitative assessment, and this recognition is reflected in the wording of the findings and recommendations (Chapter 8).[62] Limitations include the lack of a randomly drawn comparison group, likely biases in the survey results, and a focus only on Phase II awards. At the same time, drawing on quantitative analysis is a crucial component of the overall study, particularly given the need to identify and assess outcomes that are only to be found by querying individual projects and participating companies.

A Complement of Approaches

Partly because of these limitations, the committee stresses the importance of utilizing a complement of research modalities.[63] 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, insufficient to address the multiple questions

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[60]In a working paper, Sabrina Howell employs regression discontinuity analysis to examine the impact of DoE SBIR awards. Utilizing application data from DoE, she compared firms just above and below the cutoff for receiving an award. She found that receipt of a Phase I award "approximately doubles" the chance of later receiving VC funding, increases patenting, and is associated with greater commercialization. Phase II awards, on the other hand, she found to have "tiny or negative effects on VC finance," limited impact on patents, and no effect on reaching revenue. Howell's data were limited to SBIR awards in the EERE and the Fossil Energy offices and included applicants over a longer time period. Also, Phase II awards require a significant length of time for companies to realize outcomes. Sabrina Howell, "DOE SBIR Evaluation: Impact of Small Grants on Subsequent Venture Capital Investment, Patenting, and Achieving Revenue," Paper presented at the National Academy of Sciences, Engineering, and Medicine Workshop on the Economics of Entrepreneurship, June 29, 2015.

[61]Panel III of the committee's April 12, 2016, workshop on "SBIR/STTR and the Commercialization Challenge" focused specifically on tracking SBIR/STTR commercialization outcomes.

[62]For further discussion of potential sources of survey bias, see boxes 5-1 and A-1.

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

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SBIR/STTR at the Department of Energy

posed in this analysis. Consequently, the committee undertook a series of additional activities:

- **Case studies.** The committee conducted in-depth case studies of 12 DoE SBIR/STTR award recipients. These companies were geographically and demographically diverse, funded by different program areas at DoE, focused on different kinds of technologies, and at different stages of the company lifecycle. Lessons learned from the case studies are described in Chapter 7, and the cases themselves are included as Appendix E.
- **Workshops.** The committee conducted workshops, including workshops to discuss the participation of women and minorities in SBIR/STTR, the role of universities in SBIR/STTR, and the challenge of commercializing SBIR/STTR technologies,[64] to allow stakeholders, agency staff, and academic experts to provide insights into program operations, as well as to identify issues that should be addressed.
- **Analysis of agency data.** As appropriate, the committee analyzed and included data from DoE that cover various aspects of SBIR/STTR activities.
- **Open-ended responses from SBIR/STTR recipients.** For the first time, the committee collected textual responses in the survey. The comments received from 192 recipients are addressed in Chapter 7.
- **Agency consultations**. The committee engaged in discussions with agency staff about the operation of their programs and the challenges they face.
- **Literature review.** Since the start of the committee's research in this area, a number of academic and policy papers have been published addressing various aspects of the SBIR/STTR programs, many drawing from the survey and other data made available by the National Academies. In addition, other organizations—such as the Government Accountability Office—have reviewed specific parts of the SBIR/STTR programs. The committee has incorporated references to their work, where useful, into its analysis. The committee also

[64]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; *Commercializing University Research: The Role of SBIR and STTR*, February 5, 2014; *SBIR/STTR & the Role of States Programs*, October 7, 2014; *Workshop on the Small Business Technology Transfer Program*, May 1, 2015; *Economics of Entrepreneurship*, June 29, 2015; and SBIR/STTR and the Commercialization Challenge, April 12, 2016. Each of these workshops was held in Washington, DC.

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convened a workshop to learn more about new academic analysis of SBIR and STTR.[65]

Data Sources and Limitations

Multiple research modalities are especially important because limitations still exist in the data collected for the SBIR/STTR programs. As described in Chapter 5, DoE has not made its outcomes data available to the National Academies, which means that the National Academies' 2014 Survey provides the only available quantitative data on SBIR/STTR outcomes and processes at DoE.

Cooperation with DoE

The committee received substantial cooperation from the DoE SBIR/STTR Program Office and other DoE staff. Agency staff and researchers deployed by the committee engaged in numerous discussions, and DoE provided data, papers, and presentations.

In summary, within the limitations described, the study utilizes a complement of tools to ensure that a wide 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

Analyses and findings are organized as follows. Chapter 2 provides a review of program operations, describing the program in some detail and addressing a range of issues related to program management. Chapter 3 describes and analyzes agency initiatives that have been developed and implemented over the past 8 to 10 years. Chapter 4 reviews DoE data concerning applications and awards to the program, drawing out demographic and geographic differences as well as previous experience with the program. Chapter 5 provides a quantitative assessment of the program, drawing primarily on the National Academies' 2014 Survey in the absence of data from DoE. Chapter 6 addresses the congressional mandate to foster the participation of women and minorities, drawing on data and other material from DoE and from the 2014 Survey. Chapter 7 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 8 provides the findings and recommendations from the study.

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[65]National Academies of Science, Engineering, and Medicine, Workshop on *Economics of Entrepreneurship*, Washington, DC, June 29, 2015.

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SBIR/STTR at the Department of Energy

The report's appendixes 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 reproduces the 2014 Survey instrument. Appendix D lists research institutions identified by survey respondents as participating in DoE SBIR/STTR awards. Appendix E presents the case studies of selected firms with DoE awards. Appendix F serves as an annex to Chapter 5. Appendix G provides a glossary of acronyms used, and Appendix H provides a list of references.

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2

Program Management

This chapter reviews key features of the DoE SBIR/STTR programs[1] and highlights issues and concerns about their management. It introduces program initiatives launched by DoE, though these efforts are discussed in more detail in Chapter 3. The analysis found in this chapter is based on discussions with DoE staff, information from the 2014 Survey[2] and from company case studies, and documentation provided by DoE.

The DoE SBIR/STTR programs serve the Office of Science (SC) divisions and Office of Energy Efficiency and Renewable Energy (EERE) and other applied energy programs. This includes the Office of Science research programs—Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), and Nuclear Physics (NP), (collectively, the "science divisions"). The DoE SBIR/STTR programs also serve DoE's Office of Energy Efficiency and Renewable Energy (EERE), Office of Fossil Energy (FE), Office of Nuclear Energy (NE), and Office of Electricity Delivery and Energy Reliability (collectively, the "applied programs"), as well as the Office of Defense Nuclear Proliferation (DNP) and the Office of Environmental Management (EM). For fiscal year (FY) 2015, Congress allocated a total of approximately $6.6 billion to the SC divisions and EERE. Of this, less than $2 billion, or 29 percent, went to EERE. Within the Office of Science, BES received 26 percent, and HEP 12 percent (see Table 2-1).

[1]The SBIR and STTR programs are operated in as unified manner as possible at DoE, and in this chapter the discussion covers both SBIR and STTR, designated collectively as "SBIR/STTR" unless specifically described otherwise.

[2]As noted in greater detail at the beginning of Chapter 5, the overall target population for the survey reported in this chapter is DoE SBIR and STTR Phase II awards made during the period FY2001-2010, and most response data are reported at the project level. See Box 5-1 and Appendix A for a description of filters applied to the starting population. Averaged survey response data are reported to the nearest whole number.

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TABLE 2-1 Total Funding Allocations for the Office of Science (SC) Divisions and the Office of Energy Efficiency and Renewable Energy (EERE), FY 2015

Office of Science (SC) Division	Amount of Funding (Millions of Dollars)	Percentage of Total
Advanced Scientific Computing Research (ASCR)	541	8.2
Basic Energy Sciences (BES)	1,733	26.2
Biological and Environmental Research (BER)	592	8.9
Fusion Energy Sciences (FES)	468	7.1
High Energy Physics (HEP)	766	11.6
Nuclear Physics (NP)	595	9.0
Office of Energy Efficiency and Renewable Energy (EERE)	1,924	29.1
Total: SC + EERE	6,619	

SOURCE: Congressional Research Service and the Department of Energy.

Each SC division and each applied programs of EERE and the other offices listed previously is invited to suggest topics and subtopics, and SBIR/STTR funding for each is largely aligned with its extramural funding. In essence, the set-asides for SBIR and STTR are applied to the extramural budgets of each participating science division and applied program, and the resulting funding amounts are approximately equal to the amount of funding available for SBIR/STTR topics related to their interests.

DOE SBIR/STTR STAFFING

The DoE SBIR/STTR Program Office employs five full-time staff (one more in FY 2016 than in FY 2015), which represents a small portion of the workforce assigned to the program throughout DoE. The Program Office publishes solicitations, ensures compliance with program timelines and legislative requirements, and conducts outreach. Figure 2-1 shows the various components of the DoE SBIR/STTR programs as of FY 2015, including the DoE SBIR/STTR grants team depicted in the upper row of boxes, and the SBIR/STTR program contractors depicted in the lower row of boxes.

Approximately 100 federal staff in the program offices of the participating science divisions and applied programs manage the program's technical aspects. These include technical points of contact (TPOCs) prior to the Phase I award and after an award is made. Also included are technical topic managers (TTMs) who develop topics and subtopics (which are approved by the SBIR/STTR Program Office), identify reviewers, discuss possible proposals with applicants, and recommend projects for an award, as well as Technical Project Managers (TPMs). As indicated, DoE uses a variety of titles for its technical topic and program managers and points of contact. The titles may be overlapping and a single person may serve one or all of these functions. For

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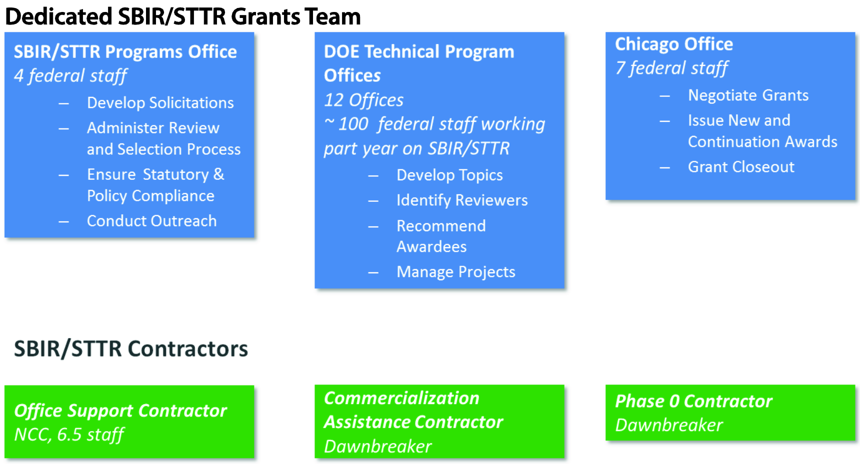

FIGURE 2-1 DoE SBIR/STTR program components, FY 2015.
SOURCE: DoE SBIR/STTR Program Office.

simplicity, we will refer to those functionally filling such positions as Topic Managers (TMs).

In recent years, the contracts support operation has changed. To improve the speed of throughput and to reduce difficulties caused by contract officers who are not familiar with the intricacies of SBIR and STTR awards, the contracts office has assigned seven full-time staff to the program. According to the Program Office, this change has significantly reduced the amount of time needed to finalize and process contracts.

Listed in Figure 2-1 in the contractor boxes is “Dawnbreaker,” a private contractor that provides two types of support services to the DoE SBIR/STTR Program Office: Advice to firms seeking to apply to the DoE program, i.e., “Phase 0 support,” and support services are to assist Phase I recipients plan for Phase II, and to provide commercialization assistance to Phase II awardees.

OUTREACH AND APPLICATION SUPPORT

DoE recognizes that it can derive significant agency-wide value from outreach activities to attract promising companies and technologies to the program. To this end, DoE participates in bus tours sponsored by the Small Business Administration (SBA) and in professional conferences and the national SBIR conference. However, it considers electronic communication to be the preferred approach to generate applications from companies that have not previously applied to the SBIR and STTR programs.

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Digital Outreach

During the past few years, DoE has developed an extensive outreach program organized primarily around the digital delivery of information, notably through a library of webinars and an enhanced SBIR/STTR website and has emphasized efforts to drive traffic to these resources. The DoE SBIR/STTR website provides considerable material to help potential applicants understand eligibility criteria, nuances of the program, and the process for application. New potential applicants are strongly encouraged to review the 1.5-hour Overview Webinar, which covers all the basic information needed to apply for an SBIR or STTR award. The PowerPoint presentation underpinning the webinar is available separately. Beginning in March 2013, DoE also began to host technical webinars that focus on specific technology areas; in April 2013, it launched a webinar series on funding opportunities, focusing on application-related questions; and in 2015, it launched a webinar series that focuses on the technical aspects of application budgeting, beginning with indirect rates.

In acknowledgment of the increasing complexity of the application process, the homepage of the DoE SBIR/STTR website provides quick links to other online systems with which applicants must register: DoE's Portfolio Analysis and Management System (PAMS), grants.gov, The U.S. government's System for Award Management (SAM), SBIR.gov, and Dunn and Bradstreet (D&B). As with other agencies, a potential applicant can no longer apply to DoE before forming a company; however, in most U.S. states, a company can now be formed rapidly and at low cost online.

New Program Entrants

To maintain a robust program that serves a broad base of small businesses, it is considered important to ensure that the SBIR/STTR program attracts new applicants and that a substantial share of funding goes to companies without previous awards. Data provided by DoE and shown in Figure 2-2 indicate that new applicants constitute a growing percentage of the applicant pool—doubling from FY 2009 to FY 2014. The share of Phase I awards to companies that had not previously won a DoE SBIR/STTR award also increased significantly during this time period, to about 40 percent in FY 2013-2014. Therefore, there is evidence that DoE's recent efforts to better inform potential applicants about the application process have been successful.

SOLICITATION TOPICS

Topic development at the DoE SBIR program[3] is highly decentralized: individual topic managers in the science divisions and in the applied programs

[3]The process has changed little in recent years. See National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008, pp. 94-95.

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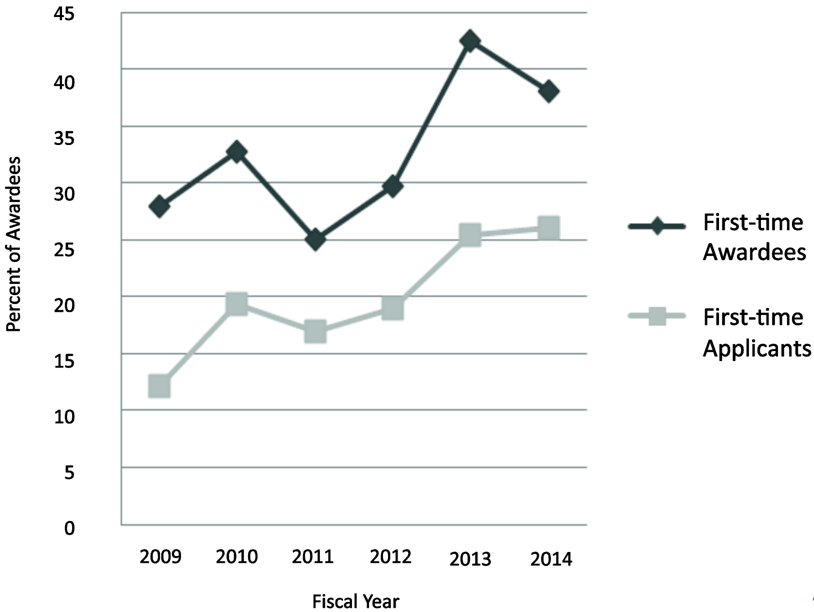

FIGURE 2-2 New applicants and new winners, SBIR/STTR Phase I at DoE, FY 2009-2014.
SOURCE: DoE SBIR/STTR Program Office.

have their own procedures for developing a list of topics for an upcoming solicitation, and the SC divisions have their own mechanisms for prioritizing amongst topics.

Each science division participates in one solicitation annually, separated into two releases to ease the workload in assessing applications and negotiating contracts. For the first of the two FY 2016 releases, science divisions ASCR, BER, BES, and NP participated, generating a total of 25 topics. The other science divisions and applied programs will participate in Release 2.

Narrow Topics

Each topic usually includes two to six subtopics, many of which are highly specific. For example, the FY 2016 solicitation included a call for "single bounce monolithic axis symmetric x-ray mirror optics with parabolic surface profile."[4] This degree of specification has been criticized by some company executives as potentially excluding other important technologies that may be a

[4]DoE FY2016 SBIR/STTR Solicitation Release 1, Topic 5.

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better fit for company expertise and easier to commercialize but that do not quite fit the specification.

Balancing Technical vs. Commercial Potential

Discussions with both program participants and company executives about the topic development process reinforced concern about a lack of commercial potential for some topics, especially those sponsored by the science divisions. Agency interviews indicated that most subtopics within the science divisions are generated by academic scientists at the National Laboratories. The SBIR/STTR Program Office performs some screening for commercial potential, but the effectiveness of this process is unclear. In addition, a number of company representatives interviewed for this study observed that DoE topics were often not focused on commercially valuable technologies—a point that is discussed in more detail in Chapter 5. On the other hand, topics can also emerge from consultations with small business concerns (SBCs). DoE's SBIR/STTR Program Executive, Dr. Manuel Oliver, described a case in which an SBC initiated a subtopic that was accepted but did not win the resulting competition.

Structural Issues

The tension between aligning topics with the scientific interests of DoE scientists and engineers versus aligning topic selection for commercial potential partly reflects the source of funds within the SBIR/STTR program. Each division's contribution of SBIR/STTR funding is proportionate to its share of extra-mural research funding: HEP, for example, oversees the allocation of approximately 11 percent of the SBIR/STTR funds because that is approximately equal to the percentage it receives of all DoE extra-mural research funds. HEP selects topics for SBIR/STTR projects to be funded out of approximately 11 percent of SBIR/STTR funds. This allocation of funding and influence over topic selection ignores systematic differences in commercial potential among the science divisions and the applied programs: commercial opportunities in high energy physics are not nearly as compelling as they are in renewable energy or fossil fuels because markets in high energy physics are smaller and needs are more specialized. For example, many research division topics support development of new scientific instruments, which, although valuable themselves, tend not to represent a large commercial market.

Dr. Oliver observed that in the past, funding was provided to the highest-scoring applications, regardless of division or program. However, this approach led to complaints from some staff in the science divisions, who believed that their reviewers were more critical and therefore scored applicants lower. The current system evolved in response to those complaints.

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Open Subtopics

In part to address the criticism of overly constrained topics/subtopics, the science divisions and most of the applied programs now offer an "other" subtopic for most topics. Therefore, applicants to all the science divisions and some of the applied programs who have a technology that fits within the broad topic but is not within the more specialized subtopics are now able to apply. All of the topics published under the first FY 2016 release (in which ASCR, BES, BER, and NP participated) included an "other" subtopic, and SBIR/STTR Program Manager, Manny Oliver, said that initial tracking of "other" subtopics indicated that for the science divisions, "other" topics were drawing 7 to 9 percent of applications.

According to the DoE SBIR/STTR Program Office, only EERE does not now offer the opportunity of an "other" subtopic category. According to agency staff, EERE has gone one step further by deliberately narrowing its topics to ensure that the numbers of applications will decline to manageable levels. Discussions with program participants and company executives, referenced above, had indicated their concern about EERE's use of overly specific topics because this practice threatened to limit their ability to apply, and, if they did apply, to limit their commercial potential.

Staffing Constraints

Reportedly EERE's principal reason for not offering an "other" option is because of concerns that this would cause it to be overwhelmed with applications. Indicative that having an open subtopic might drastically increase the number of applicants was the fact recalled by Dr. Oliver that when EERE had previously published an "other" subtopic, more than 50 percent of all EERE applications were submitted in the "other" subtopic area. This response from companies also provides evidence supporting the view that the published topics are relatively narrow, and that potentially valuable technologies are likely being excluded from program funding.

The apparent imbalance between funding patterns and commercial opportunities leaves EERE in a conflicted position: EERE understands the important goal of commercialization to increase benefits from the SBIR/STTR programs. EERE participates in outreach activities to promote applications. At the same time, EERE believes it does not have the manpower to review a potential flood of applications or the dollars to fund many of the high-quality applications it would likely receive in response to having an open subtopic category

Substantial and sometimes rapid technological change is occurring across the energy sector: the options opened up by renewables, fracking, nuclear energy, and efforts to develop cleaner fossil fuels have driven significant commercial investments. However, DoE and its SBIR/STTR programs remain structured around more traditional views of the energy sector. The narrowness

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of the opening for applications is clear. For example, in the FY 2016 funding round, EERE offered two subtopics within solar energy:

a. *Controls and systems for on-site consumption of solar energy. Within this subtopic, a number of areas of interest are identified: Areas of interest include, but are not limited to: (1) automated and predictive analytics applied to building load controls; (2) automated design tools for the development of integrated PV generation, load controls, electric vehicles and/or stationary storage, (3) intelligent controls for the charging and discharging of storage systems; (4) techniques and methods for incorporating short-term weather projections; (5) rapid, efficient, and safe installation of behind-the-meter storage, controls, and generation; and (6) techniques and methods for monetizing integrated PV, load response, and storage in electricity markets.*
b. *Shared Solar Energy Development Tools. Areas of interest include, but are not limited to: (1) development of new platforms that reduce the cost of customer acquisition for shared solar hosts and participants; and (2) data collection, billing, and project management automation.*[5]

Notably, both subtopics are open to applications within the defined technical area that is not listed as one of the "areas of interest." However, potential applications in areas outside the two defined subtopics are not eligible for funding.

Topics from Science vs. Applied Divisions

Topics within the science divisions in large measure remain unchanged from year to year, and in some cases subtopics remain unchanged or similar as well. Comparing the topics and subtopics in FY 2015 and FY 2016 (for Release 2), there were 6 new topics out of 32 (mostly in topics managed by the office of defense nuclear nonproliferation), while there were 52 new subtopics out of 186 total (30 percent). Fusion Energy and Nuclear Energy were the offices with the highest percentage of identical subtopics. However, in some areas, there was 100 percent change between years.

In the applied programs, however, subtopics do change annually. In FY 2015, for example, in EERE there were five solar energy subtopics:

1. Analytical and Numerical Modeling and Data Aggregation
2. Concentrating Solar Power: Novel Solar Collectors
3. Concentrating Solar Thermal Desalination
4. Grid Performance and Reliability
5. Labor Efficiencies through Hardware Innovation[6]

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[5]DoE SBIR/STTR Topics FY2016 Phase I Release 2, November 23, 2015, pp. 50-51.
[6]DoE SBIR/STTR Topics FY2015 Phase I Release 2, November 23, 2014, p. 59.

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In contrast, in EERE in FY 2016 there were only the two subtopics noted previously, both of which were entirely different from the 2015 subtopics.

1. Controls and Systems for the On-Site Consumption of Solar
2. Shared Solar Energy Development Tools[7]

In both cases, the solar topics reflect technical needs identified in the context of a large DoE/EERE solar initiative—the SunShot Initiative.[8] Yet, while DoE solar topics for at least 2015 and 2016 have been based on needs identified by the SunShot initiative, the subtopics changed and became more restrictive.

Overall, although the need to tailor the number of applications to the resources available is understandable, the approach adopted by EERE and more broadly by DoE in the distribution of funds means that potentially significant technologies are excluded from the SBIR/STTR programs before their value can be assessed.

THE APPLICATION PROCESS

Eligibility

The SBIR/STTR programs are in practice no longer open to individual applicants who do not have a registered company. Applicants must register with a number of government or government-mandated databases before they can apply for funding. They must have an Employer Identification Number (EIN) from the Internal Revenue Service (IRS), register on the primary government grants website (grants.gov) and the System for Award Management (SAM), have a DUNS number from Dunn and Bradstreet, and finally register with DoE's electronic management grants system (Portfolio Analysis and Management System, or PAMS). The reality, therefore, is that applicants must complete a considerable amount of paperwork and display a certain degree of commitment before they can apply for funding, as is true for all the major SBIR-awarding agencies.

Timeline

The DoE application process follows a tight and transparent timeline that is readily available to applicants (see Figure 2-3). According to DoE, the

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[7]DoE SBIR/STTR Phase I release 2 topics, November 2015, p.51. http://science.energy.gov/~/media/sbir/pdf/TechnicalTopics/FY2016_Phase_1_Release_2_Topics_Combined.pdf.

[8]The SunShot Initiative works in partnership with industry, academia, national laboratories, and other stakeholders to achieve subsidy-free, cost-competitive solar power by 2020. The potential pathways, barriers, and implications of achieving the SunShot Initiative price-reduction targets and resulting market penetration levels are examined in the SunShot Vision Study. (http://www1.eere.energy.gov/solar/sunshot/vision_study.html).

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SBIR/STTR at the Department of Energy

deadlines are posted on the DoE SBIR/STTR website 1 year in advance so that potential applicants have time to fully prepare (see Figure 2-4).

Applicants have approximately 1 month between the date that the topics are released and the date that the Funding Opportunity Announcement (FOA) is released. This period provides potential applicants with an opportunity to connect with subtopic managers to discuss technical elements of a proposed project and to become familiar with the somewhat complex application process now required by all federal SBIR agencies.

DoE has made efforts in recent years to compress the timeline and, at the same time, to allot companies more time to develop higher quality proposals. DoE claims to be now making decisions within 90 days of the application deadline.[9]

Unpublished data provided to the committee from an interagency working group that recently reviewed award timelines at all the SBIR/STTR agencies revealed that DoE has significantly improved its Phase I award selection time (defined as the lag between Funding Opportunity Announcement (FOA) and award announcement), down from about 160 days in FY 2011 to below the 90-day benchmark mandated by SBA in FY 2013. DoE almost met the 90-day benchmark for Phase II selection by 2011 and continued to make improvements in 2012 and 2013.[10]

Letters of Intent

After the FOA is released, applicants have about 3 weeks to develop a letter of intent (LOI) (see Box 2-1). DoE limits the number of LOIs to 10 per company per solicitation, which therefore also limits the total number of applications from a single company. According to DoE, the intended purpose of LOIs is to assign appropriate technical reviewers; not to weed out weak proposals. The distribution of LOIs will signal the likely pattern of Phase I applications downstream.

DoE responds to LOIs, but only to indicate whether the proposed project is responsive to the topic. Although projects deemed nonresponsive can still apply, this step in the process may cause some potential applicants to decide to not apply. Thus, the limitation on LOIs to 10 and the DoE response to LOIs that may indicate that they are not considered responsive to topic, in effect, may reduce the number of applications from what they otherwise would have been. This may sharpen companies' focus on identifying what they want to submit, and reduce the burden on the DoE reviewer process. The final Phase I application is due 5 weeks after the LOI is due and must be submitted electronically.

[9]Manny Oliver, "DoE's SBIR and STTR Programs," DoE Webinar, December 4, 2015, p. 45.
[10]See Chapter 3, "Program Initiatives," for a more detailed analysis.

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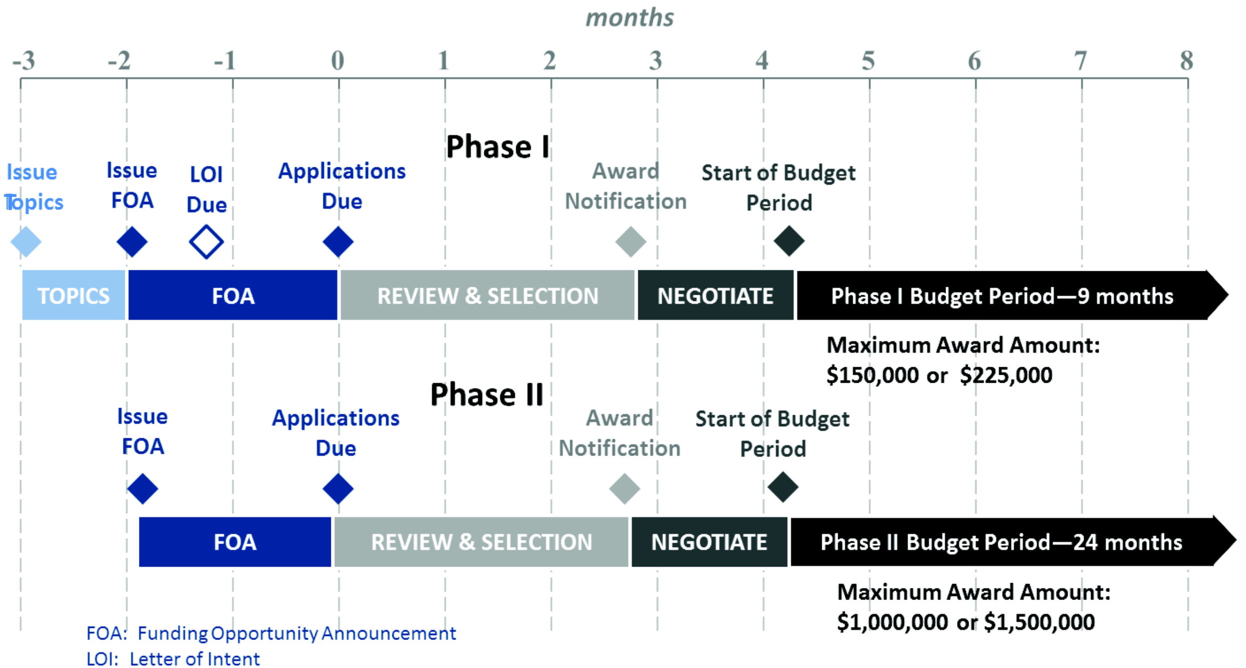

FIGURE 2-3 DoE SBIR/STTR applications and awards timeline, FY 2016.
SOURCE: DoE SBIR/STTR Program Office.

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Fiscal Year: FY17 (Future), FY16 (current), FY15 (closed)

2016

Phase I

	Release 1 FOA CLOSED FOR APPLICATIONS	Release 2
Topics Issued	Monday, July 20, 2015	Monday, November 02, 2015
Document	Phase I Release 1 Topics (809KB)	Phase I Release 2 Topics (1003KB)
Webinar(s)	Topics 1-15 Webinar Topics 17-19 Webinar Topics 21-25 Webinar	Topics Webinar 20-29 Topics Webinar 8 & 18-19 November 13: Topics 9-16: Register Here! November 17: Topics 1-7, 17 & 30-32: Register Here!
FOA Issued	Monday, August 17, 2015	Monday, November 30, 2015
Document	Phase I Release 1 FOA (819KB) (DE-FOA-0001366)	
Webinar(s)	Friday, August 21, 2015 – FOA Webinar Wednesday, September 2, 2015 – Indirect Rates	Friday, December 04, 2015
Letters of Intent (LOI) Due	Tuesday, September 08, 2015 5:00pm ET	Monday, December 21, 2015 5:00pm ET
Applications Due	Monday, October 19, 2015 11:59pm ET	Tuesday, February 09, 2016 11:59pm ET
Award Notification	Early January 2016*	Early May 2016*
Projected Grant Start Date	Monday, February 22, 2016	Monday, June 13, 2016

FIGURE 2-4 Deadlines for DoE SBIR/STTR applications, FY 2015.
SOURCE: DoE website. Accessed November 11, 2015.

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SBIR/STTR at the Department of Energy

BOX 2-1
Content of Letter of Intent (LOI)

- Title
- Topic and subtopic
- Abstract (<500 words)

Provide sufficient technical detail to enable reviewer assignment
Nonproprietary

- List of collaborators
- Small business information
    - Name, address
    - Business official and contact information
    - Principal investigator

- Phase I or Fast-Track

SOURCE: DoE SBIR/STTR Program Office.

The Program Office provided quantitative details about the effect of the LOI process on application patterns (see Figure 2-5). Of the 2,852 LOIs received in FY 2014, 572 (21 percent) were deemed unresponsive to the topic. Of these, 97 (17 percent) applied for funding anyway, and, of these, 8 percent received an award (about one-half the rate of the applicants with responsive LOIs). Thirty percent of applicants with responsive LOIs did not apply, so the actual impact of the LOI process can be estimated: assuming that all applicants submitting an LOI were equally likely to apply, a negative response led to a substantial reduction in the proportion of LOIs from that group resulting in applications. It is therefore reasonable to conclude that a negative response to the LOI has a significant impact on the decision to apply.

Technical and Commercialization Plans

DoE provides an Instruction Guide for would-be applicants to use in preparing an SBIR/STTR Phase I grant application.[11] For preparing Fast-Track and Phase II guidance, DoE refers applicants to the respective Funding Opportunity Announcement.

[11]DoE, *Instructions for Completing a DOE SBIR/STTR Phase I Grant Application*. See http://science.energy.gov/~/media/sbir/pdf/Application_Resources/Application_Guide.pdf.

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In addition to the various forms and data entries, a Phase I application contains a project narrative describing the problem or situation that is being addressed and how it will be addressed, including the proposed technology and related research design, research objectives, and methods and technical approach to be used. The applicant is asked to provide enough background information that the importance of the problem/opportunity is clear, and to provide enough information on the technical approach to make it clear how the proposed research will address the problem or take advantage of the opportunity.

Project Narrative

The project narrative also describes commercial potential of the proposed project, in terms of expected future applications and/or public benefits if the project is continued into Phase II and beyond. The applicant is asked to discuss the technical, economic, social, and other benefits to the public as a whole that are anticipated if the project is successful and is carried forward. The applicant is asked to describe the resultant product or process, the likelihood that it could lead to a marketable product, the significance of the market, and the identity of specific groups in the commercial and public sectors that would likely benefit from projected results.

Revenue Forecast

While acknowledging that Phase I commercialization plans will vary greatly with technology and application—such as for delivering improved technologies into existing markets versus delivering new technologies into emerging markets, DoE requires a revenue forecast over a 10-year period mandatory for Phase I applications.[12] This requirement is aimed at ensuring that companies do not find their proposed market to be too small for commercial operations after completion of Phase II. This is an interesting effort by DoE to balance the need to ensure that companies are working on technologies with potential commercial viability with the obvious difficulties of forecasting revenues for products that in some cases will not enter markets for many years.

Commercialization Plan

Phase II, including Phase IIB, applications require more substantial commercialization plans. Review of Phase IIB applications (discussed in Chapter 3) is more closely focused on commercial potential: 50 percent of the numerical weighting is assigned to impact, and two reviewers evaluate the commercialization plan.

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[12]DoE provided a detailed Phase I commercialization plan as an example. See http://science.energy.gov/~/media/sbir/pdf/docs/ExamplePhaseICommercializationPlan61112.pdf.

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The Review Process

The review process begins with an administrative review by the SBIR/STTR Program Office to ensure that the application includes all the relevant materials. After passing this initial screening, the application is forwarded to the TM who initiated the relevant subtopic.

There are four criteria for award selection:

> *(1) the significance of the technical and/or economic benefits of the proposed work, if successful, (2) the likelihood that the proposed work could lead to a marketable product or process, (3) the likelihood that the project could attract further development funding after the SBIR or STTR project ends and (4) the appropriateness of the data management plan for the proposed work.*

Selection Criteria

Commercial potential is considered under criterion number two. Although, as described above, some commercialization information is required for Phase I, a full-scale commercialization plan is required for Phase II. Four selection criteria apply to commercialization potential: (1) Market Opportunity, (2) Company/Team, (3) Competition/Intellectual Property, (4) Finance and Revenue Model. For many years, technology transfer staff at the National Laboratories reviewed these plans, but the Program Office determined that this work was not an appropriate use of their time and contracted with a commercial third-party to conduct the commercialization plan reviews.

Three reviewers are assigned to each Phase I and each Phase II application. Dr. Oliver said that about 50 percent of the reviewers are from National Laboratories, 30 percent are from universities, and 20 percent are from the private sector or other federal agencies (see Figure 2-5).

The Scoring System

Each reviewer generates a separate score for each of the four scoring criteria. Unlike NIH, there is no opportunity to discuss scores or develop a consensus. For each category, the proposal is rated as *not acceptable*, *acceptable*, or *outstanding*—and these are translated into a numerical scoring system with a very limited set of numbers corresponding to each descriptive rating. The numerical scores are averaged to generate an aggregate score for the proposal, which is reviewed by the TM who provides an independent score. If the TM score differs from the reviewers' average score, then the TM must provide a written justification for the difference in any of the three scoring categories. This justification is especially important when the TM is recommending the project for funding, according to Dr. Oliver.

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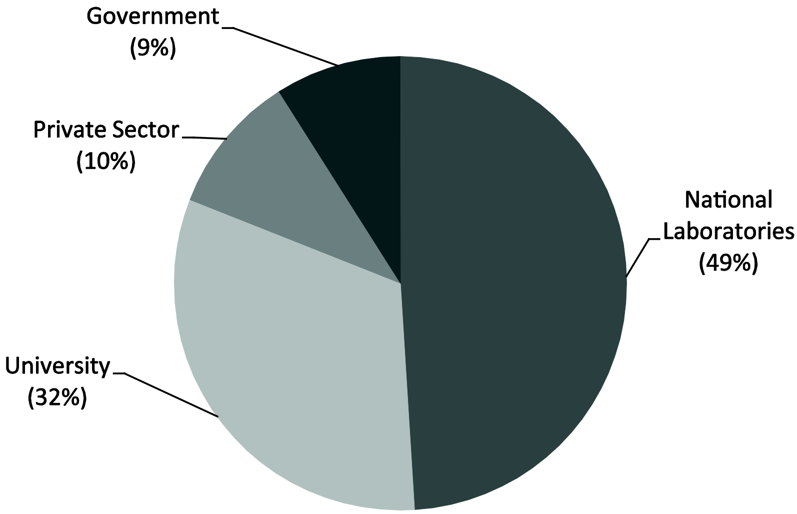

FIGURE 2-5 Sources of SBIR/STTR application reviewers, FY 2015.
SOURCE: Manny Oliver, "DoE's SBIR and STTR Programs," DoE Webinar, December 4, 2015, p. 46.

The limited scoring system significantly impacts the process and applicants' perception of the process. First, projects that do not receive an outstanding score in all three categories cannot easily recover. A maximum score for impact is unlikely to outweigh a less than favorable capabilities score. Second, there may be a lack of distinction among numerical scores of projects scored as outstanding (see Figure 2-6), while at the same time there is not enough funding to support all of the projects scored as outstanding. Almost as many Phase I applications are recommended but not funded (16 percent) as are recommended and funded (18 percent). Twelve percent of Phase II awards are recommended but not funded. From the applicant's perspective, learning that they received a score of "outstanding" and did not receive funding, while others with the same score did receive funding would likely be perceived as a lack of transparency and possible unfairness. A clear statement of selection criteria, a more nuanced scoring system that indicates ranking among proposals, and announcement of where the funding cut-off occurred, such as some aspects of the selection process used at NIH, helps prevent perceptions that the selection process lacks transparency and fairness.[13]

[13]For an overview of the selection process at the National Institutes of Health, see National Academies of Sciences, Engineering, and Medicine, *SBIR/STTR at the National Institutes of Health*, Washington, DC: The National Academies Press, 2015, pp. 41-50.

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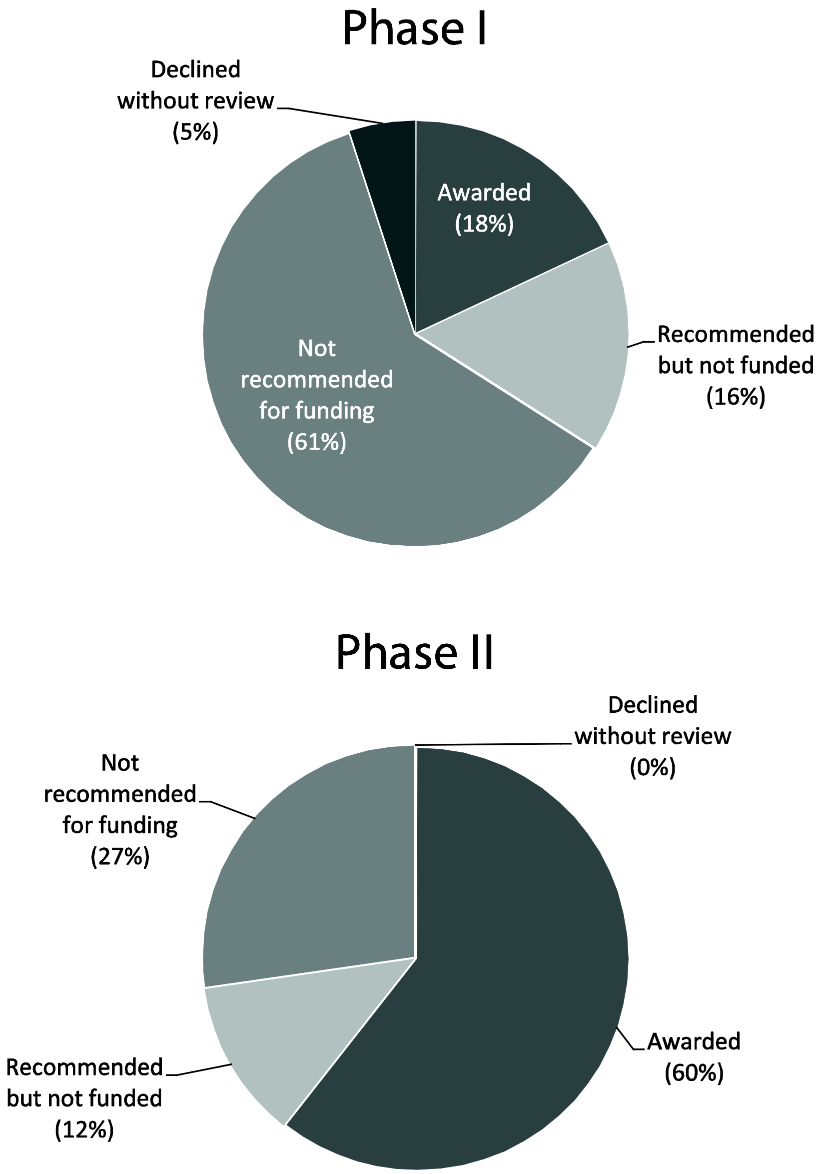

FIGURE 2-6 Outcomes from review of DoE Phase I and Phase II applications, FY 2015.
SOURCE: Manny Oliver, "DoE's SBIR and STTR Programs," DoE Webinar, December 4, 2015.

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Internal Ranking

At the conclusion of the initial review process, the TM initiates an internal ranking process for applications, first for the subtopic and then—in conjunction with other subtopic managers—for the topic overall. TM rankings are then aggregated across a program area and reviewed by senior management (often an Assistant Secretary, although the precise staff assigned varies by division). At the end of the review, a final ranking is provided by each science division and applied program. The DoE SBIR/STTR Program Office then provides a funding cut-off for the program, which is applied to the final ranking. There is room for some adjustment, particularly in the case of small programs whose funding might be rounded up to the next whole award (e.g., up from funding 1.2 awards to funding 2 awards).

Since DoE's deployment of the PAMS system in FY2013, DOE has made reviewer comments available online for all applicants.

AWARDS MANAGEMENT

DoE has moved from the paper-driven process described in the National Academies of Sciences, Engineering, and Medicine 2008 report[14] to a completely electronic application and awards management system, an adapted version of the system in use at NASA and provided by REI, a third-party contractor.

In addition, DoE has changed its organizational structure for managing applications and handling SBIR/STTR contracts. Previously, the Program Office utilized staff in the Chicago DoE contracting operation on an ad hoc basis to process applications and awards. In some cases, the staff were not familiar with SBIR/STTR,[15] and the Program Office incurred additional training costs to ensure that the number of staff assigned part time to SBIR/STTR were sufficiently familiar with the program. In 2012, the Program Office arranged to have contracts staff in Chicago dedicated to the SBIR/STTR Programs. This arrangement was made possible in part by the decision to release two annual solicitations, with some divisions participating in the spring and the others in the fall.

The resulting steadier workflow has allowed for dedicated staff, and the arrangement appears to be working well: overall, interviewees and 2014 Survey respondents had a strongly favorable view of awards management at DoE. They observed that deadlines were clear and generally met and that payment procedures were rapid and effective.

[14] National Research Council, *An Assessment of the SBIR Program at the Department of Energy*.
[15] See Appendix E for some cases in which this caused considerable difficulties.

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AWARDS TRACKING AND EVALUATION

DoE has tracked program outcomes for a number of years through post-award surveys. These surveys were first deployed on paper and now via the web. The surveys have been deployed periodically (not annually), and the next planned survey has been delayed until all awards data are available for incorporation. The Program Office anticipates that it will be deployed shortly. Program managers will be able to use the internal DoE awards tracking database (PAMS) to view selection decisions and outcomes by company and by technology, and to follow progress and patterns of success at the division/program level.

Because outcomes data collected in PAMS were not made available to the committee due to issues of privacy, it is difficult to draw conclusions about the effectiveness of this approach and options for improving it. It is also difficult to determine how widely the existing data are utilized for program management. The Program Office clearly has plans for more extensive utilization and has hired one new staff member in this area.

COMMERCIALIZATION SUPPORT

DoE provides commercialization support for awardees through a \$1.5 million annual contract with Dawnbreaker, a third-party service provider. Through a range of services, Dawnbreaker provides assistance to companies to write Phase I proposals, to Phase I companies to write Phase II proposals, and to Phase II companies to improve their commercialization plans. Commercialization support provided by DoE is described in detail in Chapter 3.

STTR

To the maximum extent possible the DoE STTR program is operated in parallel with the SBIR program, as indicated by the previous combined treatment. There is no separate solicitation; the topics are identical for both programs; application and award deadlines are identical; and companies can apply simultaneously to SBIR and STTR, leaving it to DoE staff to determine which program is more suitable. DoE has explicitly stated that it has no separate strategic objective for the STTR program and would prefer that the programs be combined if feasible. However, mandatory differences between the programs remain:

- STTR requires that the SBC enter into a formal partnership with a research institution (RI), which includes an agreement with respect to intellectual property (IP).
- STTR requires that at least 30 percent of the work be done by the RI and at least 40 percent by the SBC.

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- STTR eliminates the SBIR requirement that the principal investigator (PI) on the project work at least 51 percent time for the SBC.
- DoE provides additional time for STTR Phase I (9 months instead of 6 months).[16]

DoE manages the STTR and SBIR programs as being administratively and functionally identical, which reduces administrative overhead. While aware of the congressionally-mandated differences between the programs, the agency does not see any significant or strategic distinctions between them. Small businesses in both programs collaborate with RIs, and only a small percentage of STTR awards go to PIs employed primarily by an RI.

DoE offers one Phase I STTR solicitation from each participating science division and applied program annually, split into two releases. Uniquely among the funding agencies, both Phase I and Phase II applicants can apply to either program or to both using a single application—as long as they meet the qualifications for both. Approximately as many applicants select both SBIR and STTR as select just one of them.

Annual funding for STTR is about $25 million. Awards are highly competitive, with a success rate of about 10 percent for STTR Phase I and 50 percent for STTR Phase II. DoE offers the same performance period and award size for both programs. Phase I awards last 9 months for either $150,000 or $225,000. Phase II awards last 24 months, and may be for $1 million or $1.5 million.

The DoE SBIR and STTR programs have recently increased their emphasis on the commercialization of funded technologies. Because the programs focus on providing seed capital for early-stage research and development (R&D) with commercial potential, SBIR/STTR Phase I and Phase II applications must provide an initial evaluation of commercial potential. Awards are, like those at other agencies, comparable in size to large early stage angel investment. However, both programs will deliberately accept greater risk than will angel investors, in support of the agency mission.

Although STTR is designed to encourage collaborations between small companies and RIs, many DoE SBIR projects exhibit collaborations as well. More than one-half of all Phase II SBIR projects include some funding for RIs, and overall about 9 percent of SBIR funding goes to RIs.[17]

The STTR program supports an extensive set of collaborations with DoE National Laboratories, which on average partner on about one-third of DoE's STTR projects. According to the DoE SBIR/STTR Program Office, their share has varied—from a high of 80 percent in FY 1999 to a low of 13 percent in FY 2014, while averaging about a third.[18]

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[16]Manny Oliver, "The DoE STTR Program," presentation at the NAS STTR Workshop, May 1, 2015; discussions with DoE staff; and other material provided by DoE.
[17]Manny Oliver, private communication.
[18]See Chapter 3 (Program Initiatives) for a further discussion of National Labs and STTR.

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Principal investigators (PIs) for DoE projects mostly come from SBCs, with only 13 percent coming from RIs (including a small number primarily employed at National Laboratories)—even though STTR permits the PI to be primarily employed at the RI. In FY 2014, 3 out of 35 STTR PIs were employed at the RI.[19]

Like the other agencies, DoE has followed the 2011 reauthorization law to permit awardees to switch between SBIR and STTR when entering Phase II. DoE has found that some STTR Phase I awardees are switching from STTR to SBIR during Phase II, but not the reverse. Since the program permitted such a switch in FY 2011, 10 out of 83 STTR Phase I awardees applying for Phase II funding sought SBIR Phase II funding, and 4 received it. [20]

SBIR/STTR PROCESS ISSUES

To build on the analysis provided in the National Academies 2008 report[21] on the DoE SBIR program, the current assessment sought to identify additional information about the process of implementing SBIR/STTR awards, with a view to providing management with more detailed information about program operations. This section considers several operational aspects of the program.

Funding Gaps

In some cases, the flow of funding from DoE to the awardee can be interrupted between phases of an SBIR/STTR award. This problem is especially challenging for small firms, which are less likely than larger firms to have other funding sources to keep projects alive until Phase II funding arrives. In recent years, DoE has tried to address the problems of funding gaps. Sixty-five percent of SBIR and STTR respondents indicated that they had experienced a gap between the end of Phase I and the start of Phase II for the surveyed award.[22] As shown in Table 2-2, this funding gap can have a range of consequences for the company. Fifty-nine percent of respondents reported that they stopped work altogether during this period, while 35 percent worked at a reduced level of effort. Five percent maintained or increased the pace of their work. Aside from the obvious direct impact of delayed projects, funding gaps can have long-term consequences, especially for smaller companies, where in some cases there is insufficient work to retain key project staff during the gap period.

DoE has largely addressed the funding gap by shortening the timeline between the end of Phase I and the beginning of Phase II. It has not utilized

[19]Manny Oliver, private communication.
[20]Ibid.
[21]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*.
[22] 2014 Survey, Question 22.

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TABLE 2-2 DoE SBIR and STTR: Effects of Funding Gaps Between Phase I and Phase II, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Stopped work on this project during funding gap	59	61	48
Continued work at reduced pace during funding gap	35	33	48
Continued work at pace equal to or greater than Phase I pace during funding gap	5	5	9
Received gap funding between Phase I and Phase II	1	1	
Company ceased all operations during funding gap	1	1	
Other	2	2	
N = Number of Respondents Reporting a Gap Between Phase I and Phase II	167	144	23

SOURCE: 2014 Survey, Question 23.

some of the tools available for this purpose at other agencies; for example, NIH allows companies to work at their own risk, recouping costs expended on Phase II work during the gap if the Phase II is eventually awarded.

Ease of Application

The 2014 Survey also sought to probe more deeply into award recipient perspectives on application and award management. One question concerned the degree of difficulty involved in applying for a Phase II award compared with applications to other federal programs. As shown in Table 2-3, 31 percent of respondents reported that the application process was easier or much easier than for other sources of federal funding, and 15 percent of respondents indicated that it was more difficult or much more difficult.

Amount of Funding

Although there are obvious limitations to the utility of asking recipients whether the amount of money provided was sufficient for the surveyed project, there is at least some value in determining the extent of positive responses. It should also be noted that the funding amounts changed during the period covered by the survey. As shown in Table 2-4, in this case 66 percent of respondents said the amount was about right or more than enough, and 34 percent said that the amount was insufficient.

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TABLE 2-3 Ease of Application for SBIR and STTR at DoE, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Much easier than applying for other federal awards	14	14	10
Easier	17	18	13
About the same	44	44	40
More difficult	10	9	17
Much more difficult	5	5	3
Not sure, not applicable, or not familiar with other Federal awards or funding	11	10	17
N (Number of Respondents)	246	216	30

SOURCE: 2014 Survey, Question 53.

TABLE 2-4 Adequacy of Phase II Funding, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
More than enough	1	1	0
About the right amount	65	65	63
Not enough	34	34	37
N (Number of Respondents)	248	218	30

SOURCE: 2014 Survey, Question 54.

Size of Awards

Although awardees often suggest in other contexts (e.g., case study interviews) that the size of awards should be increased, especially before the recent changes were made during reauthorization, the 2014 Survey asked directly about the possible trade-off between the size of awards and the number of awards—the trade-off being that unless agency funding for SBIR or STTR programs increases, larger awards inevitably imply fewer awards. In the context of that trade-off, a majority of respondents did not believe that increases in award size would be appropriate (see Table 2-5).

Program Size

The survey also asked about the possible expansion of the SBIR/STTR programs. Perhaps not surprising, about two-thirds of respondents overall indicated that they would support an increase in program size, even if funding were taken from other federal programs that they value. (See Table 2-6.)

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TABLE 2-5 Preference for Larger but Fewer Awards, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Yes	21	23	10
No	57	56	57
Not sure	23	21	33
N (Number of Respondents)	248	218	30

SOURCE: 2014 Survey, Question 55.

TABLE 2-6 Views on changing the Size of the SBIR/STTR Program, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Expanded (with equivalent funding taken from other federal research programs you benefit from and value)	67	67	70
Kept at about the current level	32	32	30
Reduced (with equivalent funding applied to other federal research programs you benefit from and value)	1	1	0
Eliminated (with equivalent funding applied to other federal research programs you benefit from and value)	1	1	0
N (Number of Respondents)	246	216	30

SOURCE: 2014 Survey, Question 56.

Working with Topic Managers

Interviews with Project Managers have suggested that a critical factor affecting the success of SBIR and STTR projects may be the relationship between the awardee and the DoE Topic Manager (TM).[23] The 2014 Survey of award winners asked a series of questions aimed at identifying ways in which this relationship might be improved.

Engagement with TMs

Respondents were asked to indicate how often they engaged with their TM. Thirty-nine percent reported annual contact, and 44 percent reported quarterly contact (see Table 2-7).

[23]As was explained earlier in this chapter, DoE uses a variety of titles for the technical manager of a topic or subtopic. In this report, we refer to all those functionally filling this position as Topic Managers (TMs).

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TABLE 2-7 Frequency of SBIR and STTR Contact with DoE TMs, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Weekly	2	2	0
Monthly	15	16	10
Quarterly	44	45	40
Annually	39	37	50
N (Number of Respondents)	239	209	30

SOURCE: 2014 Survey, Question 59.

Another survey question asked about the ease or difficulty that respondents had in contacting their DoE TMs, and another asked if the TM had sufficient time to spend on their project. In response, 88 percent of respondents reported that it was easy or very easy to contact the TM when necessary,[24] and only 7 percent reported that the TM had insufficient time to spend on their project.[25]

At some agencies, the rotation of program managers has been a problem for awardee companies, especially where the program manager has a function in connecting the company to Phase III opportunities within the agency. In general, however, TM rotation has not seemed a serious problem at DoE; only 17 percent of respondents indicated that their TM was replaced during the Phase II award.[26]

Value of the TM to the Company

Interviews indicated that some TMs have had very positive effects on their awardee companies, while others have been of little help. The survey attempted to gauge the distribution of utility by asking respondents how helpful the TM was to their project (see Table 2-8). Overall, 40 percent of respondents scored TM usefulness at 4 or 5 on a 5-point scale, with 5 being invaluable. Conversely, 29 percent scored usefulness at 1 or 2.

TM Technical Understanding of SBIR/STTR

One important role of the TM is to provide technical advice to the awardee about the operations of the SBIR/STTR. It is fairly complex, so a technically knowledgeable TM can be of great use, especially to companies that are new to the program. The survey therefore asked respondents about their views on the TM's technical capacity with regard to SBIR/STTR. Overall,

[24]2014 Survey, Question 65.
[25]2014 Survey, Question 67.
[26]2014 Survey, Question 66.

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TABLE 2-8 Usefulness of the TM, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Invaluable (5)	15	16	10
4	26	26	23
3	30	31	30
2	16	17	13
No help (1)	13	11	23
N (Number of Respondents)	240	210	30

SOURCE: 2014 Survey, Question 60.

respondents appeared satisfied; almost three-quarters indicated that their TM was extremely knowledgeable or quite knowledgeable about SBIR/STTR. Only 6 percent of respondents indicated that the TM was not at all knowledgeable, while 74 percent said that the TM was extremely or quite knowledgeable.[27]

At some agencies, TMs or the equivalent provide support also for Phase II proposals. At DoE, this function is primarily outsourced to Dawnbreaker, so it is not surprising that only about a one-quarter of survey respondents indicated that the TM was very or somewhat helpful regarding Phase II proposals and awards.[28]

Because TMs are usually technically knowledgeable about the science and engineering involved in the award, they can sometimes provide valuable direct insights. Twenty percent of respondents indicated that they received substantial technical help from the TM, while 58 percent indicated that they received little or none.[29] TMs may also be in a position to introduce awardees to technical staff at research institutions (including National Laboratories) who may be able to provide critical technical support. About one-quarter of respondents indicated that this was the case for their project.[30]

BEYOND PHASE II

Commercialization initiatives, discussed in detail in Chapter 3, seek to provide additional support for companies as they seek to commercialize beyond the SBIR program's second phase. However, despite the new initiatives, the support that DoE offers beyond Phase II is limited. In particular, no programs are in place to link SBIR/STTR projects to potential uses inside DoE at the National Laboratories. A number of company executives interviewed for this report described their difficulties in persuading DoE programs to adopt

[27]2014 Survey, Question 61.
[28]2014 Survey, Question 62.
[29]Ibid.
[30]Ibid.

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technologies that they had apparently sponsored through SBIR. For example, the technologies developed by Vista Clara were in part designed to help with the cleanup of contaminated groundwater, an important priority for DoE. Yet, there is no program in place to connect the company and its technology to DoE groundwater programs. In fact, the company's strong connections to the nuclear cleanup of the Hanford Site in southeastern Washington State, overseen by two DoE Offices, have resulted in no sales, because the cleanup there is led by a third-party contractor (analogous to a Department of Defense prime) with no obligations or connections to the SBIR/STTR program.[31]

The DoE SBIR/STTR Program Office has been run on a very lean basis.[32] As a result, the office has limited its focus to the operation of the program itself, now with additional emphasis on outreach and support during Phase I and Phase II. These priorities are understandable and appropriate. However, other agencies have developed initiatives that link SBIR/STTR technologies to market opportunities in the sectors relevant to the agency, and there is no reason why DoE could not profitably follow their example. Navy operates the Navy Opportunity Forum, Air Force hosts a series of transition meetings between large companies and SBCs, and NASA maintains online access to SBIR/STTR technologies.

Technology Transfer Opportunities

In 2013, DoE began a new technology transfer initiative, using the SBIR and STTR programs to transition technology developed at DoE National Laboratories and universities to the marketplace. To accomplish this, DoE began setting aside a number of awards for Technology Transfer Opportunities (TTOs), which are subtopics for which National Laboratories offer technologies that could be appropriate for transition into a SBIR- or STTR-related project.[33] Because the agency is prohibited by statute[34] from using only the STTR program to foster technology transfer from its laboratories, it uses both SBIR and STTR, and doing so creates a range of new opportunities for collaboration between companies and RIs. The number of TTO subtopics and awards are listed in Table 2-9. Subtopics are written to describe the state of the existing technology at the lab and to underscore the point that the opportunity here is to find a commercial partner. This is, in contrast to standard topics where the opportunity is to develop a new technology to address a defined problem.

[31]See Appendix E (Case Studies).

[32] See National Research Council, *An Assessment of the SBIR Program at the Department of Energy*.

[33]Subtopics for Technology Transfer Opportunities are published in the standard SBIR/STTR solicitation.

[34]See Commerce and Trade Law 2015 (Annotated): USC Title 15. See also "The STTR Program at the Department of Energy," Presentation by Manny Oliver, Director, DoE SBIR/STTR Program Office, National Academies Workshop on the STTR Program, Washington, DC, May 1, 2015.

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TABLE 2-9 Adoption of Technology Transfer Opportunities (TTOs) at DoE, FY2013-15

	TTO subtopics	FY I Awards	FY II Awards
FY 2013	18	2	0
FY 2014	33	8	1
FY 2015	31	8	3

SOURCE: DoE SBIR/STTR Program Office.

SBIR/STTR and the National Laboratories

At DoE, many STTR awards in particular involve partnerships with DoE National Laboratories. This is not the case for other agencies, although all have at least some STTR awards for which a National Laboratories is the Research Institution partner. Much of the discussion in this section focuses on STTR linkages between SBC's and National Laboratories. As shown in Table 2-10, DoE's 17 National Laboratories are sponsored by six different programs within DoE. Partnerships with the National Laboratories account for a substantial percentage of all the STTR partnerships between SBCs and RIs at DoE. Partnerships with National Laboratories account for about one-third of all Phase I and Phase II RI partnerships (see Table 2-11).

Partnerships with National Laboratories account for 28 percent of STTR Phase I research partnerships and 33 percent of Phase II partnerships. DoE should consider exploring whether partnering with a National Lab is associated with a higher success rate for applications, given the potential for conflicts of interest. The fact that the most applied of the laboratories—National Renewable Energy Laboratory (NREL) and Pacific Northwest National Laboratory (PNNL)—account for a relatively low percentage of partnerships, suggests that partnering with the laboratories may be driven more to access very specialized technologies (such as accelerators) and related markets than it is to more generalized technologies.

Although disputed by DoE, some of the conclusions about management of the national laboratories are also reflected in comments from interviewees for this study and from survey respondents. A number of reports have highlighted what are perceived as growing issues in DoE management of the laboratories, that is, multilayered management with inflexible rules. The National Academy of Public Administration, for example, concluded in 2013 that DoE management of lab operations "...not only define the deliverables and due dates [of lab work and research] but are very prescriptive about the interim steps to be followed to complete the work assignment."[35] Also in 2013, a joint bipartisan study by the Information Technology and Innovation Foundation, Center for American Progress, and Heritage Foundation found that "DoE has replaced contractor

[35]National Academy of Public Administration, "Positioning DoE's Labs for the Future," Washington, DC: NAPA, January 2013, p. 23.

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TABLE 2-10 Location and Sponsoring Program for DoE National Laboratories, FY 2015

DoE Sponsoring Agency	DoE Lab	Location
National Nuclear Security Administration	Lawrence Livermore National Laboratory	Livermore, California
	Los Alamos National Laboratory	Los Alamos, New Mexico
	Sandia National Laboratory	Albuquerque, New Mexico
Office of Energy Efficiency and Renewable Energy	National Renewable Energy Laboratory	Golden, Colorado
Office of Environmental Management	Savannah River National Laboratory	Aiken, South Carolina
Office of Fossil Energy	National Energy Technology Laboratory	Pittsburgh, Pennsylvania Morgantown, West Virginia
Office of Nuclear Energy	Idaho National Laboratory	Idaho Falls, Idaho
Office of Science	Ames Laboratory	Ames, Iowa
	Argonne National Laboratory	Argonne, Illinois
	Brookhaven National Laboratory	Upton, New York
	Fermi National Laboratory	Batavia, Illinois
	Lawrence Berkeley National Laboratory	Berkeley, California
	Oak Ridge National Laboratory	Oak Ridge, Tennessee
	Pacific Northwest National Laboratory	Richland, Washington
	Princeton Plasma Physics Laboratory	Princeton, New Jersey
	SLAC National Accelerator Laboratory	Menlo Park, California
	Thomas Jefferson National Accelerator Facility	Newport News, Virginia

SOURCE: Adapted from Matthew Stepp, Sean Pool, Nick Loris, and John Spencer, Turning the Page: Reimagining the National Laboratories in the 21st Century, ITIF Center for American Progress and the Heritage Foundation, June 2013, Figure 1.

accountability with direct regulation of lab decisions—including hiring, worker compensation, facility safety, travel, and project management."[36] While this report is not the appropriate venue for reviewing lab management in general, it seems worthwhile to consider relevant findings of the interviews and survey.

Linking SBCs and National Laboratories

Linking SBCs and National Laboratories involves substantial structural difficulties. The latter are usually operated by government contractors—nonprofits such as Battelle—rather than directly by government staff. For the National Laboratories, even a Phase II STTR award is a small amount of money. Thus, although scientific staff may be enthusiastic about working with an SBC

[36]Matthew Stepp, Sean Pool, Nick Loris, and John Spencer, Turning the Page: Reimagining the National Labs in the 21st Century, ITIF Center for American Progress and the Heritage Foundation, June 2013.

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TABLE 2-11 SBC-National Laboratories Collaborations Under STTR at DoE, FY 2000-2013

Research Institution	Phase II	Phase I
Lawrence Berkeley National Laboratory	12	23
Argonne National Laboratory	8	21
Oak Ridge National Laboratory	8	16
Thomas Jefferson National Accelerator Facility	8	11
Fermi National Accelerator Laboratory	5	10
Pacific Northwest National Laboratory	4	10
Brookhaven National Laboratory	6	8
SLAC National Accelerator Laboratory	5	8
Los Alamos National Laboratory	2	6
Lawrence Livermore National Laboratory	2	5
Sandia National Laboratories	1	3
Idaho National Laboratory	1	2
National Renewable Energy Laboratory	1	2
Total SBC-National Laboratories Collaborations	63	125
Total number of STTR awards	187	448
Total number of research institution partners	90	155

SOURCE: Data provided by DoE SBIR/STTR Program Office.

on an exciting project, administrators may see a burden rather than an opportunity. Administrative costs for the lab can effectively swallow all of the funding that might be provided to the lab under a Phase I award. In addition, although more than one-half of DoE SBIR/STTR reviewers are from the National Laboratories, these staff also play a powerful role in determining topics. DoE should consider evaluating reviews to compare scores for SBCs that do and do not collaborate with the laboratories.

Few Incentives

More generally, there are few incentives for National Laboratories to collaborate with SBCs. Sixteen of the 17 laboratories are government-owned but contractor-operated (GOCOs). In theory this arrangement provides incentives for contractors to run the laboratories efficiently while offering enhanced government oversight compared to private-sector laboratories contracted by the government. DoE staff in onsite offices oversee the laboratories, and officers approve all lab research agreements. As noted in Appendix E, Dr. Warburton (XIA), one of our case studies, said that, in the best of cases, the lab scientists view STTR as a means of supporting their research program, in exchange for providing the company with technical support. In other cases, lab staff view the program as a means to generate funds and often are not interested in commercial outcomes or even their partner's interests.

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Teaming Agreements

In addition, lab procedures are cumbersome. All teaming agreements require a cooperative research and development agreement (CRADA), and in the case of SBIR/STTR, each phase requires a separate CRADA. Furthermore, although the basic structure of the CRADA almost always follows the standard Stevenson-Wydler model contract, according to Dr. Johnson (Muons case study in Appendix E). Any change to the statement of work must be approved not only by the lab staff but also by the DoE cognizant officer who controls lab activities on behalf of DoE.

Cumbersome procedures can lead to substantial delays. In fact, as Dr. Johnson pointed out, CRADA approvals can take months. As a result, small companies working with National Laboratories must develop mechanisms for managing substantial volatility in funding flows, which could be disastrous. He also noted that delays by the lab in approving a change to the statement of work could result in the lab and the SBC working on different timelines, and therefore the lab being as much as a year behind the agreed timeline.

Other Challenges

Working with the National Laboratories presents other challenges as well. Several interviewees explained that, because the laboratories are fundamentally research organizations, they work on principles oriented around the free exchange of information and ideas, eventually leading to peer-reviewed publication of scientific and technical advances. The SBC may, however, need to maintain closer control of IP developed under an STTR award, either through patents or trade secrets, and this need to control the flow of information can create significant cultural tensions with normal lab operations. Dr. Warburton (XIA) noted that each lab has its own culture; XIA worked quite successfully with Pacific Northwest National Lab and Lawrence Livermore National Lab, but not with other laboratories.

Several survey respondents and interviewees noted that STTR agreements with National Laboratories were less enforceable than SBIR subcontracts. Under SBIR, the SBC can simply refuse to pay or switch to another supplier if the lab fails to deliver the technology or work. Whereas, under STTR, the SBC is committed to the RI for the entire Phase I/Phase II cycle and has no recourse if the RI fails to deliver. As Dr. Johnson (Muons) noted, in such circumstances, the SBC would have to do the work itself—it could not fire or sanction the RI. Dr. Warburton (XIA) said that his company's collaboration with Brookhaven National Laboratory was especially poor, with no accountability for the project at the lab. The lab's role was to develop a specific mechanism, but it did not deliver.[37]

[37]See Appendix E (Case Studies).

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Still, case study interviewees and 2014 Survey respondents provided cases of highly successful STTR partnerships with National Laboratories. These seemed especially likely to succeed if the SBC had a deep understanding of the lab. In several cases—such as found in the Muons case study—at least one SBC executive had worked for many years within the National Lab in question and therefore was highly knowledgeable about lab culture and procedures.

Positive Outcomes from STTR Collaborations

Finally, multiple positive outcomes from STTR collaborations with the National Laboratories were in evidence. When working with the National Laboratories, some companies view commercial success as only a component of their mission. Dr. Johnson (Muons) said that his company focuses on serving the technical needs of DoE and in particular the Laboratories, much like some SBIR companies serve DoD. He believed, based in part on his extensive experience as a lab employee, that a small firm could provide creative solutions that were difficult or impossible inside the Laboratories.[38] Dr. Ives (CCR) said that his company partnered with the SLAC National Accelerator Laboratory to improve the performance of cavity resonators used in linear accelerators. Stronger electric fields within the resonators means accelerators can be shorter, potentially saving millions of dollars in construction costs. However, these cost savings did not show up in the commercialization data.[39]

It is worth noting that some survey respondents see significant changes in the Laboratories' attitudes toward STTR. Dr. Johnson (Muons), for example, observed that the Laboratories have traditionally viewed STTR (and SBIR) as a tax on research funding, but this perspective has changed in recent years. His view is that the Laboratories have become more interested in finding ways to use STTR (and SBIR) awards to meet their technical needs.[40]

CONCLUSIONS

DoE and in particular the DoE SBIR/STTR Program Office has substantially improved program management since the previous National Academies report in 2008. These improvements include:

- the shift to electronic submission
- considerably shorter time lines for applications and awards
- better connections to topic managers
- introduction of commercialization support in several areas
- perhaps the best SBIR/STTR website for applicants

[38]Ibid.
[39]Ibid.
[40]Ibid.

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- a new series of webinars which explain the application process in considerable detail
- introduction of a dedicated contracts operation
- introduction of several significant pilot programs based on best practice at other agencies (discussed in Chapter 3)

Collectively, these improvements have made a positive difference to applicants and awardees. From the point of award to the end of Phase II DoE now has what is largely a state-of-the-art operation.

Areas for potential improvement can be found prior to the Phase I award and to the end of the Phase II award. Some concerns emerge about the topics available for funding: in some cases, topics and subtopics repeat, where it may be that other areas deserve to be examined for funding. In other cases, the topics and subtopics may change too drastically to quickly to build innovation in a target area.

For EERE, the absence of open topics and the narrowness of some of the published topics means that significant opportunities for funding important innovations may be missed. The narrowness of topic definition at EERE is driven in part by the way funding is allocated across divisions and programs, and as noted in the 2008 National Academies report, this allocation may match poorly with opportunities to significant commercialization. Another factor that appears to drive the narrowness of topic definition at EERE is a deliberate effort to constrain the number of proposals. There are doubtlessly alternative, constructive methods of holding the numbers of proposals to manageable levels—while including an open topic—that are more consistent with improving the quality of proposals and enabling those with higher commercial potential. One such method used by other programs is to constrain the number of proposals per company to a level that will cause the companies to exercise greater selectivity in their submissions, while aligning submissions more closely with their technical expertise and market opportunities.

Another area for improvement is in providing a more transparent selection process that is fair both in practice and in terms of applicant perceptions. The selection criteria should be clear, easily accessible, and consistently applied; the scoring process should allow sufficient distinction among a large number of proposals to facilitate a clear ranking. Feedback to applicants should be informative and to the point.

There also possibilities for improvement after the end of Phase II. The transition to Phase III is quite challenging for many projects, and DoE should be looking for opportunities to connect SBIR/STTR projects to follow-on funding from elsewhere in DoE. This does not seem to be the case today and is therefore an area for possible improvement.

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3

DoE Initiatives

Since the 2011 reauthorization of the SBIR/STTR programs, the DoE SBIR/STTR programs have initiated a number of reforms aimed at improving program outcomes and processes in the following areas:

- Outreach
- Applications and the selection process
- Support for improved commercialization outcomes

This chapter addresses each of these areas, as well as other areas where more limited progress has been made.

OUTREACH

As noted in Chapter 2, DoE recognizes that it can derive significant agency-wide value from outreach activities and the ability to attract promising companies and technologies into the program.

Electronic Outreach

During the past few years, DoE has developed an extensive outreach program organized primarily around the delivery of digital information, notably through a library of webinars and efforts to drive traffic to these resources. Since 2012 Dawnbreaker, a third-party training organization, has maintained the website on DoE's behalf. The site offers more than 30 detailed tutorials on various aspects of the program—for example, determining whether SBIR or STTR is appropriate, understanding indirect rates, and contacting topic managers. These tutorials provide an extraordinarily detailed roadmap for addressing a range of issues. For example, the tutorial on contacting the Topic Manager (TM) explains why this step is important, the best ways to contact the TM, a preparatory chart to prepare for a phone call, and a number of explanatory

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video clips. Although it is, according to program staff, often difficult to persuade potential applicants to take full advantage of the available material, DoE has developed an impressive library of materials supporting outreach. Applicants who use them will be well positioned, other things equal, to improve their chances of obtaining funding.

In early 2013, the Program Office started two webinar series. The first, which focuses on specific technology areas, is led by TMs and therefore provides companies with a direct connection to DoE specialists. The second focuses on funding opportunities, in particular application-related questions. In 2015, the Program Office started another series that focuses on the more technical aspects of application budgeting, beginning with indirect rates. According to Program Office staff, these three series of webinars are a highly efficient way of reaching new applicants and providing answers to questions from both new and returning would-be applicants.

All webinars are archived on the DoE website, and SBIR/STTR program management notes that playback of archived webinars has proven to be a useful outreach tool because more viewers playback webinars than attend live webinars. Table 3-1 shows the take-up of webinar offerings during FY 2014 and FY 2015. DoE offered seven webinars in FY 2014 and nine in FY 2015. More than 2,000 participants attended the webinars live, and approximately 3,500 viewed the webinars through the playback mechanism. Compared to professional conferences, where program management often has limited access to participant lists and relies on the collection of business cards or similar small-scale outreach, webinars—the lists of those who accessed outreach materials by attending live webinars and watching outreach materials via recorded webinars made available through playback—provided for a more direct connection of TMs to potential applicants.

More generally, Program Office staff believe that the web-based focus is highly efficient in terms of reaching potential applicants and providing clear and specific information, compared to more traditional forms of outreach.

Phase 0

As of September 2014, DoE is providing additional support for new applicants through a pilot Phase 0 program, funded through the SBIR Administrative Fund Pilot program. The program is explicitly designed to enhance the participation of underrepresented groups, defined by DoE as

- underrepresented states,
- woman-owned businesses, or
- minority-owned businesses[1]

[1]DoE uses the definition of "minority" provided by SBA, which is discussed further in Chapter 6 of this report.

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SBIR/STTR at the Department of Energy

TABLE 3-1 Numbers of Potential Applicants Attending DoE Webinars or Viewing Them Via Playback, FY 2014-2015

Year	Title	Date	Number of Potential Applicants		
			Registered	Attended	Playbacks
FY 2014	FY14 Phase I Rel 1 Topics 29-40 (HE/NP)	7/24/2013	164	64	30
	FY14 Phase I Release I FOA	8/16/2013	504	295	321
	FY14 Sequential Phase II Rel 1	10/30/2013			91
	FY14 Phase I Rel 2 Topics 1-8 & 22	11/4/2013	228	144	361
	FY14 Phase I Rel 2 Topics 10-21	11/5/2013	92	63	150
	FY14 Phase I Release 2 FOA	12/3/2013	486	285	178
	FY14 Sequential Phase II Rel 2	2/20/2014	44	35	32
	Total		1,518	886	1,163
FY 2015	FY15 Phase I Rel 1 Topics 1-16	7/22/2014	453	294	307
	FY15 Phase I Rel 1 Topics 19-26	7/23/2014	263	124	125
	FY15 Phase I Release 1 FOA	8/15/2014	310	169	213
	FY15 Phase I Rel 2 Topics 1-9	11/4/2014	133	61	50
	FY15 Phase I Rel 2 Topics 20-25	11/5/2014	144	67	36
	FY15 Phase I Rel 2 Topics 26-33	11/6/2014	129	71	117
	FY15 Phase I Rel 2 Topics 10-19	11/7/2014	377	186	384
	FY15 Phase I Release 2 FOA	12/1/2014	360	237	1,013
	FY15 Phase II Release 2 FOA	2/1/2015	51	37	56
	Total		2,220	1,246	2,301

SOURCE: DoE SBIR/STTR Program Office.

The program is “modeled after and carried out in conjunction with” state Phase 0 programs.[2] Managed by Dawnbreaker under a $1 million annual contract, the program provides a range of services to applicants who meet one of the four target criteria listed in Chapter 2; have not received a DoE SBIR/STTR award during the past 3 years; and have not received technical assistance for a similar technology from DoE for the past 2 years.[3]

Services are available once the Funding Opportunity Announcement (FOA) has been published by DoE and on a first-come, first-served basis until funding is exhausted. According to Dawnbreaker, the program is expected to

[2]Manny Oliver, “Improving DOE’s Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs,” presentation to National Academies, October 20, 2015. See also National Research Council, Workshop on “SBIR/STTR & the Role of State Programs,” Washington, DC, October 7, 2014.

[3]DoE identifies the following states as underserved: AK, DC, GA, HI, IA, ID, IN, KS, LA, ME, MN, MS, MT, NC, ND, NE, NY, OK, PA, PR, RI, SC, SD, WA, WI.

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serve between 40 and 100 eligible applicants per release. Services are free of charge to the participating company and fall into the following categories.

- **Letter of Intent (LOI) review.** DoE is unique among the other agencies in requesting a 500 word LOI, due approximately 1 month after release of the FOA. Dawnbreaker assists applicants in developing a well-developed, two-page description of the technology and its application.
- **Phase I proposal preparation, review, and submission assistance.** Dawnbreaker provides program applicants with a coach who provides initial advice; helps the company establish and maintain a schedule for proposal preparation; and provides feedback as an independent reviewer of the draft proposal.
- **Market research assistance.** Although DoE requires only limited commercialization plans for Phase I applications, it requires revenue projections over a 10-year period. A preliminary market assessment may provide companies with insights into different potential applications, or identify the existence of strong competing products already in the market. According to Dawnbreaker, eligible applicants may be provided with one relevant Frost and Sullivan report.
- **Small business development training and mentoring.** The Dawnbreaker business coach can align services with the company's needs. For example, newly formed companies may require assistance with firm structure and initial sources of support. More established firms might require guidance on business models and strategies. Technical leaders of newly formed companies may not yet be experienced in effectively presenting their ideas to investors, and Dawnbreaker's coaching and advice may help.
- **Technology advice and consultation.** The program provides up to 3 hours of technical consultant time for feedback on the technical work plan or other technical issues.
- **Intellectual property consultation.** Because even a Phase I proposal requires some attention to intellectual property, the program provides access to legal counsel.
- **Indirect rates and financials.** To prepare a budget, an applicant must address the issue of indirect rates. The Dawnbreaker consultant helps applicants to understand indirect rates and to develop an appropriate rate structure for the DoE proposal, although the budget itself is prepared by the applicant.
- **Travel assistance.** Small business can be reimbursed for pre-approved, relevant travel expenses subject to federal travel guidelines. The travel must be germane to securing a Phase I SBIR/STTR award. This component is primarily aimed at supporting travel to meet with staff at DoE or the National Laboratories.

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It is too early to develop definitive conclusions about the DoE Phase 0 program, and initial data are mixed. Table 3-2 summarizes participation and milestone achievement for the first intake of Phase 0 participants for DoE's spring 2015 solicitation. Of the 69 initial participants, 54 developed LOIs that were deemed responsive, and all subsequent awardees were among this group. Dawnbreaker provided help to all participants. Eventually, 47 of the 69 applied for funding, and 7 were successful. Because the average overall success at DoE is 18 percent, 7 awards from 47 applications is not an unusual result. A further breakdown (not shown in the table) reveals that 4 of the 7 awards were from companies located in underrepresented states. No awards were to woman-owned firms, and the three minority-owned firms were Asian owned, so there were no awards for firms owned by African Americans, Hispanic Americans, or Native Americans.

The first round of Phase 0 focused primarily on supporting companies that were new to the program and were already interested in applying. Manny Oliver, SBIR/STTR Program Manager, indicated that, if possible, subsequent rounds will seek to attract new participants, especially from underrepresented groups, who have not yet contacted the program.

TABLE 3-2 Participation and Milestones for DoE Phase 0, Spring 2015

	Number	Percentage	
Total Phase 0 Participants	69		
Participants with Responsive LOIs	54	78%	(of Total Participants)
Applied	41	76%	(of Responsive)
No LOI Support	21	39%	(of Responsive)
Other Phase 0 Support	20	37%	(of Responsive)
Did Not Apply	13	24%	(of Responsive)
No LOI Support	2		
Other Phase 0 Support	12		
Unresponsive	15	22%	(of Total Participants)
Applied	6	40%	(of Unresponsive)
No LOI Support	3	20%	(of Unresponsive)
Other Phase 0 Support	3	20%	(of Unresponsive)
Did Not Apply	9	60%	(of Unresponsive)
No LOI Support	2		
Other Phase 0 Support	7		
Applied	47	68%	(of Total Participants)
Did Not Apply	22	32%	(of Total Participants)
Awards	7	10%	(of Total Participants)

SOURCE: DoE SBIR/STTR Program Office.

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SBIR/STTR at the Department of Energy

APPLICATION AND SELECTION PROCESS

During the past few years, DoE has made a number of changes to the application and selection processes. Taken together, these changes constitute a significant improvement in the process for many applicants, although in some cases they raise concerns about program balance between commercialization and innovation, and between outreach to increase applications and constraints to limit applications. They also raise concerns about the balance between managing reviewer loads and applicant perceptions of transparency and fairness.

Increased Commercialization Emphasis

DoE has placed an increasing emphasis on commercial outcomes from SBIR/STTR, as reflected in several areas. TMs are encouraged to ensure that their subtopics will support technologies that are commercially viable. This emphasis is also expected to be reflected in the applications themselves (this important issue is discussed in Chapter 2). Phase I applicants are now required to provide a commercialization plan that is sufficiently detailed to estimate technology-related revenues 10 years into the future, an approach identified by DoE as a best practice initiated at the National Science Foundation (NSF). Several companies interviewed for case studies observed that such projections will likely be highly inaccurate and that Phase I is designed to establish technical feasibility, long before commercialization occurs. However, other case study interviewees suggested that focusing on commercial targets at the earliest stage has important benefits: the increased emphasis on commercialization may encourage some companies to be more selective in the subtopics they pursue.

Phase II applicants are now required to provide a much more detailed and extended commercialization plan, including specific revenue calculations, which is reviewed by commercialization experts hired by DoE. Although there were some complaints about the quality of these reviews, the new process underscores DoE's expectation that SBIR/STTR projects in Phase II will focus on commercialization.

Not meeting the new commercialization requirements can block further funding for a company. The process generates several potential "red flags" of applications with low commercial potential:

- Poor commercialization history
- Low revenue forecast (based on Phase I commercialization plan)
- Low commercial potential review score (based on Phase II commercialization plan)

Applications with red flags are ineligible for funding unless a DoE program manager provides sufficient justification. Because solicitations are highly competitive, it seems likely that red flags will result in exclusion from funding.

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Finally, DoE has adopted another best practice, this time from NASA: it now limits companies to no more than 10 applications per solicitation. This change has according to case study interviewees made an impact; some welcomed it because it forced them to focus on their most promising technologies.

Fast Track

In FY 2013, DoE implemented a Fast Track program similar to that in place at NIH. Under Fast Track, companies can apply for a unified Phase I-Phase II award, in which Phase II proceeds automatically if the company meets predetermined technical milestones.

The program is designed to help companies accelerate development by eliminating the gap between Phase I and Phase II. The DoE Fast Track program allows for 6 to 9 months for Phase I activities and 24 months for Phase II activities and requires a Phase II commercialization plan (the Phase I plan is not required). DoE notes that this approach may not be suitable for companies with limited commercialization experience. Some topics, notably those from the Office of Energy Efficiency and Renewable Energy (EERE), do not permit Fast Track.

The advantages of Fast Track are obvious—companies can work under less uncertainty, and, where implemented, Fast Track has the effect of eliminating the average 5-month gap between the end of Phase I and the beginning of Phase II at DoE.

DoE Fast Track covers only 3 to 5 percent of DoE SBIR/STTR awards. DoE Fast Track applications have a success rate about one-half that of Phase I applications (9 percent). Also, a higher percentage of Fast Track awards than of Phase I applications are recommended but not funded (23 percent of DoE Fast Track are recommended but not funded) (See Figure 3-1).

Improved Process Timelines

DoE has made a concerted effort to improve processing timelines for both Phase I and Phase II. In part an effort to meet statutory guidelines under reauthorization and Small Business Administration (SBA) policy guidance, the changes also increase the time available to companies to develop their ideas and establish collaborations after the topics are published.

Figures 3-2 and 3-3 were deleted at press time. These figures were originally on pages 76 and 77, which are now intentionally blank to avoid renumbering the entire report.

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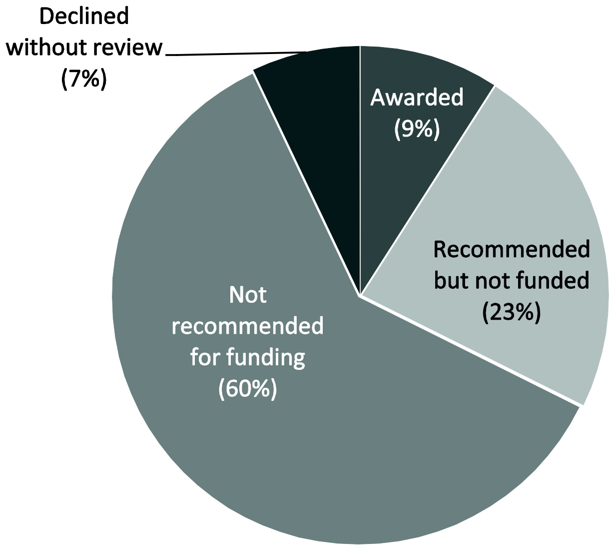

FIGURE 3-1 DoE SBIR/STTR Fast Track applications and outcomes, FY 2015.
SOURCE: DoE SBIR/STTR Program Office.

The compressed schedule has important immediate benefits: (1) companies with limited resources do not have to wait as long for funding flows to begin, and (2) the additional time between the funding announcement and the application deadline allows companies to generate better quality applications.

Much of the improvement can be attributed to the establishment of a dedicated SBIR/STTR contracts team with seven full-time staff in the DoE Chicago offices. Prior to this change, contracts were often handled by staff with little experience or training with SBIR/STTR awards, which frequently resulted in more difficult negotiations and unnecessary delays. The new dedicated team has significantly streamlined the process.

SUPPORT FOR IMPROVED COMMERCIALIZATION OUTCOMES

DoE has a taken several steps to improve commercialization outcomes from the SBIR/STTR programs.

Sequential Phase II Awards

Since FY 2014, DoE has taken advantage of the new flexibility provided under the 2011 congressional reauthorization to offer sequential

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Phase II awards. Sequential Phase II awards are aimed at providing additional R&D funding for mature existing Phase II promising technologies that are not yet ready for the market. DoE provides two kinds of sequential Phase II awards:

- Phase IIA provides the small business concern (SBC) with a small amount of additional funding to complete a Phase II project that was not completed by the original award expiration date.
- Phase IIB is modeled on Phase IIB at other agencies, notably NSF and NIH, and is designed to provide more substantial transition funding. However, unlike NSF, which requires Phase IIB SBC applicants to secure matching funds from other sources in order to be eligible for the NSF IIB grant, DoE Phase IIB awards do not require matching funds of any kind from the SBC.

Technology Transfer Opportunities (TTOs)

DoE has made new efforts to support technology transition from National Laboratories to the commercial marketplace. In FY 2013, DoE began to set aside a number of awards for Technology Transfer Opportunities (TTOs): subtopics for which National Laboratories offer technologies that could be appropriate for transition, designed to attract SBCs as commercialization partners. In contrast, most National Laboratories' participation in SBIR has been limited to providing technical expertise and equipment to SBCs as they develop and test their technologies.

TTOs are published in the standard SBIR/STTR solicitation, but these are more tightly focused than standard topics. This is not surprising because TTOs are designed for a technology that already exists and could be commercialized, rather than a technology that is needed but not yet developed. Awardees benefit both from the SBIR/STTR award and from a license to the technology provided through DoE.

Table 3-3 shows the adoption of the TTO pathway since its inception in FY 2013. Many TTOs do not result in an award and only a small percentage result in a Phase II award. It will be worth considering whether participation is useful for National Laboratories as the program evolves over time.

TABLE 3-3 Adoption of TTOs by SBCs at DoE through the SBIR/STTR, FY 2013-2015

	TTO subtopics	FY I Awards	FY II Awards
FY 2013	18	2	0
FY 2014	33	8	1
FY 2015	31	8	3

SOURCE: DoE SBIR/STTR Program Office.

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SBIR/STTR Assistance for Commercialization/Marketing

A company has two options for obtaining assistance from SBIR/STTR to develop its commercialization/marketing efforts: (1) It can choose to participate in the DoE Commercialization Assistance Program (CAP), or (2) it can choose instead to apply for a lump sum amount (currently $5,000) per Phase I award to spend on its own commercialization/marketing efforts. The second option, Opting out of the CAP, was newly offered under the December 2011 reauthorization, and must be done prior to a company submitting its Phase I application. Approximately 95-98 percent of DoE awardees have chosen to participate in CAP, while 3-5 percent have chosen to Opt-out of CAP and take the lump-sum amount.

Commercialization Assistance Program

DoE has steadily improved CAP, which it offers through a third-party contractor, Dawnbreaker.[4] Currently, all assistance for CAP is provided by Dawnbreaker through two support contracts (approximately $2.5 million, through administrative pilot program funding). Under Dawnbreaker's current contract, which expires in March 2017, participating companies can access the services they need up to a budget of $5,000 annually per project, which is paid by DoE to Dawnbreaker once the selected services have been delivered.

This pay-for-service model replaced a previous effort that simply provided a lump sum to Dawnbreaker on an annual basis. The new model incentivizes Dawnbreaker to actively market its services to SBIR/STTR companies, and to make sure that the services are tailored to the specific needs of the company—a startup is, for example, likely to have very different needs than an established company seeking to enter a new market. Money remaining in the $5,000 annual budget per project that is not spent on Dawnbreaker services is returned to the SBIR/STTR programs at DoE, and funding from the first year of a Phase II award cannot be rolled over into the second year.

Phase I CAP Assistance

Phase I assistance focuses on providing a Commercialization Readiness Assessment, which is primarily designed to help the company develop an effective commercialization plan for its Phase II proposal. The start of Phase I services is deliberately delayed, to permit companies to focus primarily on their

[4]Dawnbreaker, founded by Dr. Jenny Servo in 1990, provides a range of services to federal agencies and to small businesses. It has worked with more than 7,500 companies in both civilian and defense markets.

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R&D during the initial stages of Phase I. The CAP begins about 5 months before Phase II applications are due.[5]

A Business Acceleration Manager is assigned from Dawnbreaker to each participating company, and after each company signs Dawnbreaker's Non Disclosure Agreement (NDA), approved by DoE, it can receive services which can include:

- A Commercialization Readiness Assessment (CRA)
- Market Research
- Series of Specialty Webinars
- Business mentoring organized around the development of the Phase II Commercialization Plan (CP)

A focus is to assist the companies to develop the 15-page commercialization plan for inclusion in the Phase II application.

Phase II CAP Assistance

A much more extensive menu of options is available from Dawnbreaker for Phase II awardees. The extensive menu of available service items includes some items that are rarely used. DoE has not asked Dawnbreaker to remove the rarely used items on the grounds that if the capacity is available, it may be useful for a few companies even if it is not a core service. Services that are used less frequently include:

- Financials assessment (scientists prefer to avoid this)
- Licensing and negotiating IP (companies may not be ready for this)
- Development of a trade show booth (trade shows are much less popular now)

According to DoE staff, services used by almost all Phase II program participants include:

- Additional Commercialization Readiness Assessment (CRA). This provides information needed to select other services.
- Frost and Sullivan marketing reports
- Market research (primary and customized)
- Competitor analysis
- Business mentoring (a maximum number of hours are provided)
- Developing network contacts

[5]Dawnbreaker, DOE SBIR/STTR, Commercialization Assistance Program (CAP): Services ForPhase I and Phase II Awardees, http://science.energy.gov/~/media/sbir/ powerpoint/ DOE_CAP_Overview_Presentation.pptx, accessed November 14, 2015.

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Dawnbreaker, in association with DoE, also introduces new or expanded services as demand changes. For example, companies have in recent years sought help to develop more professional websites, a service that is now available to them.

In general, the services are expected to provide the assistance that companies need to be able to step up and improve their capacity, rather than leaning on Dawnbreaker for an extended period. DoE program staff noted that $5,000 annually is not sufficient to provide a higher level of service and that there are benefits to encouraging firms to take responsibility for commercialization themselves. Thus, for example, Dawnbreaker provides introductions of companies to potential investors, but that is the extent of their support in that area.

Effectiveness of the Commercialization Assistance Program

There are three sources of data on general program outcomes and on commercialization that, together, can shed light on the effectiveness of CAP: (1) Dawnbreaker summary reports of data from surveys it conducts 6, 12, and 18 months after the end of Phase II on commercialization results (not publicly available), (2) reports on commercialization outcomes required of companies for all previous SBIR/STTR projects (including those funded by other agencies) when applying for DoE SBIR/STTR funding, and (3) a DoE annual survey conducted from FY 2012 to FY 2014 of all Phase II awardees 5 years after the initiation of Phase I (i.e., approximately 2 years after the conclusion of the Phase II award).[6]

So far, there is no conclusive information about the impact of the CAP. One reason is that, until recently, the DoE SBIR/STTR Program Office has not had the manpower available to undertake a detailed analysis of the data. Moreover, DoE did not wish to over rely on the summary raw data compiled by Dawnbreaker about its own effectiveness. However, as new staff members have been hired, we are informed that DoE now plans to undertake an evaluation of CAP.

Despite the limited information about the impact of the CAP, the wide menu of available services and the use of a third-party provider with extensive expertise in this area appear to be positive steps. Furthermore, the use of an innovative contracting structure to incentivize the provider is, we believe, unique among SBIR/STTR agencies, and seems another promising step. The expected improvement in data collection and analytics related to the commercialization program and quantitative analysis of the data would be an additional welcomed and positive step toward understanding CAP effectiveness.

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[6]This DoE annual survey required and received approval from the Office of Management and Budget pursuant to the Paperwork Reduction Act.

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SBIR/STTR at the Department of Energy

OTHER INITIATIVES

DoE is the first agency to take advantage of the flexibility provided by the reauthorization legislation to permit companies to use up to $15,000 in Phase II funding for patenting expenses. This is a significant initiative, and one that company case study interviewees welcomed. Because the cost of patenting new technology can be prohibitive for small businesses, especially when they have not yet generated revenue, this initiative is potentially valuable.

CONCLUSIONS

The initiatives described in this chapter, many drawing from best practices at other agencies, reflect efforts to improve the DoE SBIR/STTR programs. Fast Track, Phase IIB, and third-party commercialization support were adopted directly from NSF, and Phase IIA closely resembles the availability of supplementary funding at NIH. Another beneficial initiative has been the introduction of an open period between the release of topics and the FOA (similar to a practice at the Department of Defense). The open period permits companies to explore possible applications in detail with technical staff.

DoE has also developed its own initiatives. These include the division of the solicitation into two releases annually, which has been an important facilitator of the compressed timelines and improved efficiency. The use of two releases allows DoE to assign dedicated staff to the contracting process. DoE's electronic outreach is state of the art and a potentially important model for other agencies. The extensive use of webinars is unique among the major SBIR/STTR agencies, and DoE's approach to outreach is appropriate and likely to be both cost-effective and successful. DoE's use of letters of intent is a further innovation used for topic identification. A similar program exists at NSF, although perhaps with different program objectives. Survey responses and interviewee comments indicate that SBCs approve of the LOI process, and the data show that, in addition to identifying topic/subtopic, the LOI process inadvertently also has been found to be a way to reduce the burden on both reviewers and companies as it serves to reduce the number of applications.[7]

Finally, it is anticipated that evidence about the overall effectiveness of CAP will soon become available.

[7]As was noted in Chapter 2, constraining the number of applications per company would seem a more efficient and less biasing method of limiting the number of applications while raising quality and facilitating commercialization than over-constraining topics and subtopics in conjunction with the LOI to reduce applications.

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4

SBIR and STTR Awards at DoE

The DoE SBIR/STTR programs are the fourth largest among the federal agencies offering those programs. In fiscal year (FY) 2014, they provided $184 million in funding, an increase of almost $20 million from FY 2012, after implementing changes made in the 2011 reauthorization of the SBIR/STTR programs (see Chapter 1).

Utilizing data provided by the Department of Energy, this chapter reviews applications and awards data for the DoE SBIR and STTR programs. These include data for Phase I, Phase II, as well as Fast Track and Phase IIA and Phase IIB supplemental awards. The chapter also includes data and analysis of the distribution of applications and awards among the states and data on new entrants to the program and multiple award winners.

The FY2014 funding for the DoE SBIR/STTR programs can be broken down as follows (see Table 4-1):

- SBIR provided $153.9 million (83.7 percent of total funding)
- STTR provided $30.0 million (16.3 percent of total funding)
- SBIR and STTR Fast Track awards totaled $16.1 million or 8.8 percent of total funding (FY 2014 was the first year of Fast Track at DoE)
- SBIR and STTR Phase I awards (excluding Fast Track) totaled $36.8 million (20 percent of total funding)
- SBIR and STTR Phase II awards (excluding Fast Track) totaled $131 million (71.2 percent of total funding)

This summary provides an overview of applications and awards for the DoE SBIR/STTR programs, including a review of trends, distribution of awards by state, and participation by companies new to the program. A more extended analysis of the data follows the summary.

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TABLE 4-1 SBIR/STTR Funding by Program, Phase, and Funding Mechanism, FY 2005-2014

	Funding (Millions of Dollars)								
	SBIR				STTR				
Fiscal Year	Phase I	Phase II	Fast Track	SBIR Total	Phase I	Phase II	Fast Track	STTR Total	Total
2005	25.6	74.7	0.0	100.4	2.9	9.2	0.0	24.2	124.5
2006	25.9	88.3	0.0	114.1	2.9	11.25	0.0	28.3	142.4
2007	28.2	83.0	0.0	111.2	3.7	11.16	0.0	29.7	140.9
2008	27.9	101.8	0.0	129.7	3.8	14.4	0.0	36.4	166.1
2009	37.5	113.6	0.0	151.1	4.0	11.7	0.0	31.5	182.5
2010	43.1	172.6	0.0	215.7	6.0	13.5	0.0	39.0	254.7
2011	29.4	110.7	0.0	140.1	2.6	19.2	0.0	43.6	183.7
2012	44.2	88.6	0.0	132.8	6.25	9.6	0.0	31.8	164.6
2013	38.9	100.1	0.0	139.0	4.95	14.97	0.0	39.8	178.9
2014	30.1	112.9	10.9	153.9	6.7	18.1	5.2	30.0	183.9
Total	330.7	1,046.3	10.9	1,388.0	80.8	248.3	5.2	334.2	1,722.2

NOTE: The DoE SBIR/STTR Program Office provided data for all charts and tables in this chapter unless otherwise noted. Because DoE moved its historical data to a new data structure for FY 2014 and some data were not ported over, data in this chapter do not exactly match data provided to the Small Business Administration (SBA).
SOURCE: DoE SBIR/STTR Program Office.

CHAPTER SUMMARY

SBIR Phase I Awards

The number of SBIR Phase I applications has declined in recent years. Applications held steady at just less than 1,500 annually from FY 2005 to FY 2009 before increasing sharply to almost 2,700 in FY 2010 (apparently related to the availability of additional American Recovery and Reinvestment Act [ARRA] funding). After FY 2010, applications declined steadily to just less than 1,400 in FY 2014.

The average success rate for SBIR Phase I applications during the study period was 16 percent, varying from a low of 9.3 percent in FY 2011 to a high of 25.4 percent in FY 2009. After FY 2009, the success rate did not rise above 14 percent. Changes in the amount of funding allocated were not the primary driver of the changes in success rates.

SBIR Phase I awards remain the primary gateway into the program. Until FY 2014, only Phase I winners could apply for Phase II funding. An average of about 272 Phase I awards were made each year during the study period, although the numbers have declined in recent years, reaching a low of 191 in FY 2014. Funding levels for Phase I SBIR awards varied in recent years, growing to a peak of $44.2 million in FY 2012 before falling back to a level more in line with historical trends at about $30 million in FY 2014.

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Although the number of awards declined, the average size of new Phase I awards increased, from about $100,000 in FY 2005-2009 to $180,000 in FY 2013 before declining to just less than $160,000 in FY 2014.

SBIR Phase II Awards

The number of SBIR Phase II awards has in part been driven by the number of Phase I awards, lagged by 1 year. Until FY 2015, all Phase II awards went to projects that had already received a Phase I award (except for Fast Track awards; see Fast Track section below).

Unlike Phase I, there was no sustained decline in applications for Phase II across the study period, even though the number of eligible applicants declined in recent years (because of the declining number of Phase I awards). Excluding FY 2010, which included ARRA, an average of 235 Phase II applications were submitted each year. Success rates for Phase II grant applications varied by year and declined slightly in recent years, averaging slightly less than 50 percent across the study period.

The number of Phase II SBIR awards also declined over the study period. The number of awards increased from FY 2005 to FY 2010 but dropped thereafter before increasing again in FY 2013-2014, averaging about 100 for FY 2011-2014. Excluding FY 2010, funding for Phase II awards increased slowly across the study period, from around $80 million annually in FY 2005-2007 to around $100 million annually in FY 2011-2014. The success rate dropped as the number of awards declined relative to the number of applications. With fewer awards came an increase in the average award size, which ticked up sharply in FY 2010 from less than $750,000 in the preceding period to about $950,000 and reached more than $1 million for the first time in FY 2014 (see Figure 4-1). Larger awards therefore resulted in fewer awards, even in an environment where funding was increasing.

STTR Awards

STTR is a relatively small program. Its funding grew from around $25 million in the early part of the study period to peak at more than $40 million. Funding decreased to $30 million in FY 2014, of which $6.7 million was for Phase I awards.

The numbers of Phase I STTR awards and Phase II STTR awards decreased in recent years, reaching lows of 41 and 19, respectively, in FY 2015. Funding levels per award in general tracked SBIR averages.

Fast Track

DoE initiated the Fast Track program in FY 2014, making six Phase I SBIR and seven Phase I STTR Fast Track awards.

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SBIR/STTR at the Department of Energy

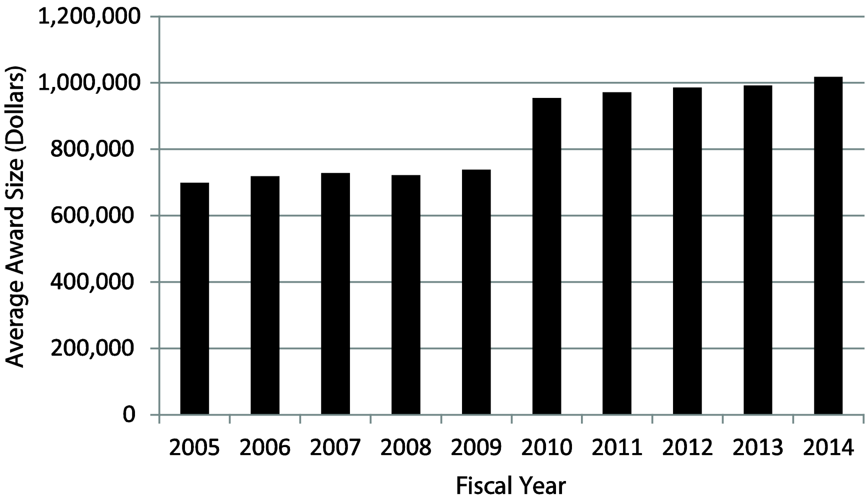

FIGURE 4-1 Average size of DoE Phase II SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

Phase IIA and Phase IIB Awards

In an effort to improve outcomes for Phase II and to help companies transition to the market, DoE has added two types of additional awards to its programs. Phase IIA provides a small amount of funding to companies completing a Phase II and requiring additional help. Phase IIB provides a larger amount to move companies into commercialization, much like the National Science Foundation (NSF) Phase IIB program. However, unlike NSF's program, the DoE program does not require matching funds, that is, funds from an alternative source to the Phase IIB award recipient to assist with commercialization.

SBIR Awards and the States

The distribution of SBIR awards among the states continues to be a matter of concern for some members of Congress. Agencies are now required to report on their efforts to encourage awards from underserved states. This shows that the distribution of SBIR awards among the states reflects the distribution of resources and talent across the nation and the merit-based approach of the SBIR program.

At the most basic level, states with larger populations tend to have more SBIR-capable applicants and therefore generate more applications. After normalizing for population, substantial differences among the states remain. The number of Phase I SBIR applications per 1 million population varies sharply,

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from more than 200 for Massachusetts, Colorado, and Delaware to fewer than 20 for 16 states, including fewer than 10 for 3 states. Therefore, factors other than population size substantially affect the number of applications.

The number of applications per 1 million population is highly correlated with the share of scientists and engineers in the working population. Unsurprisingly, states with more scientists and engineers tend to generate more applicants. Scientists and engineers are often found clustered in high-tech areas anchored by universities and R&D parks.

Finally, success rates for applications vary as well. Nine states have rates above 20 percent, while 15 states have rates half that or lower. This suggests that the quality of applications varies substantially and that simply increasing the number of applications from a state will not necessarily translate to more awards to that state. (There is also the issue of small numbers, where approval of a single application from a state that has received only one results, at least temporarily, in a success rate of 100 percent.)

New Entrants and Multiple-Award Winners

DoE data indicate that the number of new applicants and first-time awardees has expanded in recent years. At the same time, the incidence of multiple award winners has increased. The top 20 winners accounted for slightly less than 23 percent of all Phase I SBIR/STTR awards and 27 percent of all Phase II awards. Companies varied in their capacity to convert Phase I into Phase II, with a DoE average conversion rate[1] from Phase I to Phase II awards of about 45 percent across the study period.

DETAILED DATA: SBIR AND STTR AWARDS AT DOE

The remainder of the chapter provides more detailed information about SBIR and STTR applications and awards at DoE. The period of analysis is FY 2005-2014 inclusive to capture both recent and longer term trends. A 10-year period seems sufficient for trend analysis, particularly given the important changes to the program during that period.

This section covers Phase I, Phase II, and Fast Track awards, and SBIR and STTR separately. It considers awards from a range of perspectives, including distribution by state, the impact of multiple awards to individual companies, applications, and success rates. For the convenience of the reader, Table 4-2 reproduces Table 4-1 in the chapter summary, which shows funding by program and phase for FY 2005-2014. Figure 4-2 summaries the data for FY 2014 in chart format.

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

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TABLE 4-2 SBIR/STTR Funding by Program, Phase, and Funding Mechanism, FY 2005-2014

	Funding (Millions of Dollars)								
	SBIR				STTR				
Fiscal Year	Phase I	Phase II	Fast Track	SBIR Total	Phase I	Phase II	Fast Track	STTR Total	Total
2005	25.6	74.7	0.0	100.4	5.8	18.4	0.0	24.2	124.5
2006	25.9	88.3	0.0	114.1	5.8	22.5	0.0	28.3	142.4
2007	28.2	83.0	0.0	111.2	7.4	22.3	0.0	29.7	140.9
2008	27.9	101.8	0.0	129.7	7.6	28.9	0.0	36.4	166.1
2009	37.5	113.6	0.0	151.1	8.0	23.5	0.0	31.5	182.5
2010	43.1	172.6	0.0	215.7	12.0	27.0	0.0	39.0	254.7
2011	29.4	110.7	0.0	140.1	5.2	38.4	0.0	43.6	183.7
2012	44.2	88.6	0.0	132.8	12.5	19.3	0.0	31.8	164.6
2013	38.9	100.1	0.0	139.0	9.9	29.9	0.0	39.8	178.9
2014	30.1	112.9	10.9	153.9	6.7	18.1	5.2	30.0	183.9
Total	330.7	1,046.3	10.9	1,388.0	80.8	248.3	5.2	334.2	1,722.2

NOTE: The DoE SBIR/STTR Program Office provided data for all charts and tables in this chapter unless otherwise noted. Because DoE moved its historical data to a new data structure for FY 2014 and some data were not ported over, data in this chapter do not exactly match data provided to the Small Business Administration (SBA).
SOURCE: DoE SBIR/STTR Program Office.

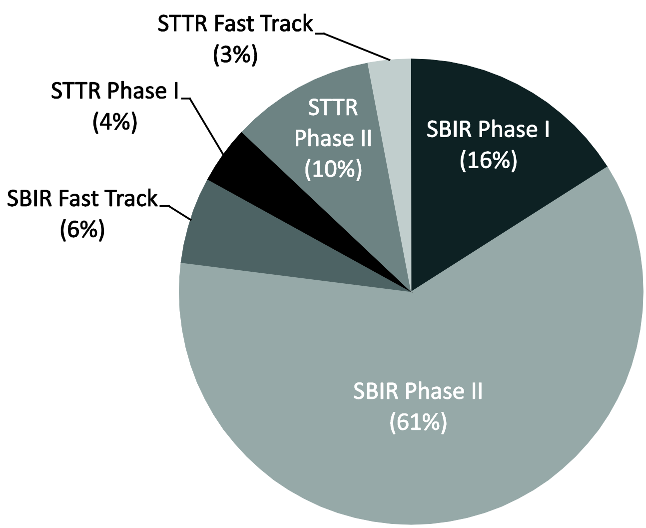

FIGURE 4-2 Breakdown of DoE SBIR/STTR funding by program, phase, and funding mechanism, FY 2014.
SOURCE: DoE SBIR/STTR Program Office.

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SBIR Awards

DoE funds both SBIR and STTR through grants rather than contracts. SBIR funding grew steadily during the study period, from $100 million in FY 2005 to $150 million in FY 2014, reflecting the expansion of the program under reauthorization (see Figure 4-3). The sharp increase in FY 2010 resulted from additional funding made available under the American Recovery and Reinvestment Act (ARRA).

Phase I SBIR Awards

Although funding for Phase I SBIR increased overall from FY 2005 to FY 2014, funding was erratic on a yearly basis (see Figure 4-4). To some degree, these data are reflected in the data for Phase I SBIR awards (see Figure 4-5), although the growth in the average award size after FY 2011 is also a factor. ARRA positively impacted the number of Phase I awards in FY 2010, but the increase in the award size (see Figure 4-6) has since reduced the number of awards possible (after reauthorization). The low number of awards in FY 2011 remains an anomaly.

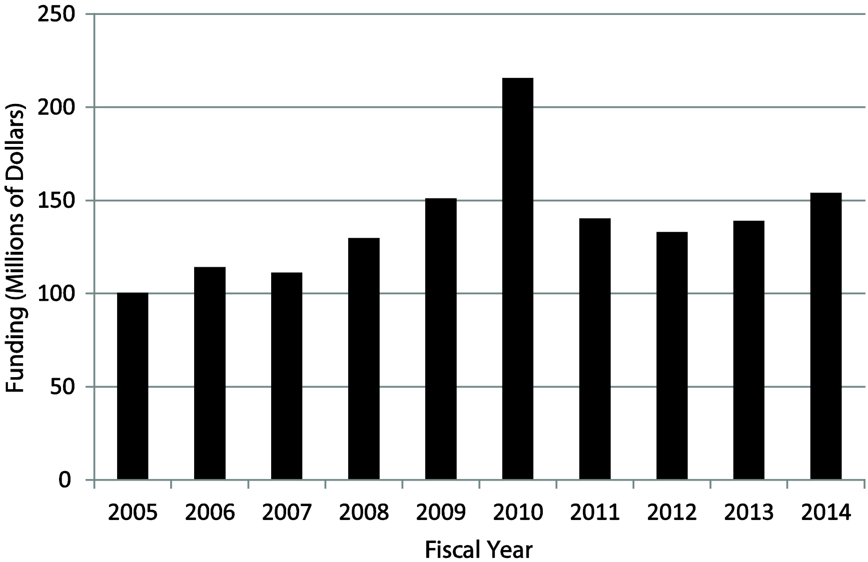

FIGURE 4-3 Total funding for SBIR, FY 2005-2014**.**
SOURCE: DoE SBIR/STTR Program Office.

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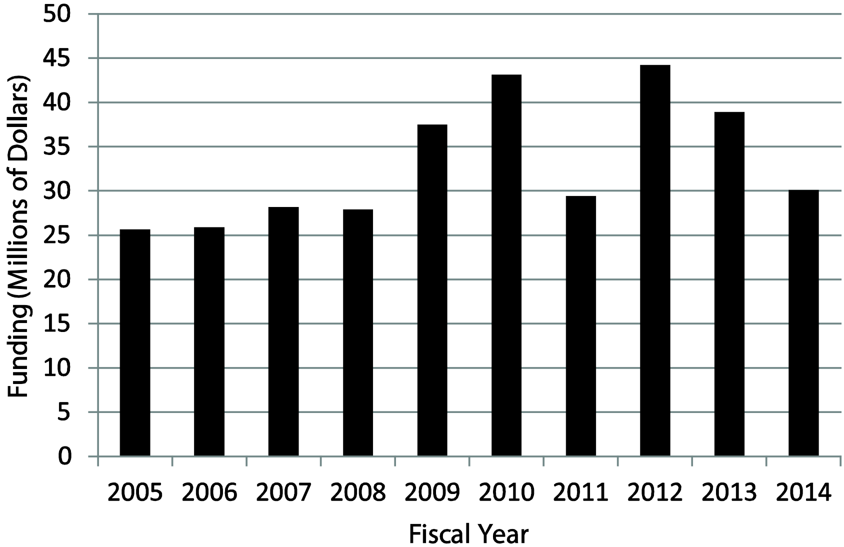

FIGURE 4-4 Funding for Phase I SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

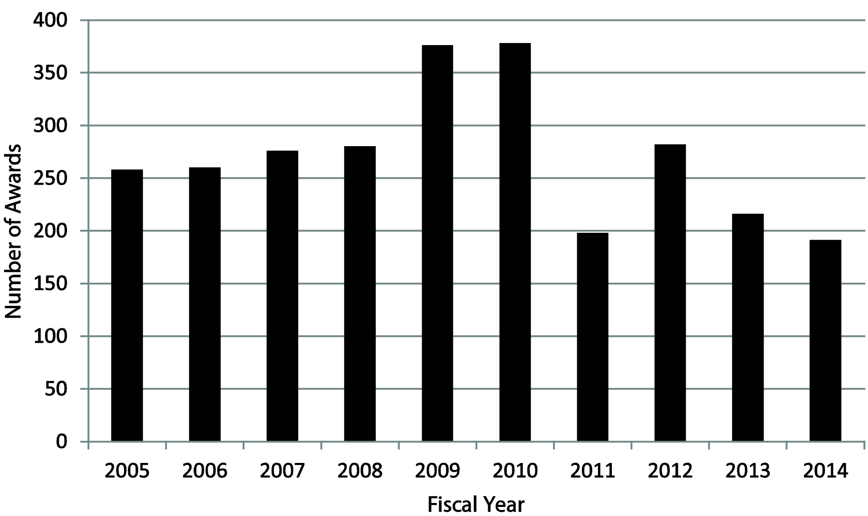

FIGURE 4-5 Number of Phase I SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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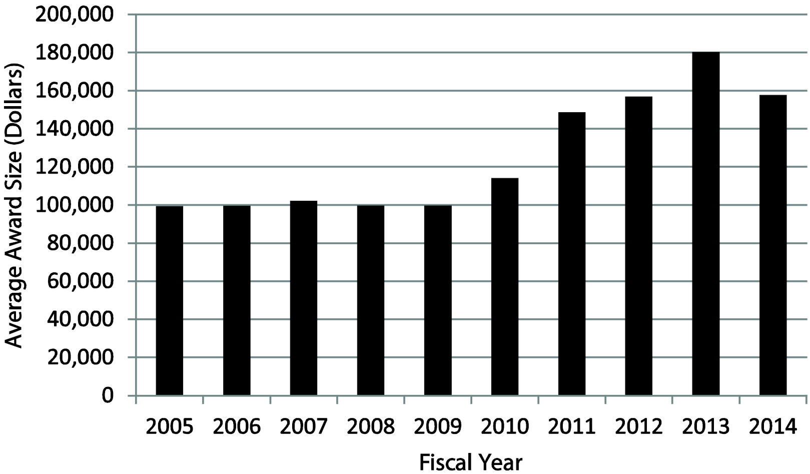

FIGURE 4-6 Average size of Phase I SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

Figure 4-7 shows the number of Phase I SBIR applications received by DoE in FY 2005-2014. Applications remained steady from FY 2005-2009 at just under 1,500 annually, increased sharply to almost 2,700 in FY 2010, then declined steadily to reach the historical level of about 1,500 in FY 2014. The increase in FY 2010 may reflect both the ripple effects from the financial crash in 2008 and expectations that DoE would be disbursing additional SBIR/STTR funding from the ARRA program.

During the study period, the average success rate[2] for Phase I SBIR applications was 16 percent, ranging from a low of 9.3 percent in FY 2011 to a high of 25.4 percent in FY 2009 (see Figure 4-8). The average success rate for FY 2010-2014 was less than 15 percent (averaging 12.7 percent for that entire period).

Phase II SBIR Awards

Aside from the one-time increase in FY 2010 due to ARRA, funding devoted to Phase II SBIR awards has trended slightly upwards and now appears likely to surpass $100 million annually (see Figure 4-9). Phase II has on average accounted for about 76 percent of all SBIR funding. The number of Phase II SBIR awards was also affected by ARRA and then by the increase in the average award size. Figure 4-10 shows the number of awards, and Figure 4-11 shows the average Phase II SBIR award size.

[2]Phase I success rates reflect the share the Phase applications that result in Phase I awards.

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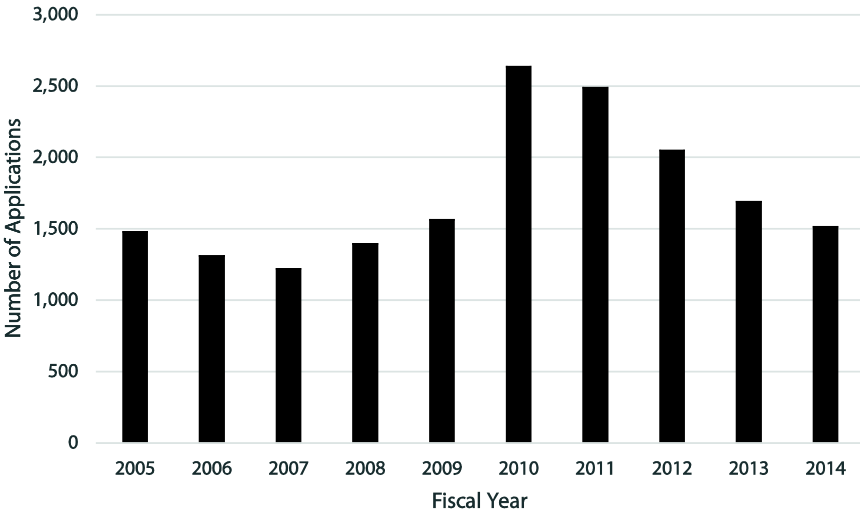

FIGURE 4-7 Number of Phase I SBIR applications, FY 2005-2014.
NOTE: In 2014, 134 Phase I applications were for both SBIR and STTR simultaneously. For the purposes of this analysis, these have been allocated 83 percent to SBIR and 17 percent to STTR, in line with the historical allocation of awards between the programs.
SOURCE: DoE SBIR/STTR Program Office.

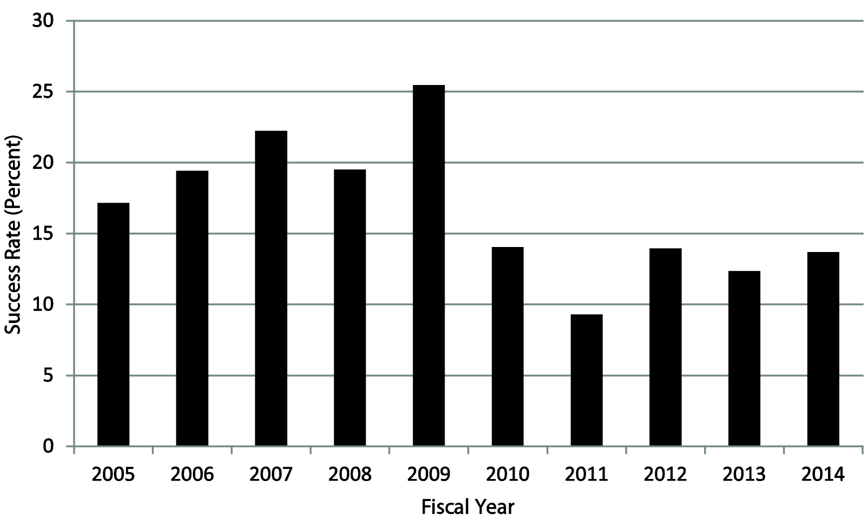

FIGURE 4-8 Success rates for Phase I SBIR applications, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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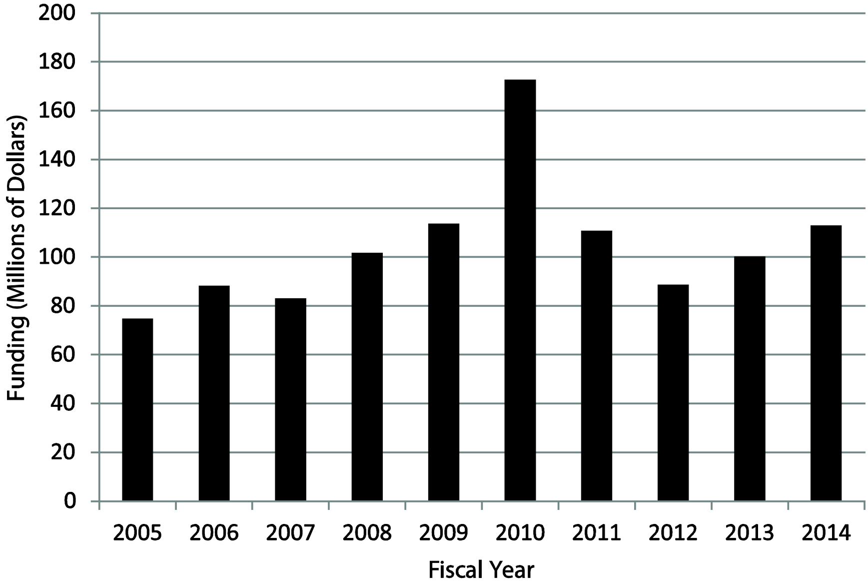

FIGURE 4-9 Funding for Phase II SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

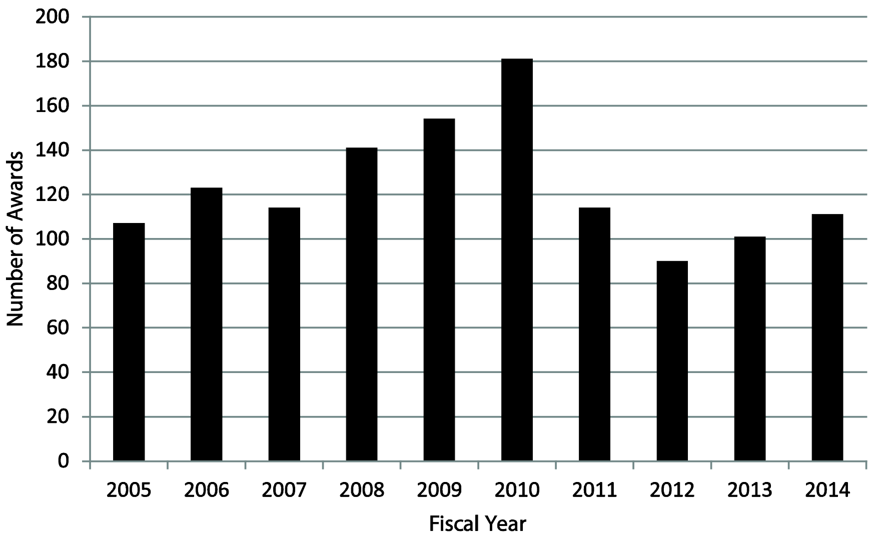

FIGURE 4-10 Number of Phase II SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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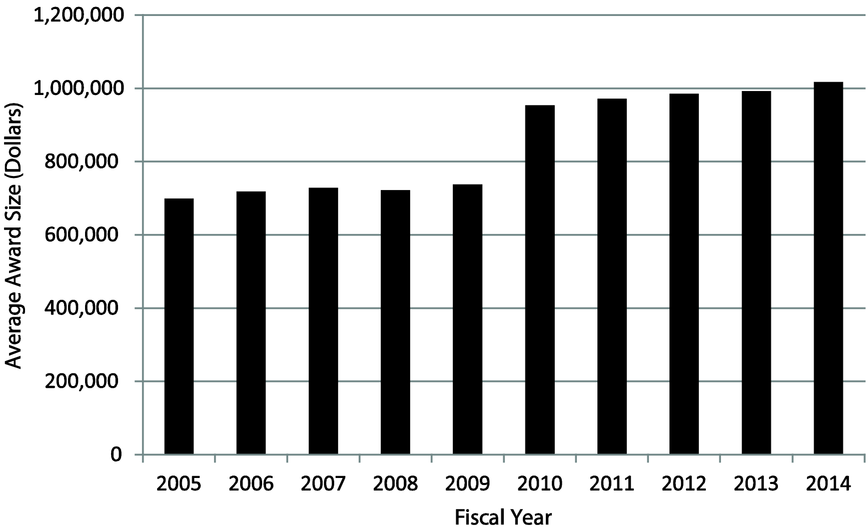

FIGURE 4-11 Average size of Phase II SBIR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

Figure 4-11 shows that funding levels per award increased first as a result of ARRA and then as a result of reauthorization. The tradeoff between increased award size and fewer awards is therefore clear.

Overall, the number of Phase II SBIR applications received by DoE has been steady, except for the increase due to ARRA in FY 2010 and the anomalous decline in FY 2012. Unlike at some other agencies, the number of applications to DoE increased during the last 2 years of the study period (see Figure 4-12).

As expected, success rates[3] for Phase II are much higher than those for Phase I. At DoE, these rates trended slightly downward during the study period, with a low point in FY 2014 of less than 40 percent (see Figure 4-13).

STTR Awards

Data on STTR are more limited, because DoE did not port application data for STTR into the new database when it was established in 2014. Accordingly, this analysis focuses only on awards and funding. Overall, funding for STTR reflects shifts in the SBIR/STTR programs rather than specific decisions about STTR. Funding varied substantially year to year, but the overall trend revealed an increase over the study period (see Figure 4-14).

[3]Phase II success rates reflect the share of Phase II applications that result in Phase II awards.

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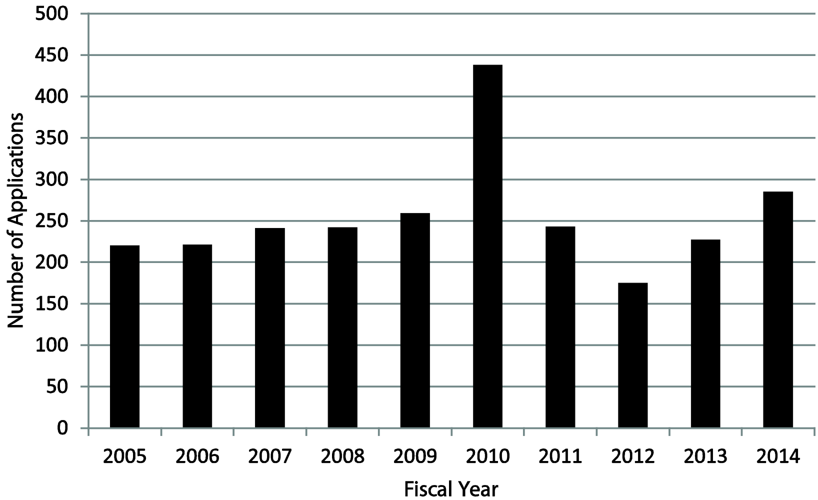

FIGURE 4-12 Number of SBIR Phase II applications, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

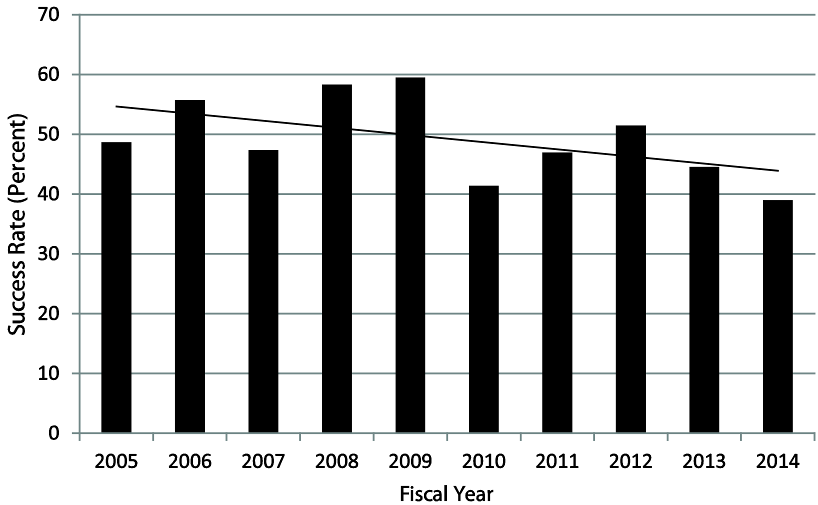

FIGURE 4-13 Phase II SBIR success rates, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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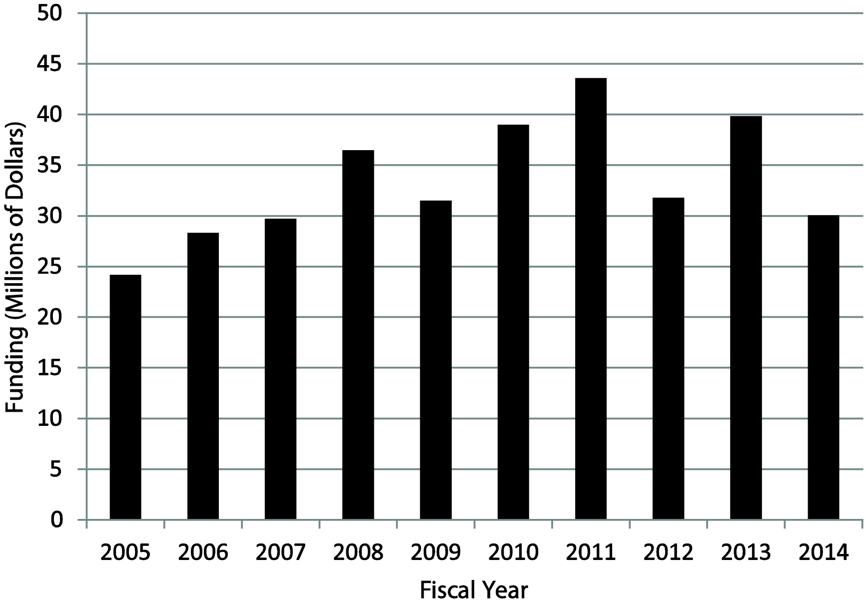

FIGURE 4-14 STTR funding, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

Phase I STTR Awards

The number of STTR Phase I awards increased from FY 2006 to FY 2010 but declined after FY 2010 (which appears to be an anomaly) (see Figure 4-15). More recently DoE has averaged about 35 STTR Phase I awards annually.

The amount of funding allocated for Phase I STTR awards peaked at about $12 million in FY 2012 and then declined by about one-half by FY 2014 (see Figure 4-16).

STTR Phase II

The numbers of awards for Phase II track fairly closely with those for Phase I, with a 1-year lag: a gradual increase from FY 2005-2010, a sharp jump in FY2011, and then a subsequent decline (see Figure 4-17). As with SBIR, Phase II STTR accounts for the lion's share of program funding. In addition, as with Phase I, funding for Phase II STTR increased through FY 2010 before declining thereafter (again with the anomalous low funding in FY 2012) (see Figure 4-18).

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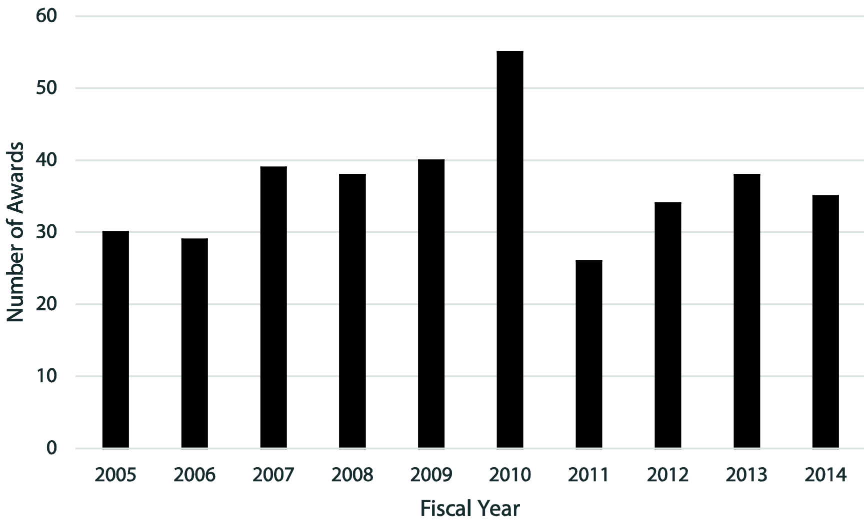

FIGURE 4-15 Number of Phase I STTR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

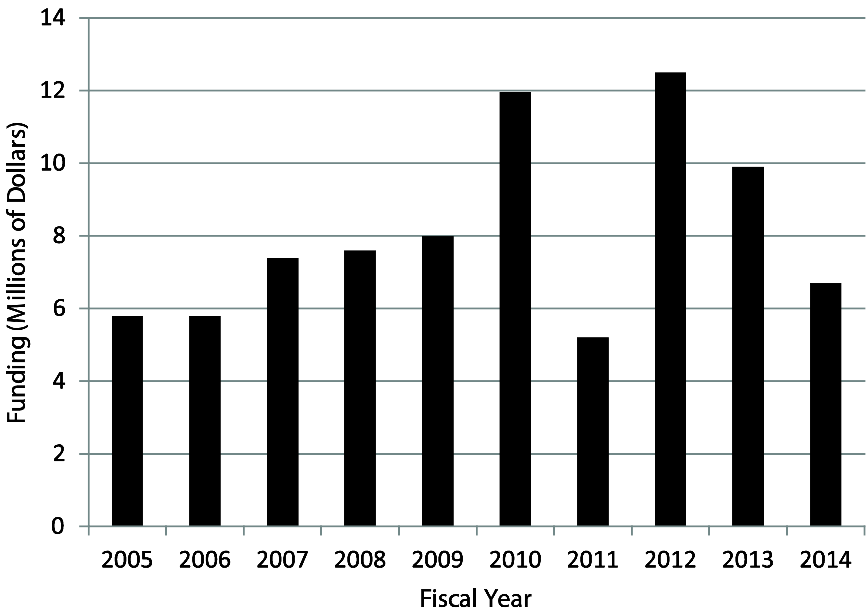

FIGURE 4-16 Funding for Phase I STTR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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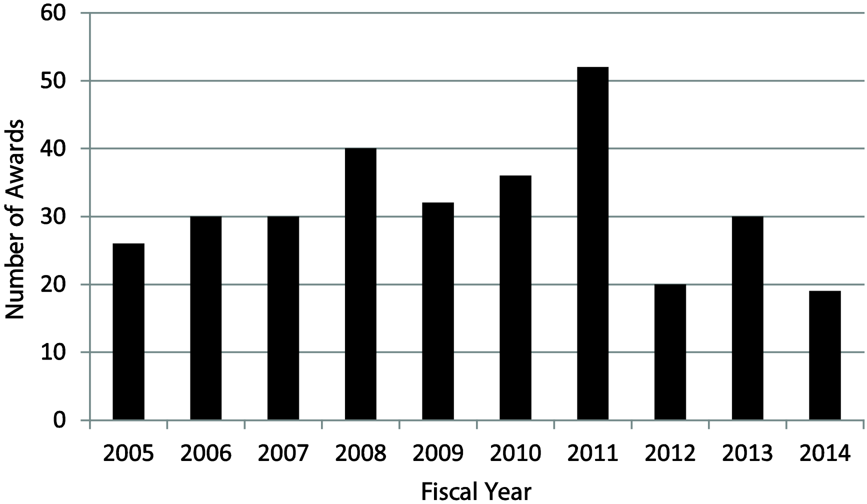

FIGURE 4-17 Number of Phase II STTR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

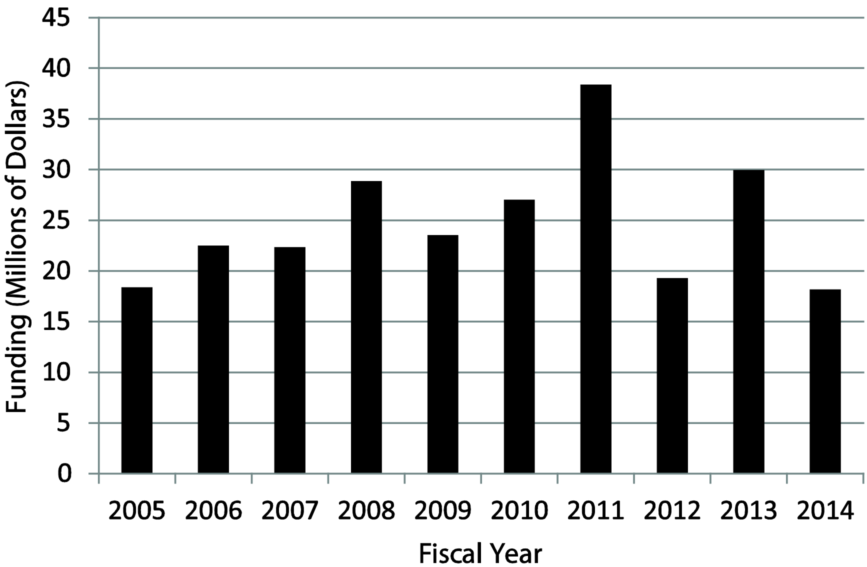

FIGURE 4-18 Funding for Phase II STTR awards, FY 2005-2014.
SOURCE: DoE SBIR/STTR Program Office.

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Fast Track

DoE offered Fast Track awards for the first time in FY 2014 (the Fast Track process is described in Chapter 2) and received 25 applications across both programs and made 13 awards (see Table 4-3).

Phase IIA and Phase IIB

In an effort to improve outcomes for Phase II and to help companies transition to the market, DoE has added two types of additional awards. Phase IIA provides a small amount of funding to companies completing a Phase II and requiring additional help. Phase IIB provides a larger amount to move companies into commercialization, much like the National Science Foundation (NSF) Phase IIB program. However, unlike NSF program, the DoE program does not require matching funds. Applications for Phase IIA are more likely to be funded than those for Phase IIB (see Table 4-4). Phase IIA applications were funded at a rate of 61.5 percent, and Phase IIB applications were funded at a rate of 32.1 percent.

SBIR Awards and the States

SBIR awards are not distributed equally across the states, reflecting the number of applications from different regions of the country and the program's merit-based selection. Reflecting Congressional interest in broader access to the program, agencies are now required to report on their effort to encourage awards from underserved states.

TABLE 4-3 Number of Fast Track Applications and Awards, FY 2005-2014

	SBIR	STTR
Number of Applications	12	13
Number of Awards	9	4

SOURCE: DoE SBIR/STTR Program Office.

TABLE 4-4 Applications Outcomes for Phase IIA and Phase IIB, FY 2014

	Phase IIA Applications	Phase IIB Applications
Awarded	61.5	32.1
Recommended for Funding - Not Awarded	23.1	13.2
Not Recommended for Funding	15.4	49.1
Declined Without Review	0.4	0.4

SOURCE: DoE SBIR/STTR Program Office.

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Phase I SBIR and the States

The number of awards per state is a function of three factors:

- The size of the state
- The number of applications per unit of population
- The success rate for applications from the state

Table 4-5 shows that all of these factors differ substantially among the states. At the most basic level, states with larger population tend to have more SBIR-eligible firms and therefore generate more applications. However, as Table 4-5 shows, even after normalizing for population substantial differences between the states remain. The table shows the number of applications per 1 million population for each state. Results vary from more than 200 for Massachusetts, Colorado, and Delaware to fewer than 20 for 16 states, including fewer than 10 for 3 states. Thus, factors other than size of population substantially affect the number of applications.

Likewise, reviewing the number of awards alone is of little analytic use. Because that number is largely driven by state population, initial analysis must consider applications normalized for population. That rate is also provided in Table 4-5 and reveals very large disparities. At the top end, Massachusetts generated 57.5 Phase I SBIR awards per million population, while Colorado, New Mexico, and Delaware each generated more than 40. In contrast, 19 states generated fewer than 3 awards per 1 million population, and 4 states generated fewer than one.

The National Science Foundation has developed a measure of the science and engineering talent deployed in a state economy. Figure 4-19 shows the relationship between the number of applications per 1 million population and the percentage share of scientists and engineers in the workforce. The correlation is substantial, with a Pearson Rho of 46.0.

The award outcomes for states are also influenced by success rates for applications, which also display substantial variation. The average success rate for all applications is 16.1 percent: 9 states have rates of 20 percent or greater, while 15 states have rates of 10 percent or lower (see Table 4-5). The latter states therefore have success rates substantially lower than the average, and less than half of those of the most successful states. This suggests that the quality of applications varies substantially and that simply seeking to increase the number of applications from firms within a state will not necessarily result in more awards to firms in that state.

Phase II SBIR and the States

Table 4-6 provides Phase II SBIR applications and awards data for FY 2005-2014 by state, normalized for population, as well as data on the science

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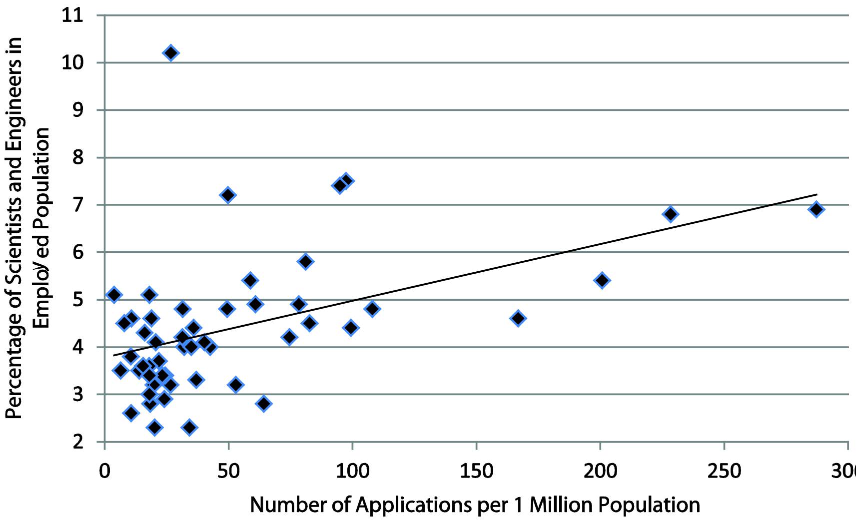

FIGURE 4-19 Number of DoE Phase I applications and the percentage share of scientists and engineers in the state workforce, FY 2014.
SOURCE: DoE SBIR/STTR Program Office (awards and applications); National Science Foundation, *Science and Engineering Indicators*, Table 8-31 (number of scientists and engineers employed) 2015; U.S. Census Bureau (state populations).

and engineering workforce. There are substantial variations between states, largely following the patterns found for Phase I.

Understanding Low-award States

Three factors appear to play a role, to differing degrees depending on the state, in why some states receive more SBIR awards than do others.

1. Some states do not have a great deal of science and engineering talent. Nationally, scientists and engineers make up 4.7 percent of the workforce. For the 10 lowest award states (normalized for population, and excluding DC), that percentage is 3.7 percent.
2. Less science and engineering talent leads in part to the second direct factor—fewer applications. The 10 lowest awarded states (normalized for population) generated an average of 12.3 applications per 1 million population over the study period. The average for all states (including low performers) was 48.5.
3. The average success rate for all states was 16.1 percent. For the 10 lowest award states, it was 6.4 percent. Although the numbers are small, it is apparent that there is no correlation between application rates and success rates for the low-award states (Pearson Rho = -0.14).

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TABLE 4-5 DoE Phase I SBIR Applications and Awards, by State, FY 2005-2014

State	No. of Apps	No. of Awards	Population (Millions)	Percent Share of Scientists and Engineers in the Workforce	No. of Applications per One Million in Population	No. of Awards per One Million in Pop	Success Rate (Percent) (Normalized for Pop)
(blank)	1	0					
AK	8	0	0.74	4.6	10.83	0.0	0.0
AL	170	19	4.86	4.0	34.99	3.9	11.2
AR	54	9	2.98	5.1	18.13	3.0	16.7
AZ	439	44	6.83	2.8	64.29	6.4	10.0
CA	3,175	519	39.14	5.8	81.11	13.3	16.3
CO	1,246	265	5.46	6.8	228.35	48.6	21.3
CT	388	73	3.59	4.8	108.05	20.3	18.8
DC	18	1	0.67	10.2	26.78	1.5	5.6
DE	190	38	0.95	5.4	200.86	40.2	20.0
FL	472	47	20.27	3.4	23.28	2.3	10.0
GA	165	22	10.21	4.3	16.15	2.2	13.3
HI	35	5	1.43	3.4	24.45	3.5	14.3
IA	20	3	3.12	3.5	6.40	1.0	15.0
ID	52	6	1.65	4.2	31.42	3.6	11.5
IL	518	60	12.86	4.1	40.28	4.7	11.6
IN	119	10	6.62	3.6	17.98	1.5	8.4
KS	64	9	2.91	3.7	21.98	3.1	14.1
KY	80	5	4.43	3.0	18.08	1.1	6.3
LA	50	1	4.67	2.6	10.70	0.2	2.0
MA	1,952	391	6.79	6.9	287.29	57.5	20.0
MD	571	75	6.01	7.4	95.07	12.5	13.1
ME	32	4	1.33	2.9	24.07	3.0	12.5
MI	367	54	9.92	3.3	36.99	5.4	14.7
MN	176	23	2.99	5.4	58.82	7.7	13.1
MO	111	16	5.49	2.3	20.22	2.9	14.4

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MS	23	2	6.08	5.1	3.78	0.3	8.7
MT	44	6	1.03	4.0	42.60	5.8	13.6
NC	140	14	10.04	3.5	13.94	1.4	10.0
ND	6	0	0.76	4.5	7.93	0.0	0.0
NE	20	4	1.90	3.8	10.55	2.1	20.0
NH	110	19	1.33	4.5	82.67	14.3	17.3
NJ	545	89	8.96	4.9	60.84	9.9	16.3
NM	348	89	2.09	4.6	166.90	42.7	25.6
NV	99	8	2.89	2.3	34.25	2.8	8.1
NY	635	102	19.80	4.0	32.08	5.2	16.1
OH	867	133	11.61	4.2	74.65	11.5	15.3
OK	71	4	3.91	3.4	18.15	1.0	5.6
OR	199	41	4.03	4.8	49.39	10.2	20.6
PA	459	57	12.80	4.4	35.85	4.5	12.4
RI	20	2	1.06	4.6	18.93	1.9	10.0
SC	76	6	4.90	3.6	15.52	1.2	7.9
SD	17	2	0.86	3.2	19.80	2.3	11.8
TN	175	51	6.60	3.2	26.51	7.7	29.1
TX	866	115	27.47	4.8	31.53	4.2	13.3
UT	235	32	3.00	4.9	78.44	10.7	13.6
VA	833	114	8.38	4.4	99.37	13.6	13.7
VT	61	17	0.63	7.5	97.44	27.2	27.9
WA	357	83	7.17	7.2	49.79	11.6	23.2
WI	119	18	5.77	4.1	20.62	3.1	15.1
WV	34	5	1.84	2.8	18.44	2.7	14.7
WY	31	3	0.59	3.2	52.89	5.1	9.7
Overall	16,863	2,715	320.83	4.7	52.56	8.5	16.1

SOURCE: DoE SBIR/STTR Program Office (awards and applications); National Science Foundation, *Science and Engineering Indicators*, Table 8-31 (number of scientists and engineers employed) 2015; U.S. Census Bureau (state populations).

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TABLE 4-6 DoE Phase II SBIR Applications, Awards, Success Rates by State, FY 2005-2014

State	No. of Apps	No. of Awards	Population (Millions)	Percent Share of Scientists and Engineers in the Workforce	No. of Applications per One Million in Pop	No. of Awards per One Million in Population	Success Rate (Percent) (Normalized for Pop)
AK	0	0	0.74	4.6	0.0	0.0	
AL	16	7	4.86	4.0	3.3	1.4	43.8
AR	7	6	2.98	5.1	2.4	2.0	85.7
AZ	44	21	6.83	2.8	6.4	3.1	47.7
CA	469	233	39.14	5.8	12.0	6.0	49.7
CO	263	132	5.46	6.8	48.2	24.2	50.2
CT	70	42	3.59	4.8	19.5	11.7	60.0
DC	1	0	0.67	10.2	1.5	0.0	0.0
DE	35	16	0.95	5.4	37.0	16.9	45.7
FL	48	21	20.27	3.4	2.4	1.0	43.8
GA	24	7	10.21	4.3	2.3	0.7	29.2
HI	3	1	1.43	3.4	2.1	0.7	33.3
IA	1	0	3.12	3.5	0.3	0.0	0.0
ID	5	2	1.65	4.2	3.0	1.2	40.0
IL	54	23	12.86	4.1	4.2	1.8	42.6
IN	8	3	6.62	3.6	1.2	0.5	37.5
KS	9	5	2.91	3.7	3.1	1.7	55.6
KY	6	1	4.43	3.0	1.4	0.2	16.7
LA	0	0	4.67	2.6	0.0	0.0	
MA	377	192	6.79	6.9	55.5	28.3	50.9
MD	72	23	6.01	7.4	12.0	3.8	31.9
ME	3	3	1.33	2.9	2.3	2.3	100.0
MI	44	23	9.92	3.3	4.4	2.3	52.3
MN	22	11	2.99	5.4	7.4	3.7	50.0
MO	15	3	5.49	2.3	2.7	0.5	20.0

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MS	2	0	6.08	5.1	0.3	0.0	0.0
MT	2	1	1.03	4.0	1.9	1.0	50.0
NC	15	7	10.04	3.5	1.5	0.7	46.7
ND	0	0	0.76	4.5	0.0	0.0	
NE	4	4	1.90	3.8	2.1	2.1	100.0
NH	18	7	1.33	4.5	13.5	5.3	38.9
NJ	84	43	8.96	4.9	9.4	4.8	51.2
NM	79	33	2.09	4.6	37.9	15.8	41.8
NV	9	5	2.89	2.3	3.1	1.7	55.6
NY	90	55	19.80	4.0	4.5	2.8	61.1
OH	127	61	11.61	4.2	10.9	5.3	48.0
OK	4	2	3.91	3.4	1.0	0.5	50.0
OR	40	20	4.03	4.8	9.9	5.0	50.0
PA	50	22	12.80	4.4	3.9	1.7	44.0
RI	2	1	1.06	4.6	1.9	0.9	50.0
SC	5	4	4.90	3.6	1.0	0.8	80.0
SD	1	0	0.86	3.2	1.2	0.0	0.0
TN	46	29	6.60	3.2	7.0	4.4	63.0
TX	115	50	27.47	4.8	4.2	1.8	43.5
UT	29	12	3.00	4.9	9.7	4.0	41.4
VA	112	49	8.38	4.4	13.4	5.8	43.8
VT	14	8	0.63	7.5	22.4	12.8	57.1
WA	81	40	7.17	7.2	11.3	5.6	49.4
WI	17	5	5.77	4.1	2.9	0.9	29.4
WV	5	1	1.84	2.8	2.7	0.5	20.0
WY	4	2	0.59	3.2	6.8	3.4	50.0
Overall	2,551	1,236	320.83	4.7	8.0	3.9	48.5

SOURCE: DoE SBIR/STTR Program Office (awards and applications); NSF Science and Engineering Indicators, Table 8-31 (number of scientists and engineers employed); U.S. Census Bureau (state populations).

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The evidence overall suggests that low application rates do tend to generate low numbers of awards, but that low application rates themselves result partly from demographics (population) and partly from the distribution of science and engineering talent in the workforce. Given the merit-based selection of the program, however, it does not appear that efforts to generate more applications will necessarily lead to many more awards for low-award states.

New Entrants into the SBIR/STTR Programs and Multiple-Award Winners

New Entrants

DoE data shown in Figure 4-20 indicate that the number of new applicants and first-time winners has expanded in recent years. In FY 2013, new awardees (companies that have not previously received an SBIR/STTR award from DoE) accounted for greater than 40 percent of all winners, while new applicants (companies that have not previously applied for DoE SBIR or STTR funding) accounted for 25 percent of all Phase I applicants.

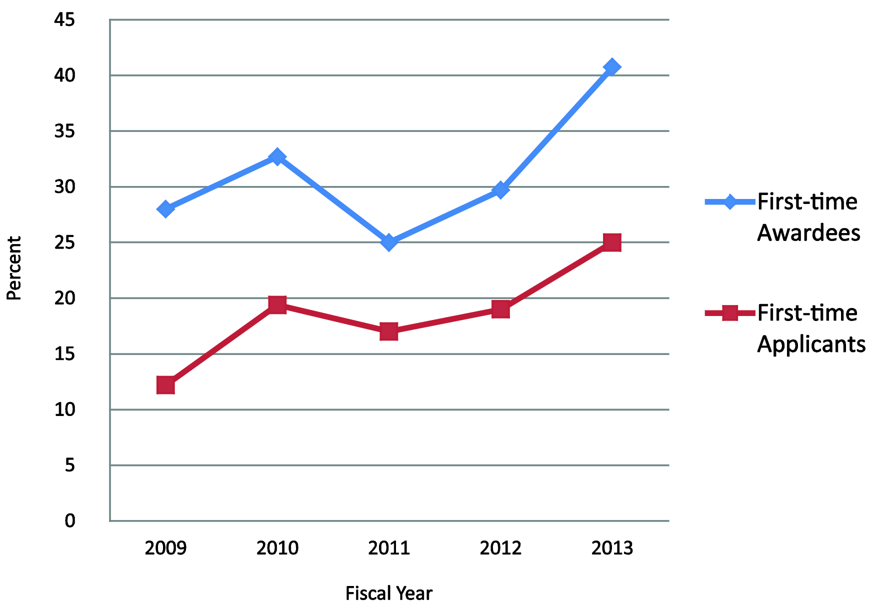

FIGURE 4-20 New applicants and new awardees, FY 2009-2013.
SOURCE: DoE SBIR/STTR Program Office.

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Multiple-Award Winners

Phase I SBIR/STTR awards at DoE are somewhat concentrated. The top 20 winners accounted for a total of 777 awards in FY 2005-2014, which is slightly less than 23 percent of all awards. (See Table 4-7.) In comparison, the top 20 winners at DoD accounted for 14.3 percent of Phase I SBIR awards.[4]

As to be expected, many of the same companies were also among the top 20 Phase II SBIR award winners. However, their ability to convert Phase I wins into Phase II awards varied substantially, with the Analysis and Measurement Services Corporation converting 80 percent of its Phase I projects into Phase II awards, while Physical Optics converted only about 40 percent. The top 20 winners' share of all Phase II awards was slightly higher than that for Phase I, at 26.8 percent of all awards (see Table 4-8).

TABLE 4-7 Top 20 Companies Winning DoE Phase I SBIR/STTR Awards, FY 2005-2014.

Company Name	Number of Phase I SBIR Awards	Number of Phase I STTR Awards	Total
Radiation Monitoring Devices	89	2	91
Tech-X Corporation	88		88
Muons	10	50	60
TDA Research	46	4	50
Radiabeam Technologies	33	6	39
Calabazas Creek Research	24	14	38
Physical Sciences	28	8	36
Physical Optics Corporation	36		36
Aerodyne Research	28	8	36
Euclid Techlabs	32	2	34
FAR-TECH	31	2	33
Compact Membrane Systems	24	8	32
Omega-P	26	4	30
Lynntech	28		28
Niowave	19	8	27
Voxtel	23	2	25
Luna Innovations	19	6	25
Eltron Research & Development	25		25
Ultramet	22		22
Southwest Sciences	20	2	22
Total	651	126	777
Percentage of all DoE Phase I SBIR and STTR Awards			22.8

SOURCE: DoE SBIR/STTR Program Office.

[4]National Research Council, *SBIR at the Department of Defense*, Washington, DC: The National Academies Press, 2014, Table 2-3.

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TABLE 4-8 Top 20 DoE Phase II SBIR/STTR Award Winners, FY 2005-2014

Company Name	Number of Phase II SBIR Awards	Number of Phase II STTR Awards	Total
Radiation Monitoring Devices	52		52
Tech-X Corporation	47		47
Muons	7	28	35
TDA Research	26	2	28
Aerodyne Research	24	4	28
Radiabeam Technologies	20	3	23
Euclid Techlabs	18	2	20
Compact Membrane Systems	11	9	20
Omega-P	15	4	19
Physical Sciences	10	6	16
FAR-TECH	16		16
Calabazas Creek Research	10	5	15
Physical Optics Corporation	14		14
Niowave	10	4	14
Voxtel	13		13
Analysis and Measurement Services Corporation	10	2	12
Luna Innovations	9	2	11
Eltron Research & Development	11		11
Composite Technology Development	9	2	11
XIA	7	3	10
Total	339	76	415
Percentage of all DoE Phase II SBIR and STTR Awards			26.8

SOURCE: DoE SBIR/STTR Program Office.

Implications of Multiple-Award Winners

Multiple-award winners are sometimes pejoratively referred to as SBIR/STTR trolls, and some observers have raised questions about whether the government should provide awards to many of the same firms over an extended period, the opportunity cost of backing a single company many times being that a new company goes unfunded.

Having a sizable percentage of awards going to a relatively small subset of awardees, which include mature companies as well as startups, is not per se evidence of a problem, but it is worth probing. There are several reasons why a given company might seek and receive multiple SBIR or STTR awards:

- The company is meeting agency mission needs by providing innovative solutions.

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- More resources are required to develop the technology and move it to commercial readiness than is provided by a single award and reasonable progress is being made.
- The company has developed a platform technology suitable for deployment in multiple application areas, each with unique challenges and expected business opportunities.
- The company specializes in research with a business model that focuses on licensing or selling its intellectual property rather than in-house product development.

If the application is consistent with the agency's published topic list, if reviewers find the proposed technology development promising without major shortcomings and the business plan reasonable, and if the agency's program managers find that the proposal competitively aligns with DoE interests relative to other applications, an application may be approved despite previous awards to the same applicant. There is no selection criterion that requires that a company be a first-time applicant or that imposes a limit on how many previous times it may have applied or on how many awards it has received.

Some argue that startups or young companies have a greater job creation impact than mature companies.[5] Others argue that since young firms have fewer internal resources and the market has less information about them, asymmetries in capital market are more likely to affect their R&D investments.[6] Alternatively, it can be argued that the specific idea that is proposed, rather than the age of the company, is what matters most. The latter position allows for the fact that mature small companies may seek to renew their technology base by pursuing innovative proposals. In that case, an existing knowledge of markets, an experienced workforce, and internal funding may well position an innovating mature company's renewal project. In any case, DoE's SBIR/STTR programs have not elected to impose a constraint on the age of the company or on its principal investigator; rather their focus is on assessment of the proposed project.

To ensure that the current approach is serving DoE's program interest, it is essential that the selection criteria and process are functioning as intended. Poorly designed and repetitive topic lists might lead to incremental or irrelevant project proposals. Reviewers who are not experts in the field may not adequately distinguish significant advances from small incremental improvements. Program Managers who do not give adequate attention to the SBIR/STTR selection process may approve yet more awards to companies who have failed to

[5]J. Haltiwanger, R.S. Jarmin, and J. Miranda, "Who Creates Jobs? Small versus Large versus Young," *Review of Economics and Statistics* 95: 347-361, 2013. Also see Evans, D. S. 1987. The relationship between firm growth, size, and age: Estimates for 100 manufacturing industries. *The Journal of Industrial Economics*, 567-581; and Calvo, J. L. 2006. Testing Gibrat's law for small, young and innovating firms. *Small Business Economics*, 26(2), 117-123.

[6]Hall, B. H. 2008. The financing of innovation. In S. Shane (ed.*), Handbook of Technology and Innovation.*

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SBIR/STTR at the Department of Energy

demonstrate results in the past. However, such an undesirable outcome would result from a failure of implementing the process rather than to a weakness in its inherent design. Therefore, there appears no compelling reason at this time to recommend that the number of awards per company or the age of company applicants or principal Investigators be constrained. At the same time, it is prudent that DoE monitor the percentage of multiple awards and the composite age of company applicants (e.g., ratio of startups to mature companies) who are applying for and receiving awards. Careful monitoring and study should inform the question of whether "small" or "young" companies are more effective in generating state-of-the-art technology and innovation in the context of SBIR. This evidence can be used by Congress to determine if encouraging participation by younger firms furthers the missions of the SBIR program.

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5

Quantitative Outcomes

As was noted in Chapter 1 (Introduction), Congress mandated four goals for the Small Business Innovation Research (SBIR) program: (1) to stimulate technological innovation; (2) to use small business to meet Federal research and development needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and (4) to increase private-sector commercialization derived from federal research and development (R&D).[1] The goals for the Small Business Technology Transfer (STTR) program are to (1) stimulate technological innovation, (2) foster technology transfer through cooperative R&D between small businesses and research institutions, and (3) increase private-sector commercialization of innovations derived from federal R&D.[2] This chapter provides an analysis of program outcomes related to the goals of stimulating technological innovation, using small business to meet federal R&D needs, increasing private-sector commercialization of federally funded research,[3] and fostering technology transfer through cooperative R&D between small businesses and research institutions. The approach analyzes outcomes as revealed primarily by the performance of Department of Energy (DoE) Phase II SBIR and STTR awards from fiscal year (FY) 2001 to FY 2010 based on data from the 2014 Survey carried out by the National Academies of Sciences, Engineering, and Medicine. The focus is on Phase II awards rather than Phase I awards because Phase II-funded projects are expected to have business plans and to have progressed toward commercialization. (See Box 5-1.)

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[1]Small Business Innovation Development Act of 1982, P.L. 97-219, July 22, 1982.
[2]Small Business Administration, "About STTR," https://www.sbir.gov/about/about-sttr, accessed July 9, 2015. Only the first two objectives are embedded in the authorizing legislation, although there is little controversy about the importance of the third, which appears to have been added by the Small Business Administration (SBA) in drafting its governing Policy Guidance for the program.
[3]The second SBIR goal of using small businesses to meet federal research and development needs was also discussed to some extent in Chapter 2 (Program Management). The third SBIR goal of fostering the participation of women and minorities is the focus of Chapter 6.

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Although DoE was an early proponent of survey-driven outcomes research (in that is started to gather outcomes data via survey some years ago), it has not led the way on tracking outcomes. According to the DoE SBIR/STTR Program Office, DoE has undertaken a twin-track approach to address this: It is building an electronic bridge between the new Small Business Administration (SBA) outcomes database (which is not yet online as of this writing); and it is investing in a new module for its own internal Performance Outcomes Data System (PODS) database, which will address outcomes. DoE currently tracks outcomes from SBIR/STTR awards using a survey administered annually. However, the agency declined to share these data on privacy grounds.

The analysis of outcomes in this report is therefore based primarily on the National Academies' 2014 Survey. The survey methodology is described in detail in Appendix A, and a description of the survey response rate and non-respondent bias[4] is provided in Box 5-1. The overall target population for the survey reported in this chapter is DoE Phase II SBIR and STTR awards made FY 2001-2010,[5] and most response data[6] is reported at the project level. Some survey questions, however, collect company-level information (such as number of employees). In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged. Tables and figures with company-level data are marked as reporting the number and percentage of responding companies. Not all survey recipients completed every survey question; as a result, the number of respondents and the number of responding companies varies.[7]

The survey data have limitations that signal the need for caution. The number of responses—although sufficient to provide useful data—was lower than for some other agencies in part because the number of awards was lower. A higher number of responses may have permitted a more detailed breakdown and cross-tabulation of results. Improved DoE data collection and reporting, and access to those data, could make such analysis feasible. In addition, the 2014 Survey inevitably captured outcomes at a specific point in time: many projects had not yet generated maximum commercial returns—some were just entering their commercialization phase, while other more mature projects may not generate revenues for many years to come. These caveats are important to bear in mind while reviewing the data in this chapter. As a result, the study findings reported in Chapter 8 are based on not only the 2014 Survey data but also the case studies and interviews presented in Chapter 7 (Insights).[8]

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[4]Multiple sources of bias in survey response are discussed in Box A-1 of Appendix A.
[5]See Box 5-1 and Appendix A for a description of filters applied to the starting population.
[6]Averaged survey response data is reported to the nearest whole number.
[7]Not all questions were applicable to all respondents, depending on their answers to particular questions. For example, questions 33-35, which address sales outcomes, were directed only to respondents reporting sales in response to question 32. In other cases, respondents did not answer particular questions. The reasons for these non-responses are unknown.
[8]See Appendix A for a detailed description of the survey methodology. The 2014 Survey questionnaire is reproduced in Appendix C.

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COUNTERFACTUALS

It is always difficult to tightly determine the impact of a given SBIR or STTR award. Many factors affect the success and failure of companies and projects, and it can be difficult to determine whether a specific factor was a *necessary* condition for success. Worse still, the large number of factors and the multiple paths to success and failure mean that it is unusual to be able to state with confidence that a particular intervention—in this case an SBIR or STTR award—constitutes a *sufficient* condition for a project's success.

Still, it is worth considering what would have occurred absent SBIR or STTR funding from the perspective of those most likely to have detailed knowledge and understanding of their particular projects: the principal investigators (PIs). Accordingly, the 2014 Survey asked a series of questions focused on the likely effect of the absence of SBIR or STTR funding. Of course, asking recipients about the impact of funding raises possible conflicts of interest, so results should be interpreted with some caution. However, these surveyed awards were made no more recently than FY 2010, and many recipients no longer apply for SBIR/STTR funding for a variety of reasons.

The committee acknowledges that the study lacks an experimental or quasi-experiment study design that allows a randomly based comparison of the outcomes of companies that applied and did not apply and of those that received SBIR/STTR awards and those that did not—a design that would allow testing of the award's impact and the effect of gender and ethnicity on applications, awards, and success rates. As is typically the case in studies of competitively based grant programs, study designs that allowed comparisons only of the application or grant effect was impossible because the populations of applications and non-applications and of award recipient and non-recipients differ in many more ways than whether or not they applied and in whether or not they received an award; also, the program has criteria for making awards that are not randomly based.

Project Go-Ahead Absent SBIR/STTR Funding

One approach has been to ask recipients for their own views on the impact of the program on their project or company. In particular, the survey asked Phase II recipients whether the project would have been undertaken absent SBIR/STTR funding and whether the scope and timing would have been affected. Responses are summarized below in Table 5-1. Ten percent of respondents indicated that the project probably or definitely would have proceeded without program funding. In contrast, 71 percent thought the project probably or definitely would not have proceeded absent SBIR/STTR funding. Eighteen percent were uncertain. These data have interesting wider implications for debates about early-stage funding: they suggest a weakness in the "crowding

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

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

The National Academies' 2014 Survey was sent to every principal investigator (PI) who won a SBIR or STTR Phase II award from DoE, FY 2001-2010 (not to the registered company point of contact (POC) for each company). Each PI was asked to complete a maximum of two questionnaires, which as a result excludes some awards from the survey.

The preliminary population was developed by taking the original set of SBIR and STTR Phase II awards made by DoE during the study period and eliminating on a random basis awards in excess of two to PIs who received more than two awards (to limit the burden on respondents). The resulting preliminary population was 1,077 awards. PIs for 583 of these awards were determined to be not contactable at the SBIR company listed in the DoE awards database. The remaining 494 awards constitute the effective population for this study. From this effective population, we received 269 responses. As a result, the response rate in relation to the preliminary population was 25.0 percent and in relation to the effective population was 54.5 percent.

The committee acknowledges that because information from non-respondent PIs was lacking, and because the agencies also have minimal information about PIs which could be used to track potential non-respondent biases, we can conclude only that the data are likely to be biased. Two potential biases are expected with regard to PIs participating in the survey: A bias toward PIs who are working at companies that are still in business as corporate entities (i.e. have not failed or been acquired), and a bias toward PIs who have received multiple awards because they are in the system multiple times and they may tend to have a greater reliance on the SBIR program, a more favorable view of it, and a greater willingness to complete the survey; furthermore, they may have greater recall about the program from working with it multiple times. Another potential bias results from the fact that the body of data is skewed, such that companies showing successful commercialization are rarer than companies having less commercial success. A random draw from the database would be less likely to produce a commercial success than not.

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

The committee chose to focus the survey on Phase II awards rather than Phase I awards because Phase II-funded projects are expected to have business plans and to have progress toward commercialization. Thus, it is reasonable to

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expect a survey based on Phase II to show more evidence of commercial activity than one based on Phase I or a combination of both phases.[a] The focus on Phase II awards reflects the effects of a "weeding out" of projects which were either not pursued by the companies for further SBIR/STTR funding or which were deemed not worthy of additional funding by the SBIR/STTR funding process. The focus on Phase II seems reasonable given the interest in commercialization.

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

[a] In a working paper, Sabrina Howell employs regression discontinuity analysis to examine the impact of DoE SBIR awards. Utilizing application data from DoE, she compared firms just above and below the cutoff for receiving an award. She found that receipt of a Phase I award "approximately doubles" the chance of later receiving VC funding, increases patenting, and is associated with greater commercialization. Phase II awards, on the other hand, she found to have "tiny or negative effects on VC finance," limited impact on patents, and no effect on reaching revenue. Howell's data were limited to SBIR awards in the EERE and the Fossil Energy offices and included applicants over a longer time period. Also, Phase II awards require a significant length of time for companies to realize outcomes. Sabrina Howell, "DOE SBIR Evaluation: Impact of Small Grants on Subsequent Venture Capital Investment, Patenting, and Achieving Revenue," Paper presented at the National Academy of Sciences, Engineering, and Medicine Workshop on the Economics of Entrepreneurship, June 29, 2015.

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

TABLE 5-1 Impact of Phase II SBIR/STTR Funding on Project Initiation, Reported by 2014 Survey Respondents

Question: In your opinion, in the absence of this SBIR/STTR award, would the company have undertaken this project?	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Definitely yes	1	1	0
Probably yes	9	10	3
Uncertain	18	20	7
Probably not	36	35	42
Definitely not	35	34	48
N (Number of Respondents)	257	226	31

SOURCE: 2014 Survey, Question 24.

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SBIR/STTR at the Department of Energy

out" hypothesis, because awardees—presumably those with the closest knowledge of funding prospects for the project—overwhelmingly believed it unlikely that alternative funding would be found.

The respondents who believed the project probably or definitely would have proceeded without SBIR/STTR funding were asked additional questions about the impact on project scope, duration, and timelines. They responded as follows:

- Project scope would have been narrower (74 percent).[9]
- Project would have been delayed by more than 6 months (85 percent).[10]
- Project would have taken longer (75 percent).

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

CHAPTER OUTLINE

The remainder of this chapter is broken into two sections: (1) Quantitative Survey Evidence that DoE Increased Commercialization and (2) Quantitative Survey Evidence that DoE Stimulated Technological Innovation. Commercialization is discussed first. An annex to this chapter, contained in Appendix F of this report, offers an extended analysis of 2014 Survey data.

QUANTITATIVE EVIDENCE THAT DOE INCREASED COMMERCIALIZATION

The committee has adopted a broad view of commercialization, taking it to include additional investments in technology development from outside the SBIR/STTR programs, as well as sales/licensing revenues. In addition, given the long time to market required for many energy technologies, the committee was careful to include a range of benchmarks and metrics, having determined that no single metric can appropriately capture such a broad concept. This analysis focuses first on different ways of measuring sales and other types of commercial revenue as well as further investment. In line with previous studies by the National Academies and consistent practice at all agencies, further investment beyond Phase II is recognized as acknowledgement by third parties that the project has developed technologies of marketable value. For many projects, further investment is moreover required before commercial sales can begin. In the private sector, commercial success over the long term requires profitability.

[9]2014 Survey, Question 25. N = 27.
[10]2014 Survey, Question 26. N = 26.

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However, in the short term, the path to successful 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. As noted, the committee uses multiple metrics to measure commercial activity in this report. An extended discussion of approaches to measuring commercialization is contained in Appendix F.

Because the DoE SBIR/STTR programs are not primarily designed to generate technologies for use by DoE itself, markets have to be found outside the agency, which can be a challenge for small innovative firms. It is therefore especially important to capture commercial sales as well as milestones met on the way to these.

Sales

Perhaps the single most used metric for assessing SBIR-type programs is sales by the company and/or licensee of products, processes, or services or other sales incorporating the technology developed during the surveyed project. As discussed in the introduction to this report—and echoing cautions in the 2008 National Academies report on the DoE SBIR program[11]—overreliance of this particular metric may lead to incorrect conclusions. While sales is a legitimate indicator of progress toward commercialization, it is not a reliable measure that commercial success has occurred. Although this warning is reflected in the wide range of metrics adopted for use in the current assessment, sales remains an important consideration.

Reaching the Market

The first question in this section concerns reaching the market: Did the project generate any sales, and if not, are sales expected (a necessary question given the long cycle time of some projects)? Responses are summarized in Figure 5-1. Overall, 49 percent of respondents reported some sales, and a further 23 percent expected sales in the future. These data are reasonably similar to those generated by the previous survey of SBIR-only DoE awardees by the National Academies in 2005 that was reported in its 2009 report, where 47 percent reported no sales yet, and 16 percent expected sales in the future.[12]

[11]National Research Council, *An Assessment of the SBIR Program at the Department of Energy,* Washington, DC: The National Academies Press Press, 2008.
[12]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, p. 143.

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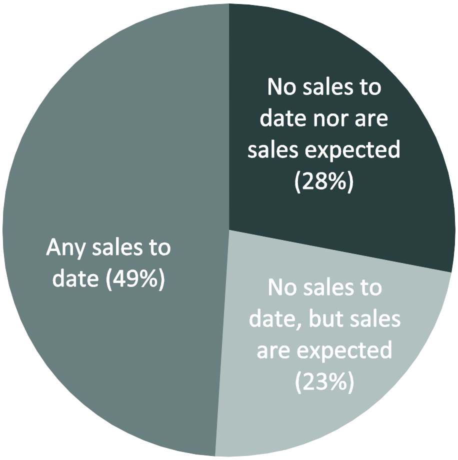

FIGURE 5-1 Status of sales to date for DoE SBIR/STTR projects, Reported by 2014 Survey Respondents.
NOTES: N (Number of Respondents) = 251. See Table F-1 for details.
SOURCE: 2014 Survey, Question 32.

Amount of Sales

Simply identifying the percentage of projects reaching the market is an important metric to signal that commercial activity has begun, but, as was noted previously, it is not sufficient to indicate commercial success. It is also necessary to understand the volume and distribution of sales, and how sales revenue relates to the costs incurred in generating the revenue.

The 2014 Survey asked those who reported some sales of the technology developed for the project to also report the amount of sales, grouped into ranges. As shown in Figure 5-2, of the 49 percent of respondents reporting sales, most were at the lower end of the scale: 55 percent or respondents reported less than $500,000. Two percent reported sales of at least $20 million, while about 7 percent reported sales between $5 million and $20 million.

Markets by Sector

For those projects with sales, the 2014 survey also asked respondents about the market sectors in which sales were made. As shown in Figure 5-3, respondents reported an average of 39 percent of project sales to the domestic private sector, followed by export markets (24 percent). An average of six percent of reported project sales were to DoE (see Figure 5-3).

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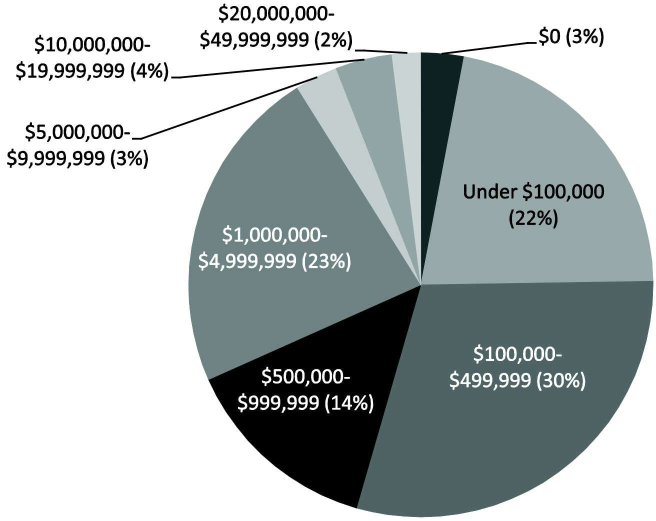

FIGURE 5-2 Distribution of total sales dollars (percentage of responses).
NOTES: N (Respondents Reporting Sales) = 118. See Table F-2 for details.
SOURCE: 2014 Survey, Question 34.

Further Investment

The ability of SBIR/STTR projects and companies to attract further investment has traditionally been a defining metric for SBIR/STTR commercialization potential.[13] There has also been interest in the sources of additional funding for high-tech innovation. While the United States has historically been a leader in venture capital and angel investment,[14] these are not the only or even the primary sources of additional investment funding for DoE SBIR/STTR projects.

Overall, 78 percent of survey respondents indicated that their project received additional investment in the technology related to the surveyed project (see Table 5-2). As shown in the previous National Academies survey, there is substantial skew in the amount of additional funding received. Table 5-2 shows the amount of funding received. About 59 percent of all projects reported receiving some but less than $1 million in additional investment, while 1 percent reported receiving $5 million or more.

[13]National Research Council, *An Assessment of the SBIR/STTR Program*, Washington, DC: The National Academies Press, 2008.
[14]Ernst and Young, “Venture Capital Insights 4Q14,” p.5.

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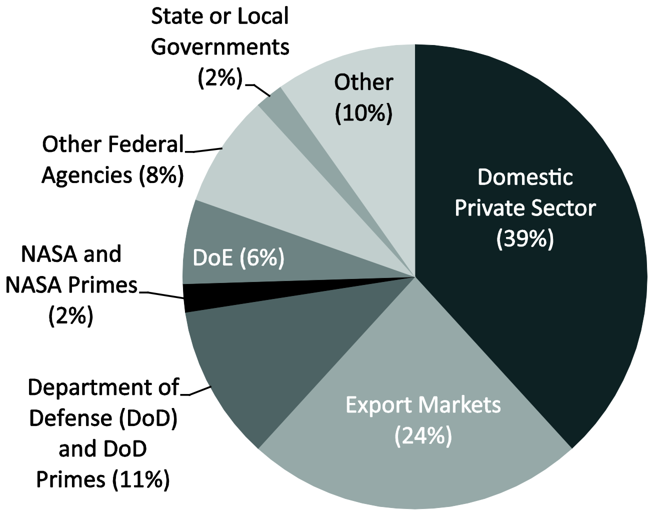

FIGURE 5-3 Average percentage of project sales by market sector, Reported by 2014 Survey respondents.
NOTES: N (Respondents reporting sales) = 120. See Table F-3 for details. For this question, each respondent reported a percentage distribution. The values above are calculated by deriving the mean value for all the responses for each category.
SOURCE: 2014 Survey, Question 36.

TABLE 5-2 Additional Investment by Amount to Surveyed Project, Reported by 2014 Survey Respondents

Amount of Additional Investment (Dollars)	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
None (0)	22	23	15
1-99,999	25	23	37
100,000-499,999	23	24	19
500,000-999,999	11	11	15
1,000,000-4,999,999	18	18	15
5,000,000-9,999,999	1	1	0
10,000,000-19,999,999	0	1	0
20,000,000-49,999,999	0	0	0
50,000,000 or more	0	0	0
Mean (Thousands of Dollars)	814	836	630
Median (Thousands of Dollars)	300	300	50
N (Number of Respondents)	245	218	27

SOURCE: 2014 Survey, Question 30.

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The 2014 Survey asked respondents to report all sources of additional project investment. Table 5-3 shows the breakout of reported sources. Of those projects that received additional investment from U.S. sources, 39 percent received private-sector funding, with 2 percent having received venture capital funding, and 5 percent having received angel or other private equity funding. Twenty percent received strategic investments from U.S. partners. Forty percent of respondents reported receiving further investment from non-SBIR/-STTR federal sources, which would include additional sources of funding within DoE. Twenty percent of respondents reported receiving additional project investment from other external sources, including 12 percent from state and local governments and 9 percent from research institutions. Overall, the most utilized funding source was the company itself (reported by 75 percent of respondents).

QUANTITATIVE EVIDENCE THAT DOE STIMULATED TECHNOLOGICAL INNOVATION

One of the congressionally mandated objectives for the SBIR and STTR programs is to "stimulate technological innovation." Evidence for this

TABLE 5-3 Sources of Further Project Investment, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Source	Overall	SBIR Awardees	STTR Awardees
Non-SBIR/STTR Federal Funds	40	40	39
Private Investment: U.S. Sources	39	41	23
Venture capital (VC)	2	2	0
U.S. angel funding or other private equity investment (not VC)	5	6	0
Friends and family	3	3	0
Strategic investors/partners	20	20	15
Other sources	15	17	8
Foreign Investment	2	2	0
Financial investors	1	1	0
Strategic investors/partners	2	2	0
Other External Sources	20	17	39
State or local governments	12	11	19
Research institutions (such as colleges, universities or medical centers)	9	8	19
Foundations	0	0	0
Internal Sources	75	75	73
Your own company (Including money you have borrowed)	72	72	73
Personal funds	8	9	4
N (Number of Respondents Reporting Additional Investment Funding)	195	169	26

NOTE: Respondents were asked to select applicable categories and subcategories of sources of further investment.
SOURCE: 2014 Survey, Question 31.

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includes linkages to universities, publication of articles in peer-reviewed journals, patent filings, and evidence that SBIR and STTR foster innovative companies. A review of patents and peer-reviewed articles offers a useful starting point.

Figure 5-4 shows the number of patents reported by respondents to the 2014 Survey that were related to all SBIR/STTR awards (not just DoE SBIR or STTR awards) received by the responding company. Sixty-eight percent of responding companies received at least one such patent, and 17 percent of responding companies received 10 or more such patents. Thirty-two percent received none. With regard to patents related to the specific project being surveyed, 39 percent of respondents reported at least one patent related to the surveyed project, and 2 percent reported the receipt of five or more related patents (see Table 5-4).

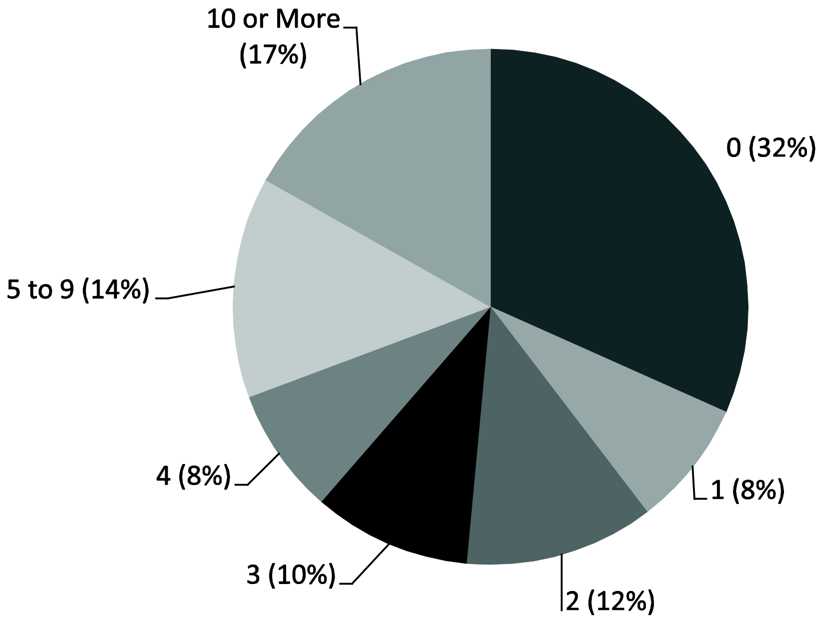

FIGURE 5-4 Number of patents per company related to all company SBIR/STTR awards, by percentage of companies responding to the 2014 Survey.

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged.

SOURCE: 2014 Survey, Question 12.

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TABLE 5-4 Number of Patents Received Related to Surveyed Project, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
0	61	62	55
1	22	21	36
2	8	9	0
3 or 4	7	7	9
5 to 9	1	1	0
10 or more	1	1	0
1 or more	39	38	45
N (Number of Respondents)	206	184	22

SOURCE: 2014 Survey, Question 38.

In addition to patents, the survey asked about articles in scientific publications. Interviews with company executives such as those of Calabazas Creek Research and Physical Sciences indicated that, for many companies, even though technical knowledge and trade secrets are very important, the company strongly supported peer-reviewed publishing (see Appendix E). In part, this was seen as a means of signaling and marketing among their peers, both for eventual products and as a means to attract talent. Seventy-three percent of all 2014 Survey respondents reported that at least one article had been published in a scientific publication for the technology developed as a result of the surveyed project. Thirty-nine percent reported at least three such articles. See Figure 5-5.

Links to Research Institutions

Another mechanism for knowledge transfer is the development of links between SBIR/STTR companies and their projects on the one hand and research institutions (RIs) on the other. Half of respondents reported some connection to an RI (as did nearly all STTR respondents). Thirty-five percent of all projects reported that an RI was a subcontractor on the project. Many respondents reported that RI faculty worked on the project (29 percent used faculty as consultants), while smaller percentages reported that the technology was originally developed at and/or licensed from the RI. The responses reflected substantial differences between STTR and SBIR projects as STTR projects on average worked much more closely with an RI on almost all the dimensions measured by the survey (see Table 5-5).

Respondents were also asked to identify the research institutions with which they worked in various capacities on the surveyed project. Overall, 149 different RIs were identified for 116 projects. See Appendix D for the complete list of RIs that were indicated by respondents.

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SBIR/STTR at the Department of Energy

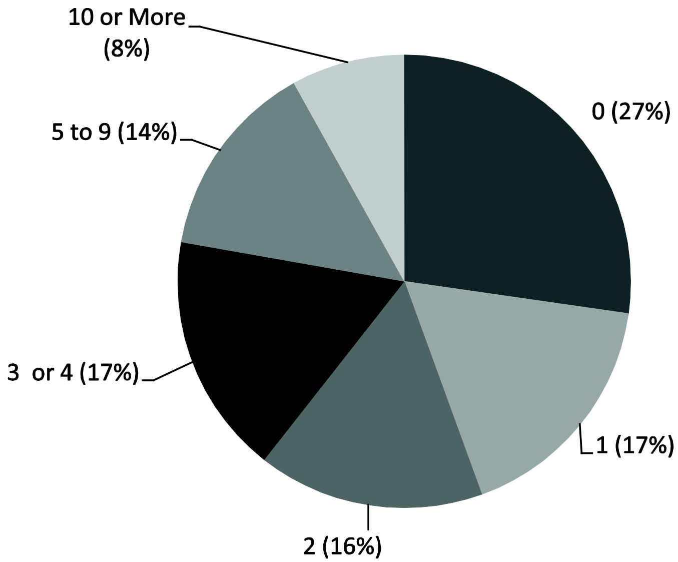

FIGURE 5-5 Number of peer-reviewed articles relating to surveyed project (percentage of 2014 respondents).
NOTE: N = 210 Respondents.
SOURCE: 2014 Survey, Question 38.

TABLE 5-5 Connections to Research Institutions (RI), Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
The PI for this project was at the time of the project an RI faculty member	1	0	10
The PI for this project was at the time of the project an RI adjunct faculty member	2	2	3
Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI	29	26	47
Graduate students worked on this project	25	21	50
The technology for this project was licensed from an RI	5	4	13
The technology for this project was originally developed at an RI by one of the participants in this project	9	6	30
An RI was a subcontractor on this project	35	29	77
None of the above	50	57	7
N (Number of Respondents)	244	214	30

SOURCE: 2014 Survey, Question 71.

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Finally, 68 percent of companies responding to the survey indicated that at least one founder had an academic background.[15] Thirty-one percent of responding companies reported that at least one founder was most recently employed by a research institution.[16]

Box 5-2 describes a workshop that the committee convened to address a range of issues related to university-SBIR linkages. Linkages to university is an important component in examining evidence that DoE "stimulated technological innovation," a goal of both the SBIR and STTR programs. University connections can also benefit SBCs by giving access to technical expertise.

Fostering Innovative Companies

Although the effect of SBIR/STTR funding on the company is not directly included in the congressional objectives for the program, helping small companies to become self-sufficient (and in some cases to grow rapidly) has implications for program impacts and is therefore included.

Small high-tech companies are often fluid in organization, and the 2014 Survey found that many participating companies had changed structurally in recent years. Thirty percent had established strategic partnerships with major players, 19 percent had spun-off at least one company, and 8 percent had been acquired by or merged with another firm.[17]

Ideally, companies that receive SBIR/STTR funding become more stable and develop non-SBIR/STTR-related contracts over time. This appears to be the case for DoE SBIR/STTR companies as dependence on SBIR/STTR is limited. 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- or STTR-funded projects. Overall, 40 percent of respondents indicated that 10 percent or less of the compay's total R&D effort was devoted to SBIR or STTR activities during the most recent fiscal year (at the time of the survey), and 23 percent indicated greater than one-half.[18] This picture is reinforced by data on sources of company revenues. Twenty-seven percent of responding companies reported that zero percent of company revenue was was SBIR/STTR funding for the most recent fiscal year at the time of the survey, while 24 percent reported that more than one-half of the company's revenues consisted of SBIR/STTR funding for the most recent fiscal year.[19]

The survey also asked about the overall impact of SBIR/STTR on the company. As Figure 5-6 shows, 61 percent saw a highly positive or transformative effect, and another 35 percent reported a positive impact. Only two respondents reported a negative impact.[20]

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[15]See Table F-15.
[16]See Table F-16.
[17]2014 Survey, Question 11. N = 131 (companies).
[18]2014 Survey, Question 10. N = 128 (companies).
[19]2014 Survey, Question 9. N = 129 (companies).
[20]See Table F-22.

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BOX 5-2
SBIR and the University Connection

When the SBIR was created in the early 1980s, many universities strongly objected to the program, seeing it as a source of competition for federal R&D funds. This perception of program has significantly evolved over the past decades. In the commercialization-sensitive environment created by the Bayh-Dole Act, SBIR and STTR awards are increasingly seen as a source of early-stage financial support for promising ideas arising from university laboratories. Further, SBIR and STTR are seen as effective tools to help universities directly address new missions in technology commercialization and regional development.

To explore this issue, the committee convened a workshop on February 5, 2014, on *Commercializing University Research: The Role of SBIR and STTR*. The committee revisited this issue again in its April 12, 2016 workshop on *SBIR and the Challenge of Commercialization*. These meetings revealed that universities use SBIR and STTR as tools to lower risks and provide incentives to their faculty to create startups and to commercialize their federally funded university research.

Jack Miner of the University of Michigan, speaking at the 2016 meeting, posted data showing that counties in Michigan with public research institutions that receive SBIR/STTR funds create the most technology companies and also create the most technology jobs. For this reason, he noted, the University of Michigan has "embraced" SBIR and STTR as a way of stimulating startups.

Speaking at the 2014 meeting, Barry Rosenbaum of the University of Akron Research Foundation noted that his institution uses SBIR to advance its mission of commercialization and regional development. It encourages and supports faculty to seek SBIR awards and helps them find commercial partners to bring new products to market.

Similarly, Jane Muir of the University of Florida, speaking at the 2014 meeting, noted that the UF Tech Connect program conducts SBIR workshops and other training programs, providing essential technical knowledge for early stage companies, including—particularly—women entrepreneurs.

The value of these partnerships is also reflected in the case studies of the firms profiled in Appendix E of this report. Adelphi Technology Inc., for example, has worked with the University of Florida and other research institutions that are seeking ways to bring their technology to market. In some cases, Adelphi has identified opportunities. In others—for example a recent STTR project—the driver is the university where the researcher is the PI. Another case study company, Calabazas Creek Research, is partnering with North Carolina State University by tapping into university expertise and equipment within a Phase II STTR award.

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These complementarities notwithstanding, some speakers and case study companies acknowledged the challenges involved in managing a successful partnership. These include working through administrative details of the company–university collaboration to assure smooth working relationships, sorting out who pays for what and who owns what, and supporting faculty that are not skilled in the technology commercialization aspects of SBIR/STTR programs.

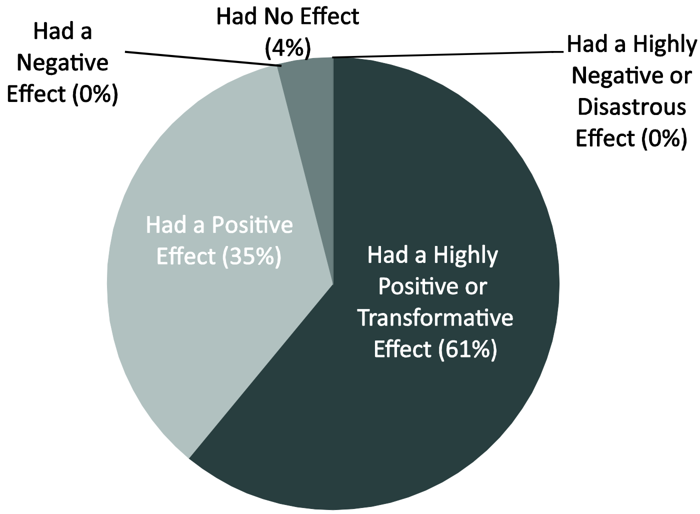

FIGURE 5-6 Long-term impact of SBIR/STTR on companies.
SOURCE: 2014 Survey, Question 57. N = 248.

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6

Participation of Women and Minorities

One of the four primary Congressional objectives for the Small Business Innovation Research (SBIR) program is "to foster and encourage participation by minority and disadvantaged persons in technological innovation."[1] The 1992 reauthorization reaffirmed that the purpose of the SBIR program is "to improve the Federal Government's dissemination of information concerning the Small Business Innovation Research Program, particularly with regard to program participation by woman-owned small business concerns and by socially and economically disadvantaged small business concerns."[2] Within the SBIR program, disadvantaged persons are defined as those who are either women or are members of a disadvantaged group as identified by the Small Business Administration (SBA).[3]

The committee concluded that these traditional interpretations are inadequate for two reasons. First, the SBA definition of minority includes Asian Americans, which has the effect of obscuring what are extremely low levels of participation by African Americans, Hispanic Americans, and Native Americans, and relatively high levels of participation by Asian Americans. In the committee's related report on the Small Business Technology Transfer (STTR) program, it recommends that the SBA change its definitions to address congressional intent with regard to minorities (See Box 6-1).[4] Second, company ownership is too narrow a metric to gauge overall participation. Although participation can encompass more than ownership, available agency data did not support detailed analysis of participation of disadvantaged persons beyond

[1]P.L. 97–219, § 2, July 22, 1982, 96 Stat. 217.
[2]P.L. 102-564, October 28, 1992, 106 STAT 4249.
[3]For the SBA definition of disadvantaged persons, see https://www.sba.gov/category/navigation-structure/eligibility-requirements. Accessed August 4, 2015.
[4]See Finding D-2 in National Academies of Sciences, Engineering, and Medicine, *STTR: An Assessment of the Small Business Technology Transfer Program*, Washington, DC: The National Academies Press, 2016.

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BOX 6-1
Changing SBA Definitions with Regard to Minorities

The National Academies' 2014 Survey of Department of Energy (DoE) SBIR and STTR awardees enabled for the first time a disaggregation of participants by minority status. In the committee's related report on the Small Business Technology Transfer Program, it recommends that the SBA change its definitions to address congressional intent with regard to minorities. Recommendation B reads—

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

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

[a] See Finding D.
[b] See, for example, Anuradha Basu and Meghna Virick (2015), "Silicon Valley's Indian diaspora: networking and entrepreneurial success," South Asian Journal of Global Business Research, 4(2):190-208.

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

company ownership. The National Academies of Sciences, Engineering, and Medicine[5] 2014 Survey of Department of Energy (DoE) SBIR and STTR

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

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SBIR/STTR at the Department of Energy

awardees enabled a disaggregation of participants by minority status as well as information on participation of women and minorities as principal investigators in addition to company owners.

To analyze the role of women and minorities in DoE's SBIR/STTR program, the committee relied primarily on three sources: (1) agency data, which is comprehensive; (2) 2014 Survey data, which probes awardee demographics and adds data about principal investigators; and (3) a workshop convened by this committee on the issue of diversity. The committee finds that current efforts have not been sufficient to meet the Congressional objective.

DEFINING THE ISSUE

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

Participants in the workshop examined broad demographic trends in the science and engineering workforce and statistical measures from the SBIR program for women and minorities, and searched for pragmatic solutions to boost SBIR and STTR awards to women and minorities. The workshop highlighted the fact that women comprise 51 percent of the U.S. population and 27 percent of STEM graduates, but woman-owned companies have received only about 6 percent of SBIR awards. Hispanics, African Americans, Asian Americans, and Native Americans together comprise 36 percent of the U.S. population and 26 percent of STEM graduates, but less than 10 percent of all SBIR awards.

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

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Women and Minority Participation Rates in SBIR/STTR in the Context of their National Participation Rates in Science and Engineering

The biennial report, *Women, Minorities, and Persons with Disabilities in Science and Engineering 2015*,[7] highlights and provides on-going key statistics drawn from a variety of data sources on women, persons with disabilities, and racial and ethnic groups and their representation in science and engineering (S&E) education, employment, and federal contracting. A comparison is provided of their representation in S&E and in the U.S. population, showing that these groups constitute disproportionally smaller percentages of S&E degree recipients, employed scientists and engineers, and federal contract recipients than their representation in the U.S. population. The report concludes that differences in representation in these areas arise from differences in current and past representation in education in science and engineering. It also concludes that differences vary by field of study or by occupation, with women's participation lowest in engineering (13 percent) and computer and mathematical sciences (26 percent), and much higher in biological and medical sciences (51 percent) and in social sciences (53 percent).[8]

Although the number of women with full-time, full professorships has more than doubled since 1993, women nevertheless still occupy only about one-fourth of the senior faculty positions at the nation's colleges and universities. This may partially explain the relatively fewer women than men serving as Principal Investigators in STTR projects. The same explanation may apply to underrepresented minorities, whose share of full-time, full professorships is lower than, and has risen more slowly than the share held by women. When associate professorships in addition to full professorship are taken into consideration, underrepresented minorities occupied on average eight percent of these senior faculty positions at all 4-year colleges and universities.

A comparison of women in the overall workforce and women in the science and engineering (S&E) workforce is depicted in Table 6-1. It shows that women in 2012 comprised 47 percent of the overall workforce but only 27 percent of the S&E workforce.

Table 6-2 shows employed scientists and engineers by ethnicity and race and by sex. More than 70 percent of males and females employed as scientists and engineers in 2013 were white. Overall, Black or African-Americans comprised 0.3 percent, Native Americans, also 0.3 percent, while Hispanic or Latino made up 7.6 percent, and Asians 11.4 percent.

[7]National Science Foundation, National Center for Science and Engineering Statistics, *Women, Minorities, and Persons with Disabilities in Science and Engineering 2015*, is a biennial report mandated by the Science and Engineering Equal Opportunities Act (Public Law 96-516).

[8]National Science Board, *Science and Engineering Indicators 2012*, NSB 12-01, Arlington, VA: National Science Foundation, 2012.

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

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

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

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

As a result, all participation other than via ownership is disregarded by agencies—including DoE. For example, no data appear to be maintained by any SBIR-awarding agency on female and minority principal investigators. Yet, serving as a principal investigator may provide entry for women and minorities into the SBIR/STTR programs. And as we shall see, SBA definitions of

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"socially and economically disadvantaged" have the effect of largely obscuring agency performance in addressing the congressional objective.

To overcome these shortcomings, this study administers a survey which goes beyond company ownership and gathers data also on participation by female and minority principal investigators. Furthermore, it breaks down minority participation by racial and ethnic groups to provide detailed data on participation.

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[a] National Research Council, *Expanding Underrepresented Minority Participation*, Washington, DC: The National Academies Press, 2011, 37-38.
[b] Ibid., 38-39.
[c] Ibid., 38. Here, underrepresented minorities are also defined as African Americans, Hispanics, and Native Americans/Alaska Natives.
[d] National Science Board, *Science and Engineering Indicators 2014*, Arlington, VA: National Science Foundation, 2014, pp. 2-26, 2-29, 2-32, and appendix table 2-29.
[e] SBA SBIR/STTR Policy Directive, February 24, 2014, p. 3.

BOX 6-3
Considering the Impact of Quotas

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

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

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

As a result, the committee decided that quotas would not be an appropriate solution to the problems described in the report, particularly as the report also notes that the agency has not yet made adequate efforts to foster and encourage participation by woman- and minority-owned firms.

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TABLE 6-1 A Comparison of Women in the Science & Engineering (S&E) Workforce with Women in the Overall U.S. Workforce, 2012

Composition of Women versus Men	Women	Men
Percentage of the S&E Workforce	27	73
Percentage of the Overall Workforce	47	53

SOURCE: National Science Board, *Science and Engineering Indicators 2012*, (NSB 12-01), Arlington, VA: National Science Foundation, 2012.

TABLE 6-2 Employed Scientists and Engineers by Ethnicity and Race and Sex 2013

	Percentage of Employed Scientists and Engineers		
Composition of by Ethnicity & Race	Women	Men	Both Sexes
Hispanic or Latino	8.2	7.1	7.6
Not Hispanic			
American Indian or Alaska Native	0.4	0.2	0.3
Asian	10.3	12.3	11.4
Black or African American	7.7	5.0	6.2
Native Hawaiian or Other Pacific Islander	0.3	0.3	0.3
White	71.4	73.7	72.6
More than one race	1.7	1.4	1.5

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Scientists and Engineers Statistical Data System (SESTAT), 2013 (preliminary), taken from Table 9-38.

Table 6-3 shows full-time faculty in 4-year institutions who have science, engineering, and health doctorates and, in 2013, received federal support. The highest percent of faculty who received federal support was Asian men (52.5 percent), followed by white men and white women. It shows that underrepresented minorities were less likely than their white and Asian counterparts to have received federal support. Overall, women were less likely to have received federal support than men.

Thus, the problem goes deeper than the SBIR/STTR. Federal agencies operating SBIR/STTR programs face a long-term and pervasive challenge. But, on a positive note, the national participation rates of women and minorities in college and university STEM curricula have been improving and not all fields have low participation rates.

DOE SBIR/STTR APPLICATIONS AND AWARDS DATA

As discussed in Chapter 4, DoE provided data about SBIR and STTR Phase I applications The data show that, similar to other agencies there has been a significant decline in the overall number of applications at DoE. As shown in Figure 6-1, the data also show that the percentage of Phase I applications from woman-owned small businesses (WOSBs) declined quite sharply from FY 2005-2010, then rebounded before declining again from FY 2012-2015. On average, WOSBs accounted for 10 percent of Phase I applications annually.

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TABLE 6-3 Full-Time Faculty in 4-Year Institutions Who Have Science, Engineering, and Health Doctorates and Receive Federal Support, 2013

Race, Ethnicity, and Gender	Percentage that Received Federal Support
White women	40.3
White men	46.4
Asian women	39.2
Asian men	52.5
Underrepresented women	36.5
Underrepresented men	36.8

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Doctorate Recipients, 2013, Figure 7-D.

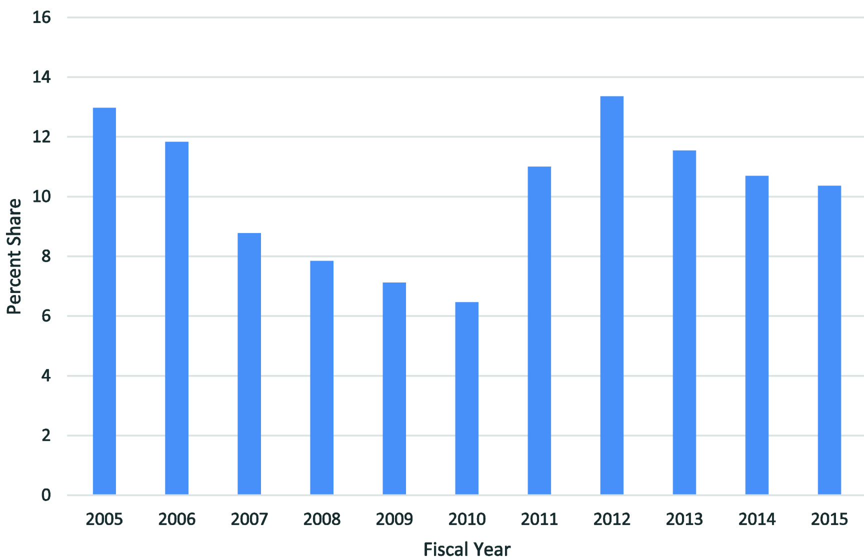

FIGURE 6-1 WOSB share of all DoE SBIR/STTR Phase I applications, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

DoE also provided data on Phase I applications from minority-owned small businesses (MOSBs) (using the SBA definition which includes Asian-owned businesses). Figure 6-2 shows that the percentage of Phase I applications coming from MOSBs has declined steadily, from just over 14 percent in FY 2005 to 6 percent in FY 2015, despite the inclusion of Asian-owned businesses with their higher than average application rate.

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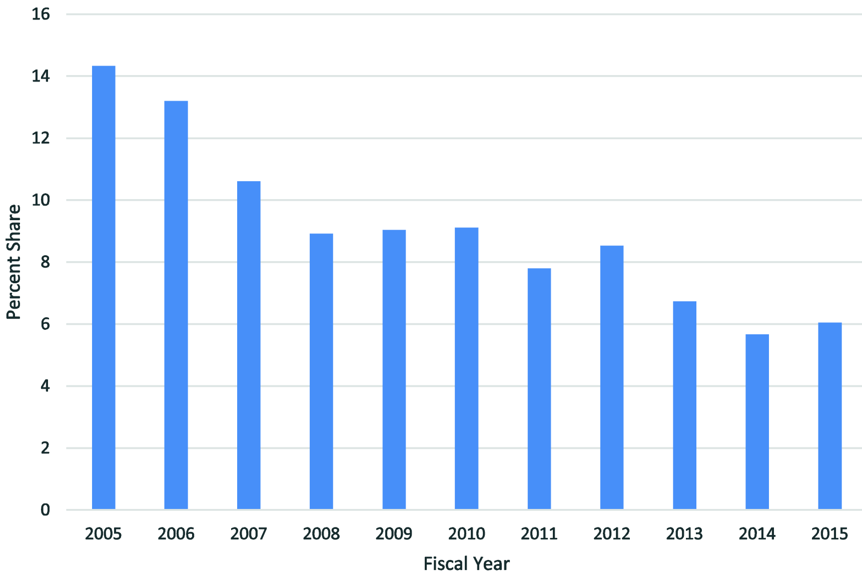

FIGURE 6-2 MOSB share of all DoE SBIR/STTR Phase I applications, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

There were low numbers of applications and low numbers of awards. Figure 6-3 shows the percentage of Phase I awards for WOSBs. Their share of all Phase I awards fell from 14 percent in FY 2005 to a low of less than 5 percent in FY 2009 before rebounding somewhat. The WOSB share was 8 percent in FY 2015, and averaged 8.6 percent over the period.

As shown in Figure 6-4, data on MOSB Phase I awards shows that their share has declined across the period, from just more than 13 percent in FY 2005 to a low of 3.5 percent in and 3.8 percent in FY 2015. MOSB averaged 6.6 percent of all Phase I awards during this period.

The share of awards is a function of the share of applications and the success rate. Figure 6-5 illustrates the success rate for WOSB Phase I applications at DoE, and shows that in every year except FY 2005, FY 2007, and FY 2010, WOSB success rates were lower than those for companies that were neither woman- nor minority-owned. The average Phase I success rate for WOSB was 15.7 percent, and the average Phase I success rate for firms that were neither woman- nor minority-owned was 18.9 percent.

MOSB applicants had even lower Phase I success rates, as Figure 6-6 shows. In this case, MOSB had a lower Phase I success rate than applicants that were neither woman- nor minority-owned in every year across the period. MOSB had an average Phase I success rate of 13.2 percent, and firms that were neither woman- nor minority-owned had an average Phase I success rate of 18.9 percent.

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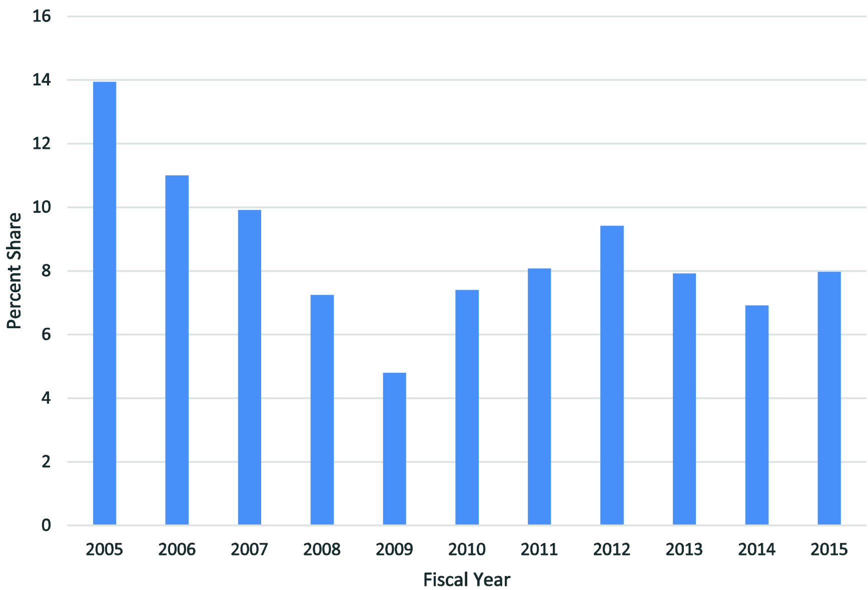

FIGURE 6-3 WOSB share of DoE SBIR/STTR Phase I awards, FY 2012-2015.
SOURCE: DoE SBIR/STTR Program Office.

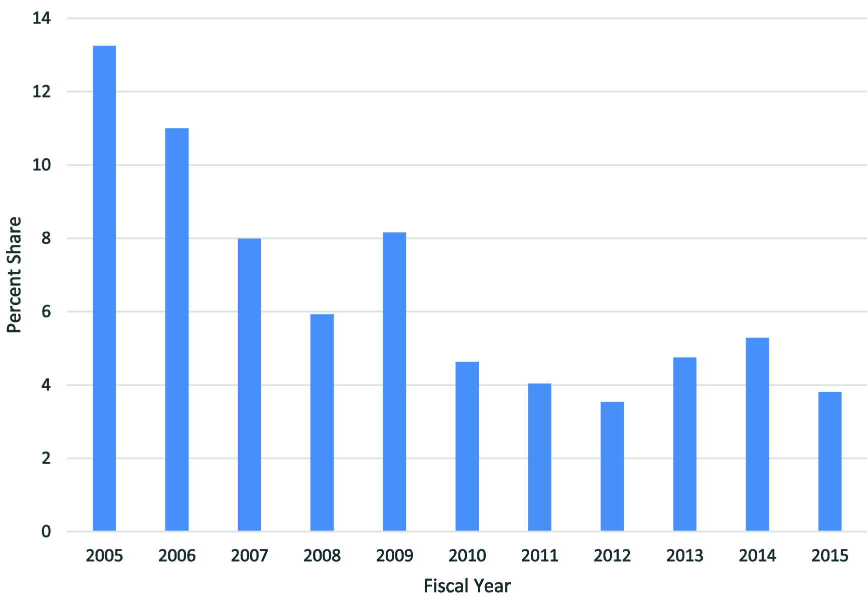

FIGURE 6-4 MOSB share of DoE SBIR/STTR Phase I awards, FY 2012-2015.
SOURCE: DoE SBIR/STTR Program Office.

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SBIR/STTR at the Department of Energy

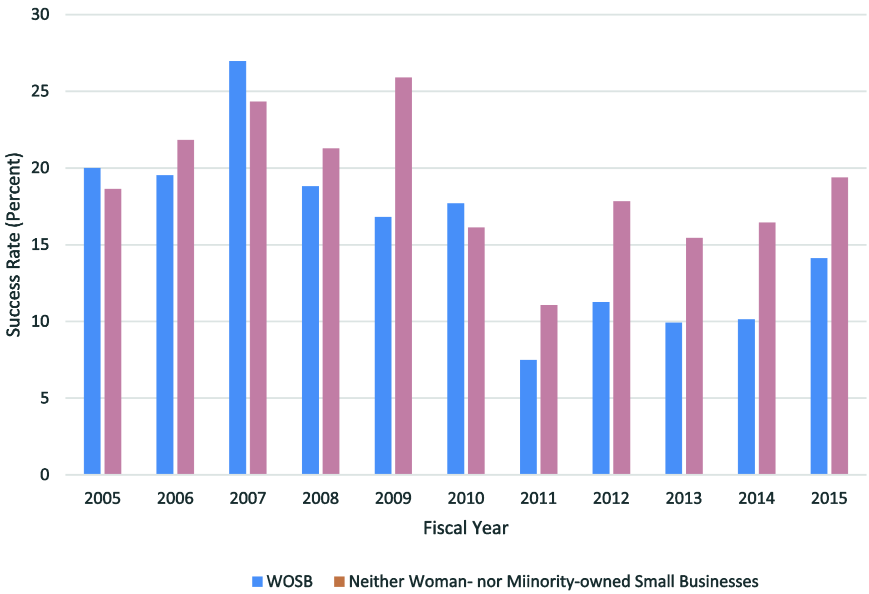

FIGURE 6-5 DoE SBIR/STTR Phase I application success rates for WOSB and for firms that were neither woman- nor minority-owned, FY 2005-2015.
NOTE: Phase I success rate equals the percentage of Phase I applications that resulted in Phase I awards.
SOURCE: DoE SBIR/STTR Program Office.

Turning to Phase II, the number of applications is to a considerable extent driven by the number of Phase I awards, as the latter is a prerequisite for a Phase II application. Figure 6-7 shows the WOSB share of Phase II applications. Overall, that share has been a flat 9.5 percent of all Phase II applications across the period. This is slightly higher than the WOSB share of Phase I awards (8.6 percent).

MOSB applicants accounted for a lower percentage of Phase II applications, 5.8 percent across the period, as shown in Figure 6-8. Ignoring the outliers in FY 2005 and FY 2006, that share has drifted down from a high of 8 percent in FY 2008 to a low of under 4 percent in FY 2012 and FY 2013. The share was 4 percent in FY 2015.

As shown in Figure 6-9, the WOSB share of Phase II awards has declined over the period (excluding what seems to be an anomalous year in FY 2005). The share peaked at 12.7 percent in FY 2006, and was 6 percent in FY 2015. WOSBs averaged 8.4 percent of all Phase II awards across the period, slightly lower than their share of Phase I awards (8.6 percent).

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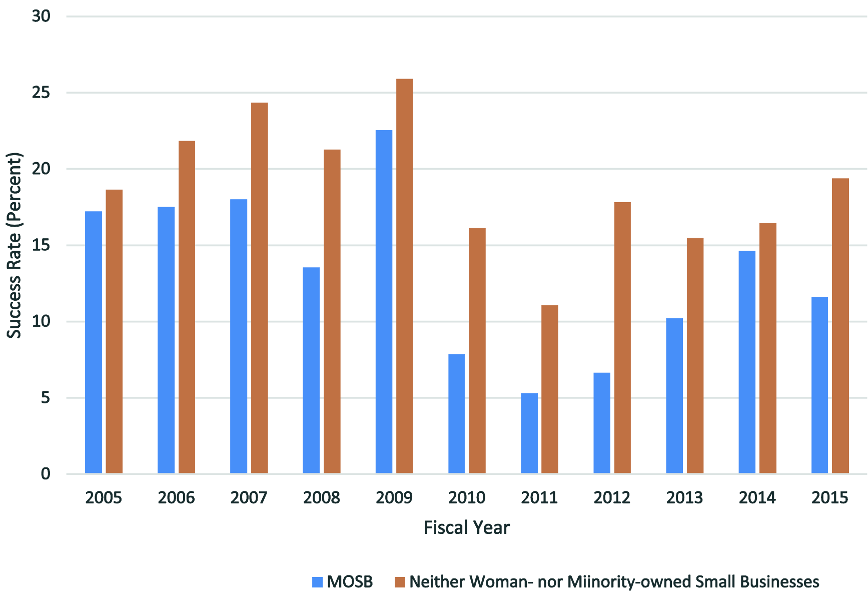

FIGURE 6-6 DoE SBIR/STTR Phase I application success rates for MOSB and for firms that were neither woman- nor minority-owned, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

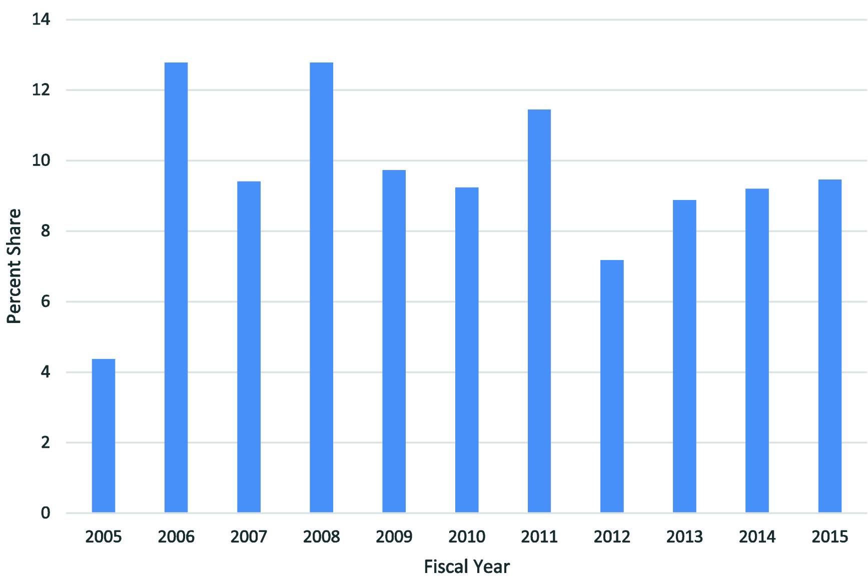

FIGURE 6-7 WOSB share of DoE Phase II applications, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

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SBIR/STTR at the Department of Energy

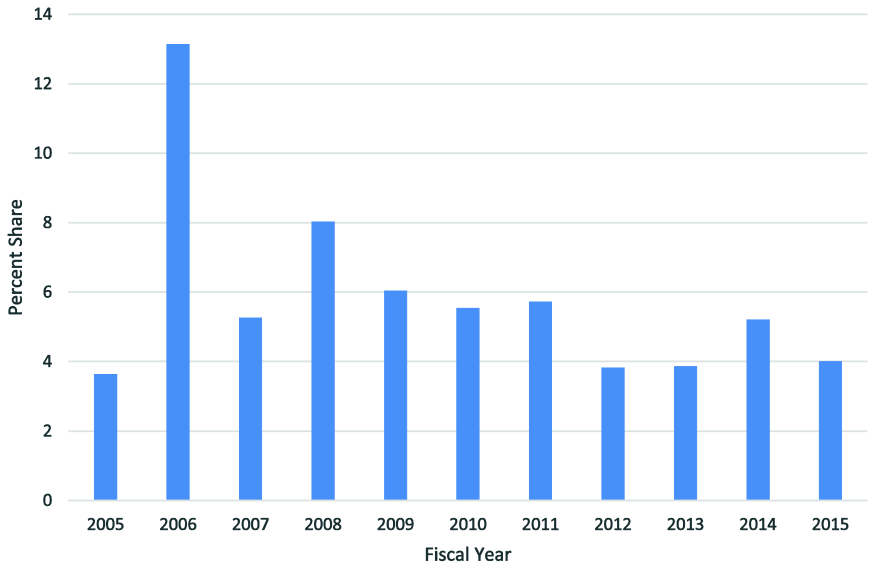

FIGURE 6-8 MOSB share of DoE Phase II applications, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

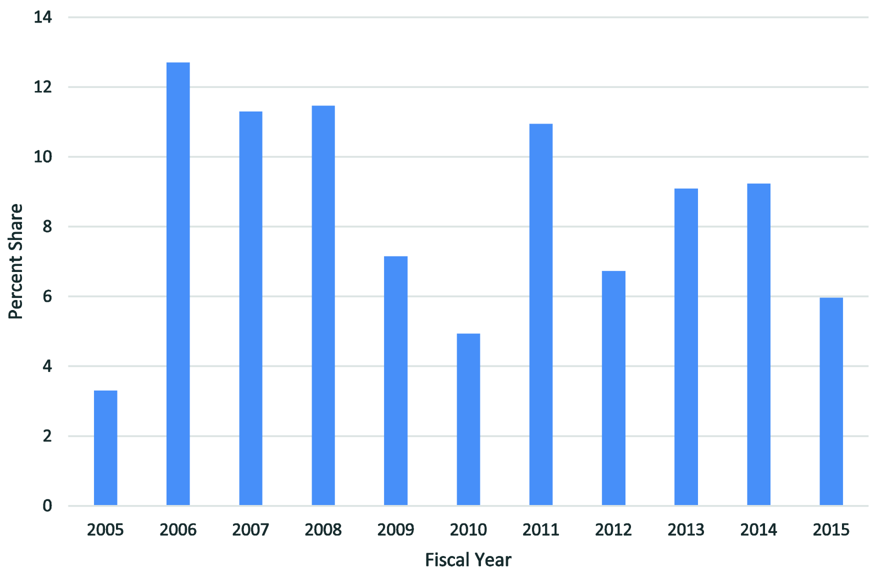

FIGURE 6-9 WOSB share of DoE SBIR/STTR Phase II awards, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

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MOSB shares of Phase II awards at DoE are very low, as shown in Figure 6-10. Except for FY 2006, MOSB shares reached 6 percent on only two occasions, and there were zero MOSB phase II awards in FY 2013. On average, MOSB accounted for 4.6 percent of all Phase II awards across the period.

Declining shares of awards are in part a function of relatively low success rates. As with Phase I, WOSB success rates for phase II applications have been consistently lower than those from firms that are neither woman- nor minority-owned. Figure 6-11 shows that except for FY 2007 and FY 2014, success rates for WOSB were lower than they were for firms that were neither woman- nor minority-owned. On average, during the period FY 2005-2015, WOSB success rates were 41.7 percent, compared to 48.8 percent for firms that were neither woman- nor minority-owned.

Relative Phase II success rates for MOSB were even lower, as shown in Figure 6-12. Overall, MOSB phase II success rates averaged 36.1 percent, against 48.8 percent for firms that were neither woman- nor minority-owned. MOSB success rates were lower than those of other firms in 8 of the 11 years shown.

The data provided by DoE show that the share of applications from WOSB and MOSB in particular have been declining across the period FY 2005-2015. On the face of it, this indicates that efforts to attract more disadvantaged applicants have not been successful.

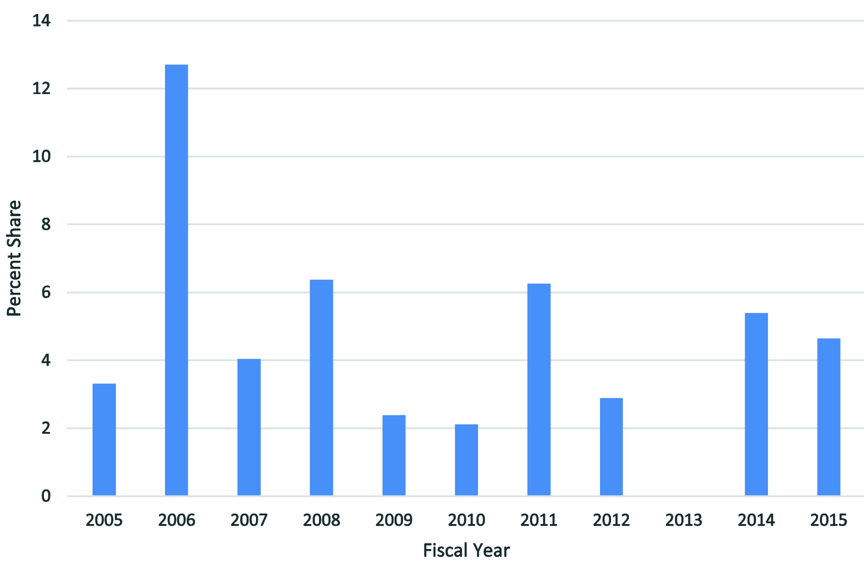

FIGURE 6-10 MOSB share of DoE SBIR/STTR Phase II awards, FY 2012-2015.
SOURCE: DoE SBIR/STTR Program Office.

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SBIR/STTR at the Department of Energy

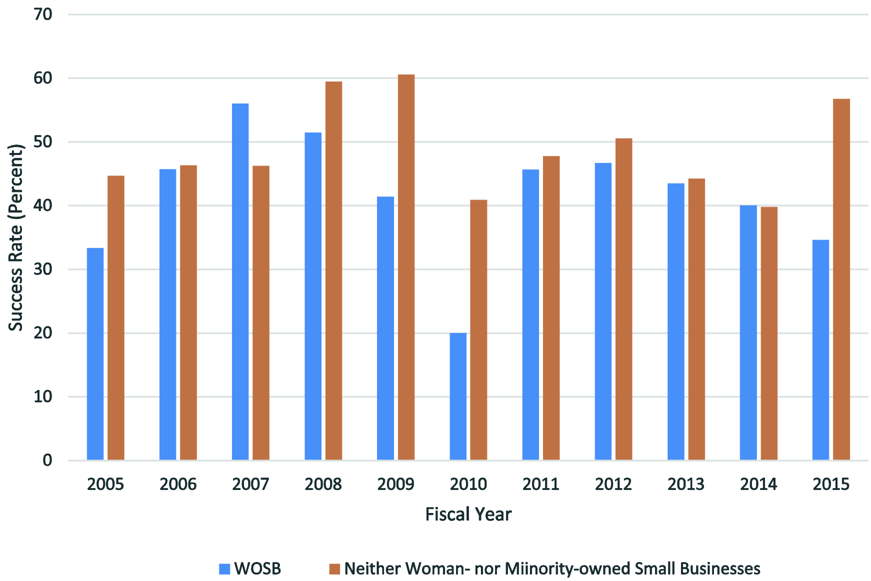

FIGURE 6-11 DoE SBIR/STTR Phase II application success rates for WOSBs and for firms that were neither woman- nor minority-owned, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

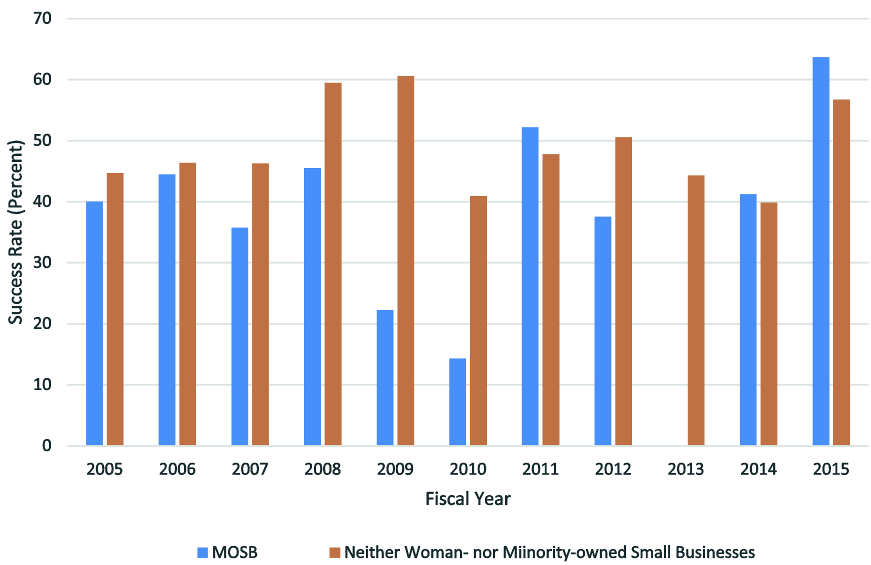

FIGURE 6-12 DoE SBIR/STTR Phase II application success rates for MOSBs and for firms that were neither woman- nor minority-owned, FY 2005-2015.
SOURCE: DoE SBIR/STTR Program Office.

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The data also show that—across the 11 years of data, across both WOSB and MOSB, and across both Phase I and Phase II—success rates for disadvantaged applicants are persistently lower than those for other applicants.

As a result, the share of awards being made to disadvantaged applicants has on the whole declined over the period for both MOSB and WOSB for Phase I and Phase II.

NATIONAL ACADEMIES SURVEY DATA

Company Ownership

Company ownership, by ethnicity and gender, was reported by respondents to the 2014 Survey and is shown in Table 6-4. Eight percent of responding companies indicated that the surveyed company was mostly owned by a member of a minority community at the time of the award. Probing more deeply into the ethnic distribution of minority company ownership provides further details. Most minority-owned companies reported that their owners were Asian-Indian or Asian-Pacific, but no Black-owned or American Indian-owned companies were reported. Only 9 percent of responding companies were woman-owned at the time of the award. The actual numbers of firms reflected in these data are very small.

Minority and Female PIs

However, the resulting data revealed that few female PIs and even fewer WOSBs were involved with the DoE SBIR/STTR program.

The survey effort carried out by the committee in its analysis of the SBIR and STTR programs is the first to its knowledge to expand the standard definitions of "socially and economically disadvantaged." Previous SBIR surveys from the National Research Council (NRC), and other organizations—and agency data itself—have sought to determine only whether the company is majority owned by members of socially and economically disadvantaged groups as defined by SBA. Because being a PI may be a stepping stone toward company ownership, the 2014 Survey gathered data on woman and minority participation in this role. As shown in Table 6-5, of the 255 respondents to the 2014 Survey, 14 percent indicated that the project's PI was from a socially or economically disadvantaged group. The survey also asked respondents to provide details about the PI's ethnic background. The ethnic groups were drawn from the SBA definitions, with the addition of an "other" category to ensure that all respondents who wished to claim minority status could do so. Among those respondents reporting a minority PI, 70 percent reported that the PI was Asian-Pacific or Asian-Indian, 19 percent reported that the PI was Hispanic, and zero percent indicated that the PI was Black or Native American. Women account for only 5 percent of SBIR PIs and 10 percent of STTR PIs.

As noted above, the actual numbers reflect in these data is very small.

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TABLE 6-4 Company Ownership, by Ethnicity and Gender, of Firms Receiving DoE SBIR/STTR Awards, Reported by 2014 Survey Responding Companies

	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
Woman-owned	9	9	13
Minority-owned	8	7	10
Asian Indian	5	5	3
Asian Pacific	1	1	0
Black	0	0	0
Hispanic	2	1	7
Native American	0	0	0
Neither woman- nor minority-owned	84	85	77
N (Number of Responding Companies)	127	112	15

SOURCE: 2014 Survey, Question 15.

TABLE 6-5 Principal Investigators for DoE SBIR/STTR Awardees, by Ethnicity and Gender, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Woman	6	5	10
Minority	11	11	10
Asian Indian	5	5	3
Asian Pacific	2	3	0
Black	0	0	0
Hispanic	2	1	7
Native American	0	0	0
Other	2	2	0
Neither a woman nor a minority	86	86	83
N (Number of Respondents)	255	22	30

SOURCE: 2014 Survey, Question 16.

DOE ACTIVITIES RELATED TO WOMEN AND MINORITIES

The DoE SBIR/STTR Program Office is well aware of the need to increase the participation of women and minorities and has taken some initial steps toward this goal. In 2013, it initiated an analysis of the potential pool of woman-owned businesses and minority-owned businesses that may be eligible to participate in the programs, utilizing several North American Industry Classification System (NAICS) codes to identify the population of firms undertaking science and engineering research. However, it became apparent that these codes captured too broad a population to serve as a benchmark for DoE

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because it included companies working far beyond the boundaries of the energy sector. DoE is now undertaking an innovative extension of this work, using NAICS codes identified by applicants through their System for Award Management (SAM) registration to develop clusters around specific six-digit codes. The Program Office expects that this approach will result in a much better defined benchmark, which, using Census and other data, will enable estimation of the percentage of WOSBs and MOSBs that might be eligible to participate in the DoE SBIR/STTR programs. If the analysis is effective, then this could provide an important benchmark against which to assess the agency's success in this area and would be a best practice for other agencies to use in setting similar benchmarks.

According to DoE staff, a major component of the agency's work to address under-served populations is the pilot Phase 0 program (see description in Chapter 3), introduced in the first release of FY 2015. Sixty-nine potential applicants received Phase 0 assistance in this initial pilot, and of these, about two-thirds applied for funding.

Outcomes for this pilot are provided in Table 6-6. Of the 69 participants in the Phase 0 program, 54 submitted letters of intent (LOIs) that were deemed responsive, and among these, 41 applied and 7 received funding. In contrast, six companies with unresponsive LOIs applied but none received funding. Of the 41 applications with LOIs that were deemed responsive, 12 were from WOSBs and 18 were from MOSBs. Four of the companies that received awards were located in underrepresented areas, and three were Asian American-owned. No funded company was woman-owned or Black-, Hispanic-, or Native American–owned. DoE program staff noted that through the Phase 0 program, the agency is beginning to establish a nationwide network of partnerships with more than 25 states and 12 national professional societies.[9]

What Might Be Done to Increase the Participation of Women and Minorities in SBIR/STTR?

There is a growing literature on participation rates of women and minorities in STEM-related activities and an ongoing national discussion about how to increase their rates of participation. It may be possible to draw from the body of work ideas on how specifically to increase participation of women and minorities in the SBIR/STTR programs.

A recent journal article,[10] for example, describes research results that show persistent gender bias in the field of geoscience. Men were found to have more mentoring, have better odds of being hired, be perceived as more

[9]Chris O'Gwinn, "DoE Phase 0 Review," presentation provided to National Academies, January 30, 2016.

[10]Christopher Intagliata, "Gender Influences Recommendations for Science Jobs," *Scientific American*, October 6, 2016.

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TABLE 6-6 Phase 0 Participation, Release 2, FY 2015

	Phase 0 Participation Data for Pilot (FY 2015 Phase I Solicitation, Release 2)		
	Number	Percent	
Total Number of Phase 0 Participants	69		
Responsive	54	78%	(of Total Participants)
Number of participants submitting applications	41	76%	(of Responsive)
No LOI Support	21	39%	(of Responsive)
Other Phase 0 Support	20	37%	(of Responsive)
Number that did not apply	13	24%	(of Responsive)
No LOI Support	2		
Other Phase 0 Support	12		
Unresponsive	15	22%	(of Total Participants)
Applied	6	40%	(of Unresponsive)
No LOI Support	3	20%	(of Unresponsive)
Other Phase 0 Support	3	20%	(of Unresponsive)
Did not apply	9	60%	(of Unresponsive)
No LOI Support	2		
Other Phase 0 Support	7		
Applied	47	68%	(of Total Participants)
Did not apply	22	32%	(of Total Participants)
Awards	7	10%	(of Total Participants)

SOURCE: DoE SBIR/STTR Program Office.

competent, and be more likely to receive excellent letters of recommendation and to receive higher starting salaries than women. This suggests a possible value in experimenting with gender-blind reviews of proposals in selecting who receives SBIR/STTR awards.

The review of national statistics on women and minority participation in STEM fields reported that women's participation was higher in some fields than in others (e.g., higher in psychology and biosciences than in engineering), and, within the field of engineering, higher in some areas of specialty than others (e.g., higher in systems engineering than in electrical engineering).[11] These areas of higher participation may offer opportunities for targeted topics development and related outreach by SBIR/STTR programs, allowing them to

[11]National Science Foundation, National Center for Science and Engineering Statistics, *Women, Minorities, and Persons with Disabilities in Science and Engineering 2015*, is a biennial report mandated by the Science and Engineering Equal Opportunities Act (Public Law 96-516).

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convey opportunities to potential applicants who are more likely to include women.

Mentoring is seen as another way to promote greater diversity in STEM careers. For example, an initiative called the "Million Women Mentors" (MWM)[12] was launched early in 2014 at the National Press Club in Washington. Its goal is to use mentorship to educate and empower women and girls to pursue careers in STEM. In addition to mentoring, the effort includes making face-to-face introductions of women and girls to those who can provide opportunities in the STEM sphere.

Similarly, experiments with mentoring may be tried in the SBIR/STTR environment. Perhaps incentives could be provided to SBIR/STTR grant winners to mentor women or minorities in the SBIR/STTR process in preparation for them to become future PIs or program applicants. Perhaps woman and minority owners of firms who have been successful in the past in being awarded SBIR/STTR grants could be mentor other woman and minority owners of technology-based firms to participate in the program.

The U.S. Library of Congress has compiled resources on the topic of women and minorities in science and technology. These include references to reports of the National Academies on the topic and provide many historical examples of women and minorities excelling in science and engineering, which may provide examples that can be used by agency planners of outreach activities.

Insights may also be gained from a new journal—*Journal of Women and Minorities in Science and Engineering*[13]—designed as a resource for educators, managers, and policymakers. The Journal publishes peer-reviewed papers that report innovative ideas, programs, concepts, and "reports from the field" related to increasing the participation of women and minorities in science and engineering, including engagement with federal and state agencies. For example, a recent article dealt with gender diversity from the perspective of developing a curriculum in engineering. Using a nationally representative survey of students from 121 engineering programs in 31 institutions, the analyses demonstrated differences in gender diversity across engineering disciplines—with programs in mechanical and electrical engineering being significantly less diverse by gender, and programs in biomedical/bioengineering, chemical, civil, and industrial engineering being more gender diverse. The research indicates that women are more drawn to disciplines that emphasize thinking from a broad, systems perspective that link across topics than disciplines with narrow perspectives. Again, this finding may be of value to planners of SBIR/STTR outreach in identifying university programs in which to pitch STTR outreach

[12]Katherine Beard, "Million Women Mentors Launched to Fill the Gap of Women in Stem Fields," *U.S. News*, January 9, 2014.

[13]*Journal of Women and Minorities in Science and Engineering,* Begell House; e.g., Knight (Virginia Tech), Lattuca (U of MI), Yin (Penn State), Kremer (Penn State), York (Penn State), and Ro (Penn State), 2012.

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activities. In addition, professors in woman- and minority-favored fields or authors of diversity studies may be helpful consultants in developing effective outreach for underserved populations.

An SBA study found that new firms in general and high-tech firms in particular have more difficulty getting financing from traditional sources than established, mature, non-high-tech firms.[14] This creates a capital problem exacerbated in firms owned by women and African Americans and Hispanics, causing them on average to utilize a different mix of equity and debt capital than do firms owned by others. The result is that they tend to be undercapitalized. Racial and gender disparities in capital access may cause these firms to be particularly vulnerable to delays and gaps in funding; they may have difficulty funding proposal preparation. Thus, participation of these companies in the SBIR/STTR programs raises the stakes of funding delays and gaps. These companies may be prime subjects for Phase 0 and complementary assistance from state and federal programs to help overcome added stresses of inadequate financing.

Surveys and case studies of woman- and minority-owned companies—including non-applicants and applicants who were successful and those who were not—offer a way to learn more about these underserved populations in order to better understand causes for the low and even declining rates of participation in the SBIR/STTR programs. Table 6-7 suggests metrics that could be collected from woman- and minority-owned firms, as well as all other firms, both applicants and non-applicants. The questions—still in draft form—are aimed at identifying perceived positive and negative factors that likely influence application rates.

The SBA Office of Women's Business Ownership (WBO),[15] whose mission is to enable and empower women entrepreneurs, may provide insights into obstacles facing women business owners and suggestions for more effective outreach, as well as direct assistance to would-be applicants. There are WBO centers located around the country. In addition, there are other state and local programs that assist small business entrepreneurs to develop business plans, find financing, and link to other resources.[16]

[14]Alicia Robb, Marin Consulting, LLC, *Access to Capital among Young Firms, Minority-owned Firms, Women-owned Firms, and High-tech Firms*, Small Business Administration Contract no. SBAHQ-11-M-0203, April 2013.

[15]See http://www.sba.gov/offices/headquarters/wbo.

[16]For an overview of the types of state services utilized, see Box 1-5. As noted in Chapter 1, a directory of state services is also maintained by SBA for applicants to use in finding local assistance with business planning, matching funds programs, and other startup activities—with contact information, web links, brief descriptions, and an interactive map—and is accessible via the home page of the SBIR-STTR website, http://sbir.gov/.

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TABLE 6-7 Illustrative Metrics on Underserved Populations

Metrics (Choose A or B)	WOSB (# / /%)	MOSB (# / /%)	Other (# / /%)
A. Non-Applicant			
• Did not know of SBIR/STTR?			
1. Expect to apply in the future?			
2. If not, why not?			
• Knew of Program but did not apply			
Reason: ______________________			
1. Expect to apply in the future			
2. Expect not to apply in the future			
Reason: _________________________			
• From the attached list of Program features, identify the top 3 that cause you to want to apply to the program.			
• From the attached list of Program features, identify any that cause you not to want to apply to the program.			
• If you could change one thing about the program what would it be?			
B. Applicant—Received award Yes/No?			
• From the attached list of Program features, identify the top 3 that caused you to apply to the program.			
• From the attached list of Program features, identify any that cause you not to apply to the program.			
• Do you think your application was treated fairly? Yes No			
• If No, what about the application process do you think was unfair? Describe:____			
• Do you expect to apply again in the future?			
• If not, why not?			
• If you could change one thing about the program, what would it be?			
• Company Attributes Location, founding date, size, other			

SUMMARY

The National Academies' 2014 Survey of SBIR/STTR awardees enabled for the first time a disaggregation of participants by minority status, in addition to the disaggregation by sex. In addition, it compiled data on PIs, as well as business ownership.

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Data from the 2014 Survey show that participation by woman and minorities to the SBIR/STTR program is low and not expanding. The committee considered and rejected the idea of quotas as a way to increase the participation of women and minorities and encouraged DoE to look for alternative approaches.

Multiple opportunities are identified for DoE to expand its efforts to increase participation by women and minorities in the SBIR/STTR programs. DoE efforts to expand participation in the SBIR/STTR by women and minorities are seen as a small but important element of a broader national imperative.

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7

Insights from Case Studies and Survey Responses

This chapter reviews a range of impacts of the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs based on written responses to open-ended questions solicited in the 2014 Survey and interviews with executives for the case studies. The survey process is described in Appendix A, and the survey instrument is provided in Appendix C. Data from the survey are used to support analysis throughout the report; this chapter draws from the written, open-ended responses to survey questions. These responses can be divided into views about the concept and advantages of the SBIR and STTR programs, where the comments were generally positive, and those on the operation of the program, where the comments were often more critical. Box 7-1 lists the case study firms, all of which were DoE SBIR and/or STTR award winners. Full case studies, carried out in 2015-2016, can be found in Appendix E.

A wide range of companies were selected for case studies. They varied in size from fewer than 5 to more than 100 employees. They operated in a wide range of technical disciplines and industrial sectors. Some firms focused solely on serving the national labs, while others focused on commercialization through the private sector. Overall, this portfolio sought to capture many of the types of companies that participate in the SBIR/STTR programs.

The 12 case study participants all represent Phase I and Phase II SBIR or STTR winners. Among these, ony two—Diversified Technologies and Woodruff Scientific—have not received STTR awards. Some, most notably Creare and Physical Sciences, have won many awards over a number of years. Creare has won 959 SBIR/STTR awards since 1985 and Physical Sciences 1,108 SBIR/STTR awards since 1983. Six companies have won fewer than 100 awards each, the fewest represented by Woodruff Scientific, which has won 3 SBIR Phase I and 3 SBIR Phase II awards. Two case studies covered

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firms that were profiled in the 2009 National Research Council[1] assessment of the DoE SBIR Program (See Box 7-2).[2]

Companies selected for case studies are not intended to be statistically representative of DoE SBIR/STTR award winners or their award outcomes. Although the number of case studies completed as part of this study is limited, case studies of selected firms can offer qualitative evidence about experiences with the program of firms that have achieved some success and may have acquired some insights regarding how the SBIR/STTR programs, particular aspects of the programs, or the manner in which the company utilized the programs may have contributed to that success. Interviewees were also asked to raise any problems and provide their own recommendations about how the programs could be improved. Future research could benefit from a broader base of case study companies, including less successful companies, whose responses could provide a useful comparison.

This qualitative review provides needed context for the data discussed in Chapter 5 and aids understanding of the perspectives of award recipients as well as those who did not receive Phase II funding for what they considered to be a highly promising project.

BOX 7-1
Companies Profiled in Case Studies

The following companies, all winners of DoE SBIR and/or STTR awards, are profiled in case studies in Appendix E:

- Adelphi Technology, Inc.
- Calabazas Creek Research, Inc.
- Compact Membrane Systems, Inc.
- Creare, Inc.
- Diversified Technologies, Inc.
- LI-COR Biosciences, Inc.
- Muons Inc.
- NanoSonic, Inc.
- Physical Sciences, Inc.
- Vista Clara, Inc.
- Woodruff Scientific Incorporated
- XIA, LLC

[1]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council, or NRC, are used in an historic context identifying programs prior to July 1, 2015.
[2]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2009.

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BOX 7-2
Case Study Companies Revisited: Creare and Physical Sciences

Of the 12 case studies in this volume two were among those profiled in the 2009 National Research Council[a] assessment of the SBIR Program at the Department of Energy.[b]

Both Creare and Physical Sciences have adapted to enhanced commercialization requirements within the DoE SBIR program. Creare's traditional focus on research was clear: a senior staffer observed that "what a product business needs isn't what an R&D business needs." More recently, Creare has focused on ensuring that it seeks funding only for projects that have a clear transition/commercialization path. It is also working to develop a batch production capability to fill the gap between technology it licenses out and hand produced solutions to address specific agency problems. The PSI case study was for DoD so sheds relatively little light on the DoE program. In general, commercialization through spin-outs and subsidiaries has not been very successful for PSI, but some licensing deals have been much more so, and generate $1 million annually in revenues for the company. Both companies observed that SBIR/STTR programs had become both more competitive and more bureaucratic.

[a] Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council, or NRC, are used in an historic context identifying programs prior to July 1, 2015.
[b] National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2009.

The chapter summarizes case study and survey data regarding program impacts and management issues. Views summarized do not necessarily reflect the views of the committee. The chapter is organized into three main sections:

1. Outcomes and Company Impacts
2. Program Management
3. STTR

The material in this chapter provides the first wide-ranging publicly available feedback of the DoE SBIR/STTR programs from program recipients.

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SBIR/STTR at the Department of Energy

OUTCOMES

This section focuses on outcomes related to commercialization and knowledge effects and on the ways in which SBIR/STTR supports the growth of an expanding ecosystem of innovative companies in energy-related fields.

In general, the case studies support the view that the programs are meeting their Congressional objectives except for encouraging the participation of women and minorities.

Commercialization

Discussions with company executives suggest that the perspective on commercialization has recently and substantially changed, for companies and for DoE itself. Dr. Rozzi (Creare) observed that in the 1980s the DoE SBIR/STTR programs primarily focused on research. Topic Managers (TMs) supported favorite technology projects, generally without a clear path to transition, which usually resulted in little commercial return. Company executives noted, and DoE staff confirmed, that topics have become more commercially oriented within the past 10 years. More recently, DoE has extended its requirements for Phase I and Phase III applications, placing more pressure on companies to have a well-defined commercialization plan in place, and companies have begun to view SBIR/STTR through a more commercial lens.

However, as discussed in Chapter 2, the DoE topic development process still does not align tightly with the drive for improved commercial outcomes, and significant disconnects exist between the SBIR program and downstream opportunities that might be available within DoE.

Commercial Results

Progress toward commercialization is primarily analyzed in Chapter 5, which focuses on results from the 2014 Survey. However, even though the information about private companies is limited, it is apparent that some DoE SBIR/STTR awardees are generating substantial income from Phase III and beyond. For example, according to the Hoovers/Dun & Bradstreet database, LI-COR generates more than $100 million annually, with an additional $14.8 million from its pair of European subsidiaries.[3] Dr. Rozzi noted that nearly 40 percent of Creare's total revenues are derived from Phase

[3]"Li-Cor, Inc. Revenue and Financial Data," http://www.hoovers.com/company-information/cs/company-profile.Li-Cor_Inc.b4245b76644713ab.html; "LI-COR BIOSCIENCES UK LTD Revenue and Financial Data," http://www.hoovers.com/company-information/cs/revenue-financial.LI-COR_BIOSCIENCES_UK_LTD.650c82d750559ca4.html; "LI-COR Biosciences GmbH Revenue and Financial Data," http://www.hoovers.com/company-information/cs/revenue-financial.LI-COR_Biosciences_GmbH.69ff7789c35f7144.html. Hoover does not report a year; revenue is assumed for 2014.

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III commercialization activities related to past SBIR/STTR projects. Other case study companies report substantial commercial results. However, neither through the survey nor the case studies was the committee able to identify a "home run": LI-COR is the most commercially successful DoE SBIR/STTR company reviewed for this assessment. Program outcomes are addressed in more detail in Chapter 5.

Spinouts

Some of the case study companies (notably Creare and Physical Sciences [PSI]) use spinouts as a primary mechanism for commercializing technology. Creare has spun out 10 companies in its history. These include the leading suppliers of plasma-based metal-cutting systems, Hypertherm, and of computational fluid dynamics software, Fluent, which was acquired for a substantial price by ANSYS in 2006. Although Creare remains a small company, these companies have generated more than 2,000 jobs and $500 million in revenues annually, according to Creare.[4]

The most recent Creare spinout is Edare, which provides manufacturing and product development services intended to transition innovative technologies into low- and medium-volume production. The Edare model centers on having two or three programs in production at any one time, providing low- to medium-volume manufacturing for government clients (although some commercial clients are anticipated). This low-volume production may be the end of the transition path for some products, but may also be an important way station on the path to larger volume sales or a licensing agreement once the technology is fully developed and the manufacturing processes rolled out. Dr. Rozzi observed that it is a good model for producing 30 to 50 units, which is a difficult level to achieve in a research and development (R&D) environment. (See Table 7-1.)

Physical Sciences, Inc. (PSI) subsidiaries tend to replicate the R&D culture of the parent company (many publications in peer-reviewed journals, use of SBIR funding), to focus on a limited (but stable) commercial opportunity, and to perform prototyping and low volume manufacturing.

In addition to establishing subsidiaries, PSI has spun out technologies into new companies. According to Dr. Green, the CEO of PSI, spinouts typically depend on venture backing and follow business models that target larger commercial markets with associated needs for product development,

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[4] "Cryogenic Machining Technology," http://www.gearsolutions.com/news/detail/7168/cryogenic-machining-technology-from-mag; Jay Rozzi, "Cryogenic Machining Background and Application to Shipbuilding," NSRP All Panel Meeting, October 2011, http://www.nsrp.org/6-Presentations/Joint/100411_Cryogenic_Machining_Background_and_Application_to_Shipbuilding_Rozzi.pdf, p. 4.

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TABLE 7-1 Creare Spinouts

Company	Year	Spun Out
Hypertherm	1968	Hypertherm was founded to commercialize plasma cutting technology developed at Creare. Still headquartered in New Hampshire, Hypertherm is now the world's largest manufacturer of plasma cutting tools.
Creonics	1982	Creonics develops and manufactures motion control systems for industrial processes. Acquired by Allen-Bradley in 1990, Creonics is now part of Rockwell International.
Spectra	1984	Spectra is a manufacturer of high speed ink jet print heads and ink deposition systems. Formed around a sophisticated deposition technology developed at Creare, Spectra was acquired by Fujifilm in 2006 and renamed Fujifilm Dimatix.
Fluent	1988	Based on Creare's longstanding expertise in computational fluid dynamics, Fluent began marketing comprehensive computational fluid dynamics software. In 2006 ANSYS Inc. acquired Fluent for $565 million.
Mikros	1991	Based on Creare's advanced electric discharge machining technology, Mikros offers precision micro-machining services.
Verax Biomedical	1999	Verax was founded to commercialize technology to detect bacterial contamination of cells and tissues intended for transfusion and transplantation. They have received seven rounds totaling $28.2 million in venture funding.
Edare	2011	Edare provides manufacturing and product development services intended to transition innovative technologies into low- and medium-volume production.

SOURCE: Creare.

manufacturing, logistics, and sales and marketing. Typically, these technologies have presented the opportunity for selling products to mass markets. PSI may take an equity stake in the company, but most of the funding comes from the venture community.

Dr. Green said that intellectual property (IP) and staff usually go with the spin-out. None of the spinouts has been highly successful, and many of the staff have returned to PSI. One spinout still exists but has been sold three times.

Knowledge Effects

The DoE SBIR/STTR programs have supported the development of numerous innovative technologies. Each of the case study companies has developed technologies that introduced new capabilities to the marketplace. Some companies have developed important, industry-leading technologies. For example:

- LI-COR's methane monitoring tools are a global leader, with more than 30,000 units sold.

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- NanoSonic leads the industry in anti-corrosion coatings.
- PSI uses tunable diode laser absorption technology, among others, to develop low-cost, high-volume applications such as natural gas leak detection and greenhouse gas monitoring.
- XIA supplies advanced digital spectrometers for x-ray, gamma-ray, and other radiation detector applications to research universities, National Laboratories, and industry.
- Vista Clara develops nuclear magnetic resonance instrumentation that delivers quantitative imaging of subsurface hydrogeologic structure.
- Adelphi Technologies produces a range of high-energy neutron sources for industrial and research applications.

These knowledge effects are also reflected in survey responses (see Box 7-3) and in the sometimes intensive use of patenting to protect SBIR-derived IP. For example, LI-COR is the assignee for 89 patents published between 1981 and 2015, according to the U.S. Patent and Trademark Office.

Innovative Technologies and Product Development

For the majority of recipients, the SBIR/STTR programs support work on their core technology. At least initially, few companies are large enough to advance multiple technologies simultaneously, although some companies are working on platform technologies that can be further developed into products that share a core technology. Over time, companies may grow to the point that they can support multiple projects but are still small enough to qualify for SBIR funding, which can then be used more selectively.

Many of the survey respondents and case study executives noted that the SBIR/STTR programs have provided critical support in developing core innovations and platform technologies (see Box 7-4). There is evidence that for smaller companies in the energy sector, funding for unproven core technologies is difficult to acquire outside of the SBIR-STTR programs. According to the PWC MoneyTree survey of venture investments, the number of seed-stage venture capital investments has declined steadily over the past decade, and in the second quarter of 2016, the industrial/energy section accounted for 3 percent of the total venture capital investment in all industries.[5] For 2015, the Center for Venture Research reported that 11 percent of angel funding deals were in the industrial/energy sector.[6] The Center

[5]PWC Moneytree Survey, https://www.pwcmoneytree.com.
[6]Jeffrey Sohl, "The Angel Investor Market in 2015: A Buyers' Market," Center for Venture Research, May 25, 2015.

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BOX 7-3
Survey Responses on Knowledge Effects

With support from the SBIR/STTR Programs:

- "[Our company] developed a much-needed ceramic insulation product that enables researchers building fusion devices to insulate, wind and react the very fragile superconducting wire, thus significantly reducing the risk of damage to the superconductor after heat treatment."
- "[Our company] was acquired by [a major corporation] for the technology developed primarily by the SBIR/STTR program. This technology is part of several products now serving researchers worldwide."
- "SBIR funding enabled development of a technology that no other program or private investor supports. In our case it is a development of an airborne sensor for environmental observations."

BOX 7-4
Survey Responses on Innovation Impacts

- "[W]ithout SBIRs, an entire class of breakthrough-focused R&D would not happen in the U.S. and neither would the strong leveraging of that R&D into new hardware high tech products. Hardware especially is hard to develop with private equity/VC approaches; the desired time scales are too short."
- "The SBIR program provided the critical funding to evaluate and attempt to develop an innovative technology that had the potential to simultaneously reduce green house gas emissions and generate methane from deep coal beds."
- "In the early days DoE funding helped [the company] to develop the technology in the new lighting arena by encouraging technology innovation and overcoming the financial risk associated with this."

also reported that the share of funding devoted to the seed stage declined sharply from 46 percent in 2013 to 25 percent in 2014.[7] In 2015 there was a 1.9 percent increase in the amount of investments.[8]

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[7]Jeffrey Sohl, "The Angel Investor Market in 2014: A Market Correction in Deal Size," Center for Venture Research, May 14, 2015.
[8]Jeffrey Sohl, "The Angel Investor Market in 2015: A Buyers' Market."

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Connecting to Research Institutions

Although the STTR program is specifically designed to connect small companies to research institutions (RIs), this objective is also accomplished to a considerable degree by the SBIR program. Survey data are provided in Chapter 5, but case study meetings and survey comments underscored the closeness of the connection for many companies. For example, XIA maintains research relationships with a broad range of academic, government, and corporate entities such as University of California, Davis, University of Texas at Austin, Michigan State University, Pacific Northwest National Laboratory, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Institute for Nuclear Physics (Germany), Radiation Protection Bureau, Health Canada, Alameda Applied Science Corporation, and IBM.

Multiple relationships exist for a number of SBIR/STTR firms, especially those that have grown over the years.

- Creare has strong relationships with machine equipment companies such as KMT, MAG IAS, Fives, Harris Aerostructures, Saint-Gobain, Guhring, Iscar, AMETEK/Precitech, and many others.
- NanoSonic reports good relationships with at least eight universities and effective partnerships with Colorado State University, the Naval Postgrad School, and the University of Arizona.
- In addition to the National Laboratories, Muons has partnered with eight universities: Cornell University, University of Chicago, Florida State University, Hampton University, Illinois Institute of Technology, North Carolina State University, Northern Illinois University, and Old Dominion University.

None of the case study companies focused exclusively on STTR. Those that partnered with RIs using STTR also partnered with those RIs, but on different terms, using SBIR.

Leverage Effects

Many DoE companies develop tools and instrumentation that are used primarily or exclusively by researchers to great effect. The enabling, though indirect effects, are in many cases substantial and represent an important way that knowledge generated through SBIR is leveraged to gain wider currency in the scientific community.

SBIR/STTR companies that serve the research community provide products and services rarely at the scale needed for a direct large commercial success. Nonetheless, they can be of enormous importance to the innovation ecosystem as whole, providing resources that others use to address large-scale problems. A few examples include the following:

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- Dr. McDermitt (LI-COR) estimated that greater than 80 percent of the measurements of the carbon balance of agricultural and natural ecosystems have been made using LI-COR instruments, noting that "much of what we now know about how climate change might influence ecosystems comes from data provided by these instruments; it's made all this scientific work possible."
- Calabazas Creek Research provides instruments to several of the National Laboratories.
- XIA's gas technology enables core functions for the massive Stanford Linear Accelerator Center (SLAC) accelerator (as well as others).
- Creare and PSI have provided numerous bespoke tools and technologies to the research community.
- Vista Clara's hydrological tools enable detailed mapping of declining water resources.

COMPANY IMPACTS

For many small companies—especially those that receive SBIR or STTR funding early in their history—receiving an award (especially Phase II) can be a highly positive or transformative experience. One-third of the respondents to the 2014 Survey indicated that program funding transformed the company. Appendix E details how SBIR/STTR funding affected the trajectory of development for each of the 12 companies studied. This section describes some of these impacts.

In general terms, the 12 case study companies described how SBIR funding made an especially significant difference early in the company's existence. For example, Dr. Warburton said that SBIR/STTR funds were critical to XIA's founding and growth because funds were not available from other sources. Mr. Nemser said that the SBIR program was not only CMS's first funding source, but also, in subsequent years, the only funding source that supported exploration of a range of possible applications for its technology.

Many of the 2014 Survey respondents stated quite bluntly that the company would not be in existence without the SBIR program (see Box 7-5). As expected, many of these respondents were from very small companies with limited access to alternative funding, at the time of award and at the time of the survey. However, several respondents were from companies that had moved far beyond the SBIR program.

Profiles of individual companies provide a more nuanced view and illustrate both the difficulties of raising very early funding and the critical role of the SBIR program in filling this gap. Many of the case study companies and a considerable number of survey respondents described major difficulties in raising funds before their products reached the market. For many companies, the road to a successful product is long and expensive. Private

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BOX 7-5
Survey Responses on Company Existence and Funding

- "SBIR funding fills a niche for advanced research funding that cannot be filled by other sources, such as Venture Capital."
- "Our core technology needed SBIR funds to gain a critical momentum to be recognized as a viable production level capability. These funds cannot be procured using the channels for basic research or venture capital."
- "A great deal of the tool and technology development done here would not have occurred without SBIR funding. The whole company grew and evolved because of this funding."
- "SBIR funding enabled development of a technology that no other program or private investor supports. In our case it is a development of an airborne sensor for environmental observations."
- "The SBIR program is unique in that it supports technology development that would otherwise not be funded as it falls between the cracks of traditional investment. But the payoff to society could be huge."

investors are often reluctant to assume the risks involved, which can be substantial even for companies that raise significant outside funding. The SBIR/STTR programs were designed to fill some of this gap, by providing funding that can be used to validate and demonstrate products.

The SBIR/STTR programs also assist in company formation because seed funding is also difficult to find. Venture capital firms have exhibited an increasing preference for supporting more established companies and technologies. The case studies (and survey responses) underscored the many types of projects for which alternative funding sources are scarce.

Companies also pointed out that the SBIR program plays a special role in funding projects that do not align well with commercial imperatives facing some large markets and the need for relatively quick returns.

Validation Effects

Often, the SBIR/STTR programs provide a unique mix of validation and funding for the acquisition of preliminary data needed to persuade potential partners that the technology has value, the management team is competent, and the company is sufficiently stable to partner with it.

The DoE SBIR program provides sufficient funding for product development in only some circumstances. However, case studies and survey responses illuminated the ways in which SBIR/STTR awards can provide the

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technological and commercial validation that underpins acquisition of funds from other sources (see Box 7-6). In particular, companies stressed that the SBIR program can provide the necessary confidence that peer review provides, while the provision of non-dilutive funding sets the stage for successful efforts to raise funds in the private sector.

It is apparent from both case study meetings and survey responses that, through the SBIR/STTR programs, DoE in effect performs important due diligence on behalf of subsequent investors and customers. The peer review provides a technical assessment that even a well-established venture capital firm would be hard pressed to match, making the investment less risky.

Niche Markets

Innovative companies, especially small innovative companies, are often driven at least initially by the passion of the founder or founders to make a difference. What they often find is a substantial gap between technical success and commercial success, and between meeting the needs of the technology users and creating a sustainable or successful business.

This is especially true when the market being served is small either in numbers or resources. Outside (and particularly venture capital)

BOX 7-6
Survey Responses on Validation Effects

- "Having our science vetted by DoE Peer Review was invaluable at getting [a major prime contractor] to adopt the technology and packaging approach."
- "It brings legitimacy when we talk to potential strategic partners. Success at obtaining SBIR funding reduces the amount of time the PI would spend finding other funding and increases the amount of time she can spend on marketing and finding strategic partners."
- "Overall SBIR funding has allowed us to attract support from private companies through licenses, sales of technology and contract research."
- "Phase I and II funding not only provided critical financial support for our company, it was also an important achievement from the perspective of our private investors."
- "Successfully obtaining SBIR/STTR Phase I and II awards has lent credibility to the technology being developed. Third parties view the company as technically qualified and at the same time as having demonstrated the discipline and business sense to achieve their (intermediate) goals successfully. It is thus a big plus both financially and from a business development point of view."

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investors are often less interested in investing when markets are small and lower revenues make it less likely that the product will eventually generate significant commercial returns.

Many of the case study companies address the needs of highly specialized markets. For example, Woodruff Scientific focuses on fusion, and Calabazas Creek and Muons focus on high-energy physics.

The products that these companies provide can have an enormous leverage effect. For example, some of XIA's technologies are necessary for the effective operation of projects run at SLAC and other accelerators. Even though the market is small, the $500 million annual investment in these projects requires XIA technologies to run effectively.

Long Cycle/High Risk

The SBIR/STTR programs also help companies to develop products and capabilities that require a longer research cycle than can be sustained with private funding. Most venture investors expect to see products succeed or fail within a few years, but some technologies take much longer to reach the market. Mr. Nemser (CMS) observed that DoE topics support longer sequences of work that develop platform technologies that permit a range of applications. A survey respondent explained:

> *I have chosen to pursue challenging and long-range technologies and hence might appear to have limited commercial success (when compared to other small businesses engaged in more rapidly commercialized technologies such as medical devices, software etc.). But developments in High Energy Physics are also useful to society, but on a longer time scale.*

Several survey respondents stated that little funding is available for long-cycle or high-risk research aside from SBIR. One respondent wrote:

> *The SBIR/STTR program is effectively the only significant early stage non-dilutive funding source for long incubation time, high risk, high payoff technologies, such as advanced materials and manufacturing technologies, that could not be developed or commercialized by private enterprise without the program.*

Another respondent explained that SBIR complements rather than replaces venture funding:

> *If a technology can be developed in a few years to reach a significant market, then private investors will probably find a way to fund it. Thus, the SBIR program should probably have a spottier record than a VC firm, judged on return on investment.*

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The potential long time to reach market presents a challenge in cutting-edge research.

Several of the case study company founders have been working on their projects for more than 20 years, and some have not yet reached scale in the market. Long-cycle research is difficult because revenues are delayed as costs mount. The core funders of advanced research besides the government (strategic partners and venture capital investors) are increasingly reluctant to fund projects that are not well along the path to market.

The DoE SBIR/STTR programs therefore support the early development of technologies that may have substantial social or even commercial value downstream, but which are too far from the market to attract other funding sources (see Box 7-7).

Platform Technologies

SBIR/STTR funding also supports the development of platform technologies (that is, technologies that can provide the basis for multiple products in different markets). Venture investors typically prefer companies to focus on a single technology for a single market, because the pursuit of multiple objectives could lead to loss of focus and eventual failure. However, platform technologies can provide the basis for work in a range of applications—many of which can be successful. For example, since successful

BOX 7-7
Survey Responses on Long-Cycle Research

- "[SBIR] provided dedicated funding to basic engineering work that would otherwise be unfunded, as there was no near term return expected."
- "Since the lead times for acceptance of our products into the research community are quite long, this particular Phase II has not yet had much impact. However, going back over the years, all of the technologies that currently support the company had a major fraction of their initial development through SBIR funding."
- "We were able to conduct research that would have taken longer to start and complete and certainly would not have allowed us to collaborate with a University as we did on this project."
- "SBIR/STTR funds allowed for a slow developing market place to catch up to the technical developments. If funding had been provided through the private sector the likelihood is that [our company] would not have been allowed to be patient for the markets to fully develop."

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development of its core SBIR/STTR-funded technology, Diversified Technology Inc. (DTI) has built applications for radar, high-energy physics, and food and wastewater processing. In 1998, DTI received SBIR funding from the Navy for an advanced radar system. In 1999, DTI received multiple Phase I and subsequent Phase II awards to assist the Stanford Linear Accelerator Center in adopting solid state switches and sources. In 2003, SBIR funding from the Environmental Protection Agency allowed DIT to investigate the application of Pulsed Electric Field (PEF) processing to waste water treatment.[9]

Hiring and Staffing

Retention of high-quality technical staff is a perennial challenge for small innovative businesses. Such businesses are challenged by the long period between the start of research and the deployment of a product in the market. Because the company is not earning revenue during this period, it must seek other funding sources, which places it at risk of losing key staff if funding gaps occur. A long gap can mean the elimination of key staff who may not be available if funding resumes.

The SBIR/STTR programs improve the certainty of funding over at least a 2-year period (for Phase II), which provides small businesses with the confidence and means to hire and retain staff (see Box 7-8.)

BOX 7-8
Survey Responses on Hiring and Staffing

Funding from SBIR/STTR:

- "allowed me to hire high qualified staff."
- "Allowed additional staff to help with the project. Able to train new staff for additional skills and provide knowledge for future work."
- "Allowed us to support more staff and learn new skills that are used in other programs."
- "allowed us to retain highly technical and experienced staff."
- "creates good, advanced employment for young scientists and provides the company with a valuable resource to build our expertise."

[9]Floyd Arntz et al., "New Concepts for Pulsed Power Modulators: Implementing a High Voltage Solid-State Marx Modulator," http://www.divtecs.com/data/File/papers/PDF/ILC_Long_Pulse_Marx.pdf; "Advanced Solid State High Repetition Rate Modulator," 1998, https://www.sbir.gov/sbirsearch/detail/147844; "Wastewater Treatment by Pulsed Electric Field Processing," 2003, https://www.sbir.gov/sbirsearch/detail/147910.

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PROGRAM MANAGEMENT

In general, the feedback on program management is positive: participants report that the DoE program is run efficiently, is reasonably transparent, provides solid technical feedback to applicants, and offers a useful array of supports at different stages. In particularly, they note that contract and award management is good, and topic managers are available when needed. Many of the case study meetings were with scientists and executives who work with other agencies and therefore could provide a comparative perspective.

For example, Dr. McDermitt (LI-COR) found the DoE SBIR program to be managed effectively. He said that the proposal process was clear, the letter of intent process was not too burdensome, and, aside from the enforced no-contact during the application process, the project managers were readily available for discussion. The administration of grants and the necessary level of documentation were reasonable and workable. Overall, he considered the DoE SBIR program to be a good program with which to work.

Dr. Johnson (Muons) agreed that the DoE STTR/SBIR programs are well managed. Recent changes, such as the introduction of letters of intent to allow for timely reviewer selection and the well-designed timeline on the agency website, he said, were welcome improvements.

Two major concerns emerged from these discussions. First, topics are often not aligned with the enhanced commercial thrust of the program, which may be channeling applications too tightly into a framework that favors some types of commercialization over breakthrough technologies. Second, the program is disconnected from the rest of DoE and offers no pathway to possible commercial opportunities within or related to the agency. These concerns are discussed in more detail in the relevant sections below.

Applications

The 2011 congressional reauthorization has resulted in more reporting and a more complex application process for companies, observe many survey respondents and case study firms. The amount of effort required to submit a proposal has, according to Dr. Green, more or less doubled even for a highly experienced company such as PSI. In his opinion, this represents a major barrier to entry into the program. Dr. Green noted that the 200-page SBIR/STTR instructions on grants.gov may partially explain why the number of applications is declining. Every SBIR/STTR proposal requires PSI to upload 10-30 different sections. One survey respondent said, “Given this situation and the excessive time required to keep current with all these sub-agencies, our company is becoming less and less enthusiastic in participating in the SBIR/STTR program.”

Dr. Green also noted that dealing with the government has generally become more difficult. Numerous forms and statements related to fraud and

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abuse are now required: companies must provide documentation for every piece of equipment it plans to buy and must prove that it is actually paying everyone that it planned to pay.

A survey respondent made a similar point:

> *The SBIR/STTR Phase I and Phase II proposal process has become increasingly cumbersome and difficult. To submit a Phase I or Phase II proposal, and subsequently do business with the federal government, a company must be registered with ASAP, grants.gov, FedConnect, FSRS, PAMs, SAM, SBA, etc., and further interact with the agency contracting/grants officers. Every year adds more levels of bureaucracy to participate in the SBIR/STTR program.*

Another respondent said,

> *The application procedure is very complicated and replete with opportunity for mistakes and missed deadlines. The myriad of government websites that are part of the process are overbearing and difficult to understand...It is almost as if Grants.gov was designed to obfuscate and complicate the application process.*

Finally, another respondent concluded,

> *The cost of preparing a proposal compared to the probability of receiving an award has become quite high.*

These issues may also help to explain why the numbers of SBIR/STTR applications have been declining across all agencies.

Dr. Gary (Adelphi) noted that agencies that provide more than one funding deadline annually, such as the Department of Defense and the National Institutes of Health, were better attuned to the speed of technical development, and suggested that DoE should consider adding at least one additional funding deadline annually.

Topics

Topics were the single area of greatest concern for the companies interviewed for this report.

- Noncommercial topics. Several companies said that some DoE topics are clearly designed to address specific technical needs of the topic manager and have little commercialization potential.
- Unfunded topics. Some companies observed that DoE wastes company time and resources when it seeks applications for topics that are not funded and suggested that DoE should focus its energies on topics that will be funded.

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- Topic development. Some companies noted that the topic development process is quite opaque to outsiders.

Dr. Gary (Adelphi) observed that DoE SBIR/STTR topics are in some cases clearly derived from the science-oriented interests of topic managers, while others also reflect a commercial interest. Adelphi initially won a series of more science-oriented awards but as a result of increasing internal focus on commercialization has become more selective about the topics to which it applies. However, some of its recent awards for neutron optics were in topics that showed limited commercial potential given market realities for that technology. A survey respondent made a similar point:

> *SBIR topics in DoE and DoD have become extremely focused on narrow agency programs and yet demand substantial commercialization potential without the realization that their focused topics have no substantial commercial potential outside of the specific agency needs.*

Dr. Gary also expressed concern that some topics are simply not funded. He believed that DoE should not publish topics with no record of funding. One survey respondent noted,

> *[T]he agency asks for a specific topic, we suggest a solution, we receive enthusiastic reviews from reviewers, but not funding. Somewhere in the process there is a disconnect between the author of the topic and funding sources.*

In addition, Dr. Gary said that the topic development process at DoE is quite opaque, and he suspects that for a number of topics the process is largely driven by research scientists within DoE. Although this approach may result in interesting science, he believes that it does not align with commercial opportunities: that is, not all good science is commercially viable.

Dr. Ives (CCR) noted that the wording of some topics does not change from year to year and that some of these topics have not been funded, which suggests that the agency is not interested in them. Because the application process requires substantial company resources, DoE should eliminate topics that are systematically not funded, .

XIA is seeing fewer topics that are potentially viable under current SBIR evaluation procedures, according to Dr. Warburton. Although DoE scientists seek tools and instruments that will enhance their research capability, these generally have extremely limited commercial potential and hence fail DoE’s “return on investment” criteria. For example, one recent topic was clearly designed to develop an instrument for use within one of the four accelerators that exist worldwide, which has almost no commercial potential.

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Dr. Warburton (XIA) said that DoE topic managers continue to regard SBIR/STTR as a tax on their research funding, and therefore seek to use it to provide tools or technologies that could further their own scientific interests and programs. These topic managers have no interest in commercial potential and therefore do not review topics for commercial potential before the solicitation is released.

Dr. McDermitt (LI-COR) said that DoE topics in environmental research have been closely attuned to cutting-edge environmental research, partly because the previous program director built close relationships with that community over many years. DoE has also been open to ideas for new topics.

Mr. Kempkes (DTI) was critical of the DoE topic development process. He said that many topics remain unchanged from year to year. In addition, because the topics provide insufficient information on which to develop a proposal, it is necessary to contact the technical staff interested in the topic to better understand what is really being sought. Although DoE publishes the contact information for subtopic managers, they are, according to Mr. Kempkes, usually not the technical staff (mostly at the National Laboratories) who drive the topic, which complicates the process.

DTI remains concerned about unfunded topics and about proposals that are marked fundable but are not funded. Mr. Kempkes observed that DoE SBIR/STTR is selective in the way that Harvard is selective—that is, there are invisible processes and perhaps a lottery occurring behind the scenes. DoE does not publicly prioritize its topics, and as a result DTI has written proposals to address a topic only to find out later that "DoE didn't care about that anymore." Because they compete with each other, not all subtopics are funded.

Dr. McDermitt (LI-COR) strongly supports the idea of providing an "open" category in the solicitation (currently available for most DoE divisions but not the Office of Energy Efficiency and Renewable Energy [EERE]). He had, for example, looked at the current solicitation and found nothing of relevance to LI-COR.

Letters of Intent

In general, interviewees were strongly positive about the letter of intent (LOI) process and believe that it generates useful feedback for applicants. They suggested that DoE find ways to make the letter more detailed and thus provide more guidance.

Dr. Ives (CCR) said that the LOI process provides a good opportunity for companies to explore possible applications without committing substantial resources.

Mr. Nemser (CMS) observed that, although he never likes rejection, he would rather receive rejection of a 1-page document than a 20-page proposal.

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SBIR/STTR at the Department of Energy

Commercialization Benchmarks and Expectations

The new commercialization benchmarks—which include those mandated by Congress and implemented through Small Business Administration (SBA) guidance, and those developed by DoE for use during the application process—have clearly had a substantial effect and were generally welcomed by the interviewees.

Dr. Ives (CCR) supports the new SBA commercialization benchmarks for awardees with a minimum number of awards as a way to encourage firms to take a more commercial approach to their activities.

Dr. Johnson explained that, from its founding in 2002 until 2010, Muons mainly focused on muon collider particle research and development of related technology. It used consulting contracts and SBIR/STTR awards to fund this work. Introduction of the new SBIR/STTR commercialization metrics after reauthorization nearly bankrupted Muons, according to Dr. Johnson. In 2011-2012, the company was designated as not commercial and hence SBIR/STTR funding dried up, leading to layoffs. In 2010, the company started to explore Accelerator Driven Subcritical Reactors (ADSRs), which have become a thrust of its commercialization efforts. The company ramped up its commercial activity, winning contracts from Fermilab to upgrade one of its flagship experiments and with Toshiba and Niowave to build magnetrons. As a result, Muons is once again considered by DoE to be a commercial company eligible for SBIR/STTR awards.

Dr. Johnson remains concerned that the DoE SBIR/STTR programs appear to expect commercial outcomes soon after the conclusion of a Phase II award. He noted that a typical time from conception to start of payback even in large commercial enterprises is close to 9 years. A survey respondent also made this point:

> *[T]he time for a new technical idea to be turned into a product with return on investment by large companies is about 9 years. It is unrealistic to think that a small company without experience in marketing or sales staff, etc., can do better. To saddle a very small company with additional commercialization tasks, when developing a new technology typically requires more effort than the grant covers, is unfair and likely to fail.*

Dr. Green said that PSI was already evolving toward a more pronounced focus on commercialization before the SBIR/STTR programs made changes in the same direction. Today, PSI is a strong supporter of the program's shift away from research-only projects. The company no longer looks for only projects that it can win. Before they write a Phase I proposal, staff must have a commercialization plan; it is part of the bid decision for PSI.

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Review

Overall, companies reported a positive opinion of the review process. Many said that the quality of the technical review is generally good and that the technical feedback is helpful. For example, one company executive said, "DoE has an excellent reputation for running an open program where each proposal is evaluated on its merits, with high-quality technical review."

Criticisms focused on the following:

- The lack of transparency in funding decisions
- Uneven quality of commercial review
- Overly specific demands for commercialization plans
- Anonymous reviewers and lack of supervision

Dr. McDermitt (LI-COR) was positive about the review process. His company has a good success rate and therefore no major complaints. LI-COR has not received a review in which the reviewer missed the point, which has happened with peer-reviewed papers. Some reviews offered significant insights to important questions, which improved the project.

Dr. Gary (Adelphi) stated that insufficient information is provided to applicants about funding decisions—in particular, too many applications are graded as excellent but not funded. He is a strong proponent of better feedback more generally. For example, NIH provides an online resource (ERA Commons) where applicants can find all of their applications and reviews. In contrast, DoE applicants must submit a request to have a review sent to them, the window for which is limited.

Dr. Walsh (Clara Vista) said that he believed that DoE reviews in some cases rely too heavily on academic reviewers. He found that proposals could be downgraded if they did not include an academic partner.

Dr. Warburton (XIA) said that the DoE process lacks a consensus-building mechanism for reviewers, which in part stems from the lack of in-person interaction among them. In contrast, face-to-face (or phone conference) meetings of NIH review panels boost the effectiveness of the review overall.[10] In particular, the discussions between the reviewers quickly expose the strengths and weaknesses of the arguments of the applicants and reviewers.

Mr. Nemser explained that CMS strongly prefers application systems that generate quantitative scores. This allows companies to see their place along the funding line. DoE provides strong technical feedback, but its program would be improved by clearer scoring and clear information about paylines.

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[10]See Chapter 2 (Program Management) in National Academies of Sciences, Engineering, and Medicine, *SBIR/STTR at the National Institutes of Health*, Washington, DC: The National Academies Press, 2015.

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More generally, one survey respondent said, "[P]roposals should be judged more based on innovation, company, PI, facilities, and equipment with less emphasis on connections and collaborations." Another respondent criticized the use of university researchers: "[U]se of external (typically university reviewers), is a bad practice. These reviewers are not objective, and base their reviews based on their personal objectives and research."

Some survey respondents stressed that the anonymity of reviewers has negative consequences: companies cannot tell whether they (or their technical approach) are systematically rejected by the same reviewer. One survey respondent said:

> *The reviewer not having his name revealed cannot be challenged and basically they can say what they want without oversight or checks and balances. Also, the reviewers are likely to be the same, year over year, and the company gets one or more reviewer that does not like it, the company is out of luck.*

Commercialization Review

Some companies and survey respondents expressed concern that the commercialization plans demanded by DoE for Phase I and Phase II are not helpful.

One survey respondent said, "[A] commercialization plan to be part of the Phase I proposal seems completely unjustified given that the Phase I proposal in most cases is a feasibility study to just investigate the idea." Another respondent said,

> *The emphasis on 'making a business case' has become excessive. Particularly with truly innovative concepts the risks are high and the future very fuzzy. In our experience, generating a business plan and pro forma documents at the level now required is more an exercise in creative writing than the production of a realistic road map for the future.*

Dr. Warburton (XIA) sees a substantial disconnect between the science and technical needs of topic managers and commercialization review. XIA found it difficult to pass both reviews simultaneously. He also observed that explicit hurdle rates (projected internal rates of return for the project, which must be addressed in the application) present significant challenges to any company providing high-tech, low-volume scientific instruments.

Dr. Warburton also wondered whether DoE has ever compared actual commercial outcomes in funded Phase II projects to the outcomes projected in the submitted commercialization plans, to evaluate whether the present methodology has any predictive capability or is just an exercise in creative writing.

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Mr. Kempkes (DTI) said that commercial review is generally poor and that the required commercialization plans are of little overall value. When developing a new technology, a company typically has some idea of its possible applications, but at the Phase I stage neither the company nor the reviewer has a clear vision of whether those applications will be useful. The market is simply too far away to address. By Phase II, a company should be thinking about transition, but sometimes even then it is too early.

Mr. Kempkes suggested that DoE focus its efforts on ensuring that companies develop a strong commercialization plan by the end of Phase II. Demanding significant work on a plan before then wastes the time of the applicant and the reviewer. He also noted that commercialization reviewers are of variable quality.

A number of survey respondents argued that the current emphasis on commercialization comes at the cost of potential important innovations (Box 7-9).

BOX 7-9
Survey Responses on Recent Commercialization Thrust

- "Recently, SBIRs have been more focused on commercial return. I think there is still merit in programs for developing technology for specific agency needs that may not turn into large scale products. Even developing a 'one of a kind' sensor for a specific application (e.g., in nuclear proliferation) provides capabilities worth of government funding (and advances technology at the small business for other products)."
- "[We] recommend keeping the program (at least a significant portion) focused on innovation, and high risk, high payoff development activities. I am concerned with the realignment of the program to focus on later-stage technologies, as a venture capital substitute as opposed to high risk, exploratory and long term development support for entrepreneurs."
- "SBIR was intended to support high risk research. The present trend for funding safe development is counter to the goals of the program and to the best interests of the country's future technologies."
- "The goal of the small-business innovative research (SBIR) program is to perform innovative research. Somehow, this has been obfuscated by commercialization considerations."
- "The review of bids in the DoE/HEP, BES, NP sectors should allow for a mix of far term commercial payoff and near-term innovative solutions that apply directly to FFRDCs programs."

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SBIR/STTR at the Department of Energy

Rebuttal and a More Iterative Review Process

A number of case study company executives shared their frustration with the lack of a mechanism to rectify minor problems with applications upon first submission, which forces them into resubmission or rejection and hence into lengthy delays. However, Manny Oliver, the DoE SBIR/STTR Program Executive, explained that DoE can sometimes make deadlines flexible to allow companies to correct minor errors on their applications.

Several company executives suggested different ways in which the connection between applicant and study section review panel could be improved. Mr. Nemser (CMS) supports processes that would allow companies to address errors or omissions and respond to reviewer comments before reviews are finalized, perhaps through some version of face-to-face defense, to the extent possible. He also supports the resubmission approach adopted by NIH. Dr. Warburton (XIA) noted that DoE offers no appeal process and no possibility for formal resubmission (as at NIH).[11] He is therefore a strong proponent of the idea that companies be provided the opportunity to respond in writing (one to two pages maximum) to reviewer comments before final decisions are made.

These opinions were echoed by comments from survey respondents. One respondent said, "For proposals that are recommended for funding and are not funded DOE should provide an improvement and resubmission opportunity." Another respondent compared DoE's process to that of NIH:

> *[C]ompared to the NIH's Review Panel approach, where the reviewers meet to discuss the proposals they have reviewed, DoE's review system is often problematic since there is no process to correct reviewer errors or misunderstandings and the process is competitive enough so that even a single reviewer mistake can sink a proposal.*

Along those same lines, another respondent explained,

> *Some comments from reviewers can be answered by a simple sentence, sometimes there is a misunderstanding, sometimes a point is just overlooked by a reviewer. It would be great if there was an option to respond to reviewers comments before the decision about award is made.*

Finally, referring to other agencies' resubmission processes, another respondent suggested that

[11]Ibid.

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the most important improvement that the SBIR program needs to make is to allow resubmission of a phase II after the initial evaluation . . . giving the technology a real chance and for submitters to address concerns of the reviewers.

Policy Innovations

Recent policy initiatives of the DoE SBIR/STTR programs are discussed more systematically in Chapter 3. This section provides feedback about innovations from companies.

Funding Mechanisms: Phase IIB

Dr. Walsh (Vista Clara) explained that the company received Phase IIB funding from DoE to develop a custom cable for down-hole data logging. It sought $300,000 from DoE and planned to invest $75,000 of its own capital, and, although not required by DoE, he believes that these matching funds helped the company win the award.

Mr. Nemser (Compact Membrane Systems [CMS]) said that changes to the DoE SBIR/STTR programs have been significant improvements. The program appears to be focusing away from science and farther downstream, and CMS strongly supports the introduction of Phase IIA and Phase IIB at DoE, because CMS believes that a single Phase II award is often insufficient to develop a marketable product. Phase IIB provides up to one-third of Phase II funding to support moving the product to market. CMS has also participated in the introductory accelerator program.

Other Innovations

Dr. Walsh (Vista Clara) strongly supported DoE's approach to set aside part of the STTR budget to pay for articles in peer-reviewed publications, which is often a significant amount. DoE allows labor costs for preparing articles and presenting at conferences and publication fees for print journals, although these costs do have to be included in the initial proposal budget. He believes that other agencies should follow DoE's lead in this area.

DoE also now allows companies to charge patent application expenses, to a certain limit, as direct costs. This is a very welcome initiative, according to Dr. Walsh, because such costs otherwise come directly out of the company's profit.

Dr. Warburton said that XIA supports recent efforts to add broader topics, which are occasionally funded. XIA won a Phase I for a broader topic, although it did not go to Phase II.

Mr. Nemser said that the Phase II accelerator program helped CMS launch its oil dehydration systems. Their success underpinned further grants

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focused on solvent dehydration, a technology which is being commercialized by capitalizing on the existing infrastructure and manufacturing capability.

Ms. Nemser explained that, under current guidelines, direct to Phase II[12] excludes work completed under a previous Phase I—that is, the program only supports work completed by the company without SBIR/STTR Phase I funding. This seems to be an unnecessary barrier, because previous Phase I work may have entirely novel applications. He recommends that DoE be more flexible in this area.

Phase III Within DoE

DoE does not have a Phase III policy to support the commercialization of technology developed in the SBIR/STTR programs. Moreover, DoE has no plan in place to encourage (or track) the take-up of technologies sponsored by DoE within DoE itself.

One interviewee explained that a recent experience with a National Laboratory suggests that the Laboratories are not following the Phase III directives in the current SBIR law. More generally, he noted that Phase III is currently not seen as a responsibility of the SBIR/STTR program office, and it does not appear that it is the responsibility of any other office within the agencies.

Mr. Nemser (CMS) observed that DoE is very good at supporting companies through Phase I and Phase II, but not after: companies face the "valley of death" on their own. He said that venture investors understand the need to double down on their investments to get through this period before products are introduced into the market, but that DoE has no capacity in place to do so and has made no real effort to help in this area.

Dr. Walsh (Vista Clara) said that DoE's interest in Vista Clara technology stems from its need to manage groundwater contamination more effectively. DoE facilities are currently spending hundreds of millions of dollars on soil and groundwater remediation, and Vista Clara technology offers significant upgrades on existing approaches. However, despite the funding and interest implied through SBIR awards sponsored by the Office of Subsurface Biology, Vista Clara has made no sales to DoE. Dr. Walsh observed that there seems to be no clear connection between the SBIR program and other parts of the agency. Thus, although there is a topic every year on subsurface characterization and remediation, there are no follow-on contracts for SBIR winners.

DoE should develop a better path for the commercialization of SBIR/STTR technologies, Mr. Kempkes suggested. Because acquisition is a

[12]"Direct to Phase II" refers to a recent change that allows a company to bypass a Phase I award and apply directly for a Phase II award. Previously, it was required that a company first apply for and receive a Phase I award before they were eligible to apply for a Phase II award.

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function of the National Laboratories, DoE should require all Laboratories to develop and publish a plan to integrate SBIR technologies into their programs.

These criticisms were also reflected in numerous comments from survey respondents (see Box 7-10).

Connecting to Topic Managers

Dr. Gary (Adelphi) said that connections with DoE staff tend to be very limited. Project liaisons appear to have other more pressing responsibilities, and in most cases there is almost no contact between DoE staff and the principal investigator (PI) or company representatives beyond the resolution of contracting issues. At best, DoE staff are of little help in finding potential markets for the technology within DoE, he said.

BOX 7-10
Survey Responses on Phase III within DoE

- "[DoE] in general does not effectively enough seek more advanced development of its SBIR technologies through DoE's non-SBIR portfolio of developing technologies. SBIRs are insufficiently considered as seed technologies for use in non-SBIR programs or to advance DoE policy areas."
- "DoE is a mission agency and more help on guidance for Phase III sales to DoE would go a long way in light of the uncertainties pertaining to federal budget appropriations."
- "More SBIR technologies would be transitioned into mainstream DoE programs were it not for DoE's requirement for cost-share regardless of small business financial capability. Better practice would be for DoE to seek out the best technology without placing a cost-share hurdle upon the provider."
- "The SBIR program leads to new technology innovation and development critical to growing America's economy and jobs. Its lack of integration into other Federal mission objectives and non-SBIR funding programs means that the DoE is missing the opportunity to really advance these embryonic technologies to major scale impact upon DoE mission objectives."
- "There is a huge disconnect between what constitutes 'market driven demand' and the nature of the R&D, pie-in-the-sky projects which are funded. In our case, there was actually a negative incentive for the prime contractors, who are paid on a cost plus basis, to adopt our technology which could have accelerated closure of and reduced some costs associated with the weapons complex cleanup."

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SBIR/STTR at the Department of Energy

Mr. Kempkes (DTI) said that DoE SBIR topic managers are usually helpful—if the company contacts them. In his experience, one DoE staff member is often manager for 4-10 subtopics, and as a result they become quickly overwhelmed. The quality of email responses vary. To be fair, topic managers are spread too thin, and improvements in this area would be helpful.

Funding Levels

Given the recent increase in funding levels, there was less interest in this issue among both case study companies and survey respondents. Dr. Gary said that Adelphi would certainly consider applying for less funding if there was some benefit to doing so—for example, a higher likelihood of success. However, because this is currently not the case, the company designs the project to meet the funding available.

One survey respondent focused on projects that include use of expensive hardware. Noting that “programs with high technical content or high hardware content are severely limited by the SBIR funding limit,” the respondent recommended that projects involving substantial amounts of research hardware should be identified and funded at a higher level.

National Laboratories

Many of the case study companies have worked closely with the National Laboratories, and in several cases, founders had worked at National Laboratories for many years before starting their company.

Dr. Johnson said that most of Muons’ work focuses on identifying projects and technologies that will help the National Laboratories, but for which there is no available funding. Most other STTR projects work to transfer technology in the other direction, from the laboratory to the marketplace. STTR in particular has been used to meet those needs, perhaps acting as a DoE analog to Lockheed’s famed Skunk Works as a source of innovative technologies.

Dr. Warburton (XIA) said that SBIR-funded electronics to control spectrometers replaced the difficult-to-tune and expensive-to-maintain analog controls that had been the industry standard, leading to very substantial increases in efficiency for National Laboratories using the new technology. He noted that XIA has sold approximately $10 million to $20 million in instruments for synchrotrons, which cost $500 million to build and approximately $200 million annually to operate. A large percentage of the research undertaken with these systems requires instruments such as those developed by XIA. Synchrotron x-ray fluorescence experiments would not run at all without them, and overall productivity (and hence return on investment) would be a fraction of what it was today.

National Laboratories have few incentives to cooperate fully with small businesses, Dr. Warburton observed. In the best of cases, the Laboratory

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scientists involved see STTR as a means of supporting their own research program, in exchange for providing the company with technical support. In other cases, Laboratory staff see the program as a means to generate funds and have no interest in commercial outcomes or even their partner's interests.

Dr. Warburton noted that each National Laboratory has its own culture: XIA has worked quite successfully, for example, with Pacific Northwest National Laboratory and with a few departments at Lawrence Livermore National Laboratory, but essentially not at all with Lawrence Berkeley National Laboratory even though it is the closest of the three Laboratories to XIA headquarters.

The National Laboratories vary widely in their capacity to address SBIR, according to Mr. Kempkes (DTI). Some Laboratory staff have figured out how to use SBIR to advance their work. Others consider SBIR to be the competition. These differences are often more personal than institutional. It is not the case that some Laboratories are better to deal with than others; rather, it is the case that some contracting officers and some Laboratory staff are easier to deal with. Therefore, for example, SLAC contains the best partners DTI has found across the system, and also the worst.

One survey respondent indicated that contracting staff at National Laboratories are sometimes not familiar with SBIR: "National Labs [staff] should be trained to understand and implement the SBIR policy directive, and not attempt to appropriate intellectual property. My experience with legal personnel at Brookhaven was that they were completely ignorant of the goals and constraints of the SBIR program."

Mr. Kempkes agreed that National Laboratory staff do a poor job of protecting company IP: the Laboratories are more academic than commercial, and hence they have a different mindset. Part of their job is to collect and disseminate information: "They live for publication." Therefore, they are not mindful of keeping track of whose IP is whose. In every case, the company had experienced difficulties in creating an IP agreement with the National Laboratory.

Mr. Kempkes said that there are indirect challenges as well: SBIR proposals are considerably stronger when they are bolstered by letters of support from potential users. However, National Laboratories are not in a position to provide such letters because that would prevent a specific Laboratory from reviewing the proposal. The dual nature of the Laboratories as both customer and reviewer can therefore present a problem.

STTR

Several of the companies interviewed had extensive experience with STTR at DoE, and were able to provide more detailed insights especially into the relationship between STTR and the National Laboratories.

Dr. Johnson noted that STTR projects can only work well if there is goodwill between the Laboratory and the company. He noted that his

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company, Muons, has long and deep connections with National Laboratories, its staff know most of their counterparts at the laboratories, so the connection is always positive.

Still, Laboratory administrators in general tend to view STTR awards as small projects. From a $150,000 award, the Laboratory will receive maybe $50,000 to $60,000, and it costs them almost that much just to do the paperwork, according to Dr. Johnson. So STTR agreements can take a long time to receive signoff from the Laboratories because they are a low priority for Laboratory administrations.

Dr. Gary (Adelphi) is a strong supporter of the STTR program and believes that companies are best positioned to determine whether a project should be SBIR or STTR, based on the needs of the project. He observed that a separate solicitation for STTR is likely to generate poor quality partnerships put together primarily to pursue funding, and that SBIR/STTR should provide a single opportunity for funding

Dr. Ives (CCR) sees STTR as an enormously helpful program and finds that, in some cases, it is a better vehicle for company initiatives than SBIR (in which the company also participates extensively). STTR provides an appropriate structure for partnering with RIs and offers access to the creativity and enthusiasm of graduate students. A recent STTR project with North Carolina State University led to the incorporation of student-developed designs into CCR products.

CCR has had differing experiences with RIs. Some research institutions, such as North Carolina State, offered realistic licensing terms and welcomed collaboration with small companies. Other RIs did not appear to understand the limited resources of small businesses and required unrealistic upfront licensing fees and royalties.

Dr. Ives said that DoE STTR grants for projects partnering with a National Laboratory used to require a cooperative research and development agreement (CRADA), but now they require only an IP agreement with the laboratory. An STTR grant also requires approval from the DoE Cognizant Officer who is responsible for Laboratory activities, which can take considerable time to receive. Currently, most Laboratories that use CRADAs require separate CRADAs for each of the two award phases, which lengthens delays and adds cost. Each CRADA specifies a time period for work to be completed, and amending this time requires a change to the CRADA, as does any other significant change to the statement of work (e.g., a shift to a different part of the Laboratory as provider of a device or service).

Partnering with RIs results in other challenges. In particular, universities and students want to publish their research. It was therefore, in Dr. Ives' view, important to understand this need and provide opportunities to publish without compromising company IP. Dr. Ives believes this can be accomplished, as the record of publications related to CCR–university collaborations shows.

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Dr. Johnson (Muons) observed that most companies do not want to deal with STTR grants—"We are masochists," he said, "since most companies do not want to deal with National Lab bureaucracies and do not want to share their grant money with the labs."

Dr. Green (PSI) is a strong supporter of the STTR concept. However, although STTR provides funding for the RI, industry has to be the bridge that transitions technology out of academia. STTR cannot just be pass-through funding to the RI. He believes that STTR encourages each partner to work to its strength: the RI does research and education, and the industry partner does commercialization, and this structure is perfect for technology transition.

PSI's connections to RIs go far beyond STTR. Over a 6-year period, PSI funded 53 different universities. The company watches the scientific literature to identify possible partners, focusing on faculty who are making cutting-edge advances that can meet the needs of PSI's customers. It is rare that a professor is not interested in collaboration.

Although Dr. Walsh (Vista Clara) does not object to partnering with RIs on occasion, he believes that, in most cases, Vista Clara could have done a better job without them. In only a few of the seven or eight partnerships formed for SBIR/STTR did the university add real value.

XIA has not had good experiences with the STTR program, Dr. Warburton explained. For example, a collaboration with Brookhaven National Laboratory worked out poorly, with no accountability for the project at the laboratory.

Mr. Kempkes said that DTI is wary of undertaking STTR projects, although it is currently in a partnership with Lincoln laboratory at MIT and has applied under some past STTR solicitations in partnership with Arizona State University (ASU). Typically, DTI does not bid on STTR solicitations unless there is something that the company cannot do itself (e.g., ASU grows algae). Usually, there is not enough funding in an SBIR to start with, and sharing the funding with a RI exacerbates this problem.

Dr. McDermitt explained that LI-COR's experience with STTR has not been very positive. The company encountered a considerable amount of paperwork and issues related to IP that were difficult to resolve. As a result, the company has decided to not apply for STTR awards in the future. He noted that beyond STTR, LI-COR has continued to work with universities on a regular basis, and has developed a close relationship with the University of Nebraska–Lincoln (UNL). Li-COR Staff members worked as adjunct professors at UNL, the company has had numerous and valuable interactions with UNL, and two former staff members now work in the UNL Technology Transfer Office (TTO). LI-COR and UNL faculty worked together on a DNA sequencer in the 1990s, which was used on the human genome project and is still in use for protein detection and by LI-COR for the development of clinical applications.

In most cases, Creare directs STTR projects, Dr. Rozzi observed. However, a number of universities have established TTOs and incubators for

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emergent small business concerns. Faculty are encouraged to form companies and work through the incubator. In these cases, they often seek companies such as Creare to partner on STTR proposals. However, Creare is very cautious about becoming involved in a partnership where the faculty member is the driver.

Dr. Lalli (NanoSonic) observed that, 5 years ago, she would have wanted to see the STTR program folded into the SBIR program, in large part because managing International Trafficking in Arms Regulations (ITAR) in the context of a partnership with an RI are often extremely challenging.

More recently, NanoSonic has found the process to move more smoothly. The clear tension that exists between academic interests in publishing and company needs for confidentiality can be addressed effectively with the right partner. Today, she said, NanoSonic is a very strong supporter of the STTR program. The company found a formal agreement to use university equipment to be very helpful. The program has helped NanoSonic to reach out to cutting-edge researchers and to gain access to high-quality graduate students.

ITAR

Dr. Rozzi noted that ITAR, the International Traffic in Arms Regulations,[13] presents particular challenges to STTR. ITAR implements the Arms Export Control Act, which authorizes the President to "control the import and the export of defense articles and defense services . . . ."[14] Creare has taken a very conservative view of ITAR and has found it difficult to ensure that universities understand and accept the relevant restrictions, particularly when there are considerable numbers of foreign students in most high-quality engineering departments.

Dr. Lalli (NanoSonic) also noted that the need to deal with ITAR is challenging. Most SBIR topics from DoD and NASA require compliance with ITAR, and NanoSonic is working to improve its capacity to deal with ITAR-related issues.

IP Conflicts

Dr. Rozzi (Creare) highlighted past conflicts over publishing results. RIs, academics, and graduate students all want to publish, which may lead to conflicts with the company's need to preserve trade secrets. However, he noted that there are ways to publish without breaching disclosure limitations.

Dr. McDermitt (LI-COR) said that IP ownership is one of the most complex issues to manage in an RI collaboration. LI-COR wants to own the IP in part because it usually provides most of the funding. Some RIs are good to

[13] 22 CFR 120-130.
[14] 22 USC, Section 2778.

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work with, and others are not: If the RI views STTR strategically as revenue generation opportunity, then significant conflicts and problems will almost always follow.

Partnerships with Research Institutions

STTR partnerships tend to be with RIs that are well known to Creare engineers, Dr. Rozzi observed. For example, Purdue, where Dr. Rozzi earned his PhD, is a top Creare partner. Creare has also worked closely with MIT in the past, but not as extensively in recent years. Similarly, another engineer had developed a close relationship with the University of Minnesota.

For Creare, the bar for involvement in STTR is simply higher than that for SBIR. Dr. Rozzi said that unless the RI is a great partner, paying the RI will not generate results that are nearly as efficient as if Creare did the work itself. STTR works best when Creare requires access to unique RI technologies—for example, previous STTR partnerships with Purdue provided access to modeling for composites machining. Because an RI cannot be easily made accountable or "fired," Creare has to be very careful about entering into a partnership. Finally, STTR also requires an IP agreement, so if one is not in place and Creare does not have an existing relationship with the RI contracts staff, a considerable amount of work is needed before the proposal can even be advanced. Therefore, the partnership really has to be worth it, from Creare's point of view.

OTHER COMMENTS

Because of the difficulties finding outside funding for further product development prior to revenue generation, Ms. Nemser said that the CMS's top priority is for DoE to shift more funding downstream to help with commercialization.

Dr. Green (PSI) said that the agencies should simplify the application process and limit the amount of paperwork required. Every company should have a fair shot at an award, but this is not the case. Although it has a fully trained technical publications department, it still takes PSI significant time and effort to develop an application. It is important that the SBIR/STTR programs remain fully merit-based so that the best solutions find their way to the market.

Dr. Warburton (XIA) said that small instrument sales in support of the National Laboratories' missions are in the national interest and that this class of SBIR topic should be assigned evaluation criteria that properly reflect their value to those missions. Alternatively, if DoE only wants proposals capable of large commercial returns, it should revamp its solicitations to bring them into conformance with that objective.

Mr. Kempkes (DTI) said that DoE prioritizes topics after the proposals are reviewed. He believed that this had nothing to do with proposal quality but simply reflects program need. He said that this process should be

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undertaken before publication of the solicitation, not after companies have expended hundreds of hours of effort on topics that are in fact low priority and unlikely to be funded.

Dr. Johnson (Muons) said that DoE program managers are quite flexible but are constrained by STTR legislation that requires that the RI receive a minimum percentage of the award. Program managers will sometimes allow replacement of an RI, which is usually not practical because the RI was selected for its specialized expertise. He suggested that program managers should be given the flexibility to revert STTR funding back to the company in special circumstances. One survey respondent recommended: "[T]he proportion of funds for the RI should be left to negotiations between the PI and the RI Program Manager. This could mean higher or lower amounts of funds going to each party."

Mr. Kempkes (DTI) suggested that data rights should be extended beyond 5 years, which in terms of product development is far too short. For example, DTI worked on helicopter blades under an SBIR contract. It entered into negotiations with a helicopter manufacturer, which in the end decided to wait out the 5 years.

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8

Findings and Recommendations

The findings and recommendations in this chapter reflect the performance of the DoE Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program against the broad congressional objectives for the programs.[1]

For SBIR, these objectives were reiterated in the 2011 program reauthorization and elaborated in the subsequent policy directive of the Small Business Administration (SBA).[2] Section 1c of the SBA SBIR Directive states program goals as follows:

> *The statutory purpose of the SBIR Program is to strengthen the role of innovative small business concerns (SBCs) in Federally-funded research or research and development (R-R&D). Specific goals are to:*
>
> *(1) Stimulate technological innovation;*
> *(2) use small business to meet Federal R-R&D needs;*
> *(3) foster and encourage participation by socially and economically disadvantaged small businesses (SDBs; [also called minority-owned small businesses—MOSBs—elsewhere in the report], and by women-owned small businesses (WOSBs), in technological innovation; and*
> *(4) Increase private sector commercialization of innovations derived from Federal R-R&D, thereby increasing competition, productivity and economic growth.*[3]

[1] See Box 1-3 and the discussion of the committee's task in Chapter 1 (Introduction).
[2] SBA SBIR-STTR Policy Directive, October 18, 2012.
[3] Small Business Administration, Small Business Innovation Research (SBIR) Program Policy Directive, February 24, 2014.

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The parallel language from the SBA's STTR Policy Directive is as follows:

> *(c) The statutory purpose of the STTR Program is to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and Research Institutions through Federally-funded research or research and development (R-R&D). By providing awards to SBCs for cooperative R-R&D efforts with Research Institutions, the STTR Program assists the small business and research communities by commercializing innovative technologies.*[4]

This chapter reviews the extent to which each of these program goals is being addressed at DoE. The chapter also addresses some specific aspects of DoE's management of the program.

SOURCES OF FINDINGS

The committee's findings are based on a complement of quantitative and qualitative tools including a survey, case studies of award recipients, agency data, public workshops, and agency meetings. The methodology is described in Chapter 1 and Appendix A of this report. In reviewing the findings below, it is important to note that the National Academies of Sciences, Engineering, and Medicine 2014 Survey—hereafter referred to as the 2014 Survey—was sent to every principal investigator (PI) who won a Phase II award from DoE, FY 2001-2010 (not the registered company points of contact [POC] for each company.)[5] Each PI was asked to complete a maximum of two questionnaires, which as a result excludes some awards from the survey. The preliminary population was developed by taking the original set of SBIR and STTR Phase II awards made by DoE during the study period and eliminating on a random basis awards to PIs who received more than two awards (to limit the burden on respondents). The resulting preliminary population was 1,077 awards. PIs for 583 of these awards were determined to be not contactable at the SBIR/STTR company listed in the DoE awards database. The remaining 494 awards constitute the effective population for this study. From the effective population, we received 269 responses. As a result, the response rate in relation to the preliminary population was 25.0 percent and in relation to the effective population was 54.5 percent.

In addition to information from this survey, the committee has drawn on company case studies, discussions with agency staff, and other documentation. In

[4]Small Business Administration, Office of Investment and Innovation, "Small Business Technology Transfer (STTR) Program—Policy Guidance," updated February 24, 2014.
[5]Because there is a time lag in commercialization for new technologies, the survey did not include more recent awards than 2010. See Box A-1 for a discussion of this commercialization lag.

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interpreting the findings and recommendations set out below, the reader needs to keep in mind the size of the survey population and response rates, and the overall potential sources of bias.[6]

FINDINGS

The SBIR program at the DoE is having a positive overall impact. It is meeting three of the four legislative objectives of the program with regard to stimulating technological innovation, using small businesses to meet federal research and development (R&D) needs, and increasing private-sector commercialization of innovations derived from federal R&D. However, the committee finds that more needs to be done to "foster and encourage participation by socially and economically disadvantaged small businesses (SDBs), and by woman-owned small businesses (WOSBs), in technological innovation." The STTR program at DoE is also meeting the program's statutory objectives, defined above, in that it is encouraging and supporting linkages between small business corporations (SBCs) and research institutions (RIs).

The findings are organized according to the legislative goals for SBIR/STTR plus findings on the management of the program. The order in which the findings are presented reflects the committee's relative emphasis. The first set of findings concerns the management of the programs at DoE. The second focuses on the commercialization of SBIR- and STTR-funded projects. This is followed by findings concerning the participation of women and minorities in the program. The fourth and fifth sets of findings address how well the DoE SBIR/STTR programs are stimulating technological innovation and fostering innovative companies. The final set of findings concerns STTR. The summary below provides a guide to the more detailed description to follow.

Summary of Findings

I. Program Management

A. DoE has substantially improved its SBIR/STTR programs since 2008 (the publication year of the previous National Academies report on the DoE SBIR program).
B. DoE has not addressed some other important recommendations from the National Academies' 2008 report.
C. The DoE application review system can be improved.
D. The DoE SBIR/STTR programs provide companies some flexibility, but can offer more.
E. DoE is seeking ways to improve its data collection and tracking of SRIR/STTR project outcomes.

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[6]For an overview of the potential sources of survey bias, see Box A-1 in Appendix A.

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II. Commercialization

A. Nearly half of the respondents to the National Academies' 2014 Survey reported some sales, and a further 23 percent reported anticipating future sales.
B. Commercialization of DoE SBIR/STTR projects takes place primarily in the domestic private sector.
C. Subsequent investment in DoE SBIR/STTR projects is an indicator that they are seen as having the potential for commercial value even if they have not yet reached the market.
D. Direct job growth from DoE SBIR/STTR awards is in general limited, though some awardees reported large employment gains.
E. SBIR/STTR funding makes a substantial difference in determining project initiation, scope, and timing.
F. Venture capital funding plays only a modest role for DoE SBIR/STTR firms.

III. Fostering the Participation of Women and Other Underserved Groups in the SBIR/STTR Programs

A. Current data show that the objective of fostering the participation of women and underserved minorities has not been met by the DoE SBIR/STTR programs.
B. DoE efforts to "foster and encourage" the participation of woman-owned and minority-owned small businesses are not adequate.
C. DoE is making efforts to understand the patterns of woman and minority participation in the SBIR program, but more is needed.

IV. Stimulating Technological Innovation and Meeting Agency Mission Needs

A. The DoE SBIR/STTR programs support the development and adoption of technological innovations that advance the agency's mission.
B. The DoE SBIR/STTR programs continue to connect companies to universities and research institutions.
C. DoE SBIR/STTR projects generate substantial knowledge-based outputs such as patents and peer-reviewed publications.
D. The DoE SBIR/STTR programs fund some projects that have high scientific or social value, but are unlikely to generate significant market outcomes in the short term.
E. SBIR/STTR funds the development of research tools, multiplying the impact of the award.

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V. Fostering Innovative Companies

A. The DoE SBIR/STTR programs encourage new firm start-up.
B. DoE SBIR/STTR funding helps small innovative companies in a variety of ways.
C. Most DoE SBIR/STTR awardees surveyed report positive impacts on their company.
D. Company dependence on the DoE SBIR/STTR programs is limited.

VI. STTR

A. STTR is meeting the program objectives defined in the Small Business Administration's Policy Guidance for STTR.
B. At DoE, the STTR program is administered as an adjunct to the much larger SBIR program.
C. Outcomes from STTR are broadly similar to those from SBIR, but there were some differences that should be noted.
D. In some cases, companies utilize STTR and SBIR differently.
E. The DoE SBIR and STTR programs are not sufficiently integrated with the DoE National Laboratories.

I. Program Management

A. DoE has substantially improved its SBIR/STTR programs since 2008 (the publication year of the previous National Academies report on the DoE SBIR program).

1. A number of recommendations from the 2008 report have been adopted:

- DoE publishes contact information for each topic and subtopic in the solicitation.
- DoE collects outcomes data on a regular basis and a new staff member is tasked with undertaking more systematic analysis of the program for management purposes.
- DoE provides for a pre-release period during which technical staff can be contacted to discuss possible approaches to topics.

2. DoE has adopted a number of other initiatives and pilot programs,[7] which collectively have improved the program. Among the more important are:

[7]See Chapter 3 (DoE Initiatives).

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- Integration of SBIR/STTR applications, so that applicants can, when appropriate, apply to both programs with a single application
- Introduction of a Fast Track option to combine Phase I and Phase II into a single application
- Introduction of sequential Phase II awards, with the Phase IIA and Phase IIB programs
- Provision up to $15,000 for patenting expenses in approved budgets
- Introduction of the letter of intent procedure, which provides a company with guidance about its proposed approach before it develops a full-scale application
- Inclusion of a line item for publication costs in project budgets

3. DoE is increasing the number of Fast Track awards (combined Phase I and Phase II).

- The number of Fast Track awards has grown steadily and in FY 2014 reached 70 awards.
- As percentage of all regular Phase II + Fast Track awards, Fast Track awards increased from 8 percent in FY 2005 to 24 percent in FY 2014.

4. DoE has increased the emphasis on commercialization, which affects topic managers and companies.[8]

- Commercialization plans are required for Phase I proposals, and a very detailed plan is required for Phase II.
- Topics are now scrutinized for commercial possibility before they approved by the DoE SBIR/STTR Program Office, although it appears that more could be done in this area.
- One case study company explained that it was excluded from the program because its commercialization record was insufficient.

5. DoE has fully embraced the benefits of electronic and electronic provision of application information and support.[9]

- In 2008 DoE was one of the last remaining agencies to require paper applications. As with the other study agencies in this series, all applications to DoE are now electronic only.
- DoE provides training and support through webinars, both live and archived, which reached more than 3,000 viewers during the past year.

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[8]See Chapter 2 (Program Management).
[9]See section on "Awards Management" in Chapter 2 (Program Management).

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- Dawnbreaker, the agency's commercialization support contractor, provides more detailed support materials electronically.

6. The Phase 0 program piloted in FY 2014 is a promising effort to provide more support to underrepresented groups.[10]
7. DoE has appropriate mechanisms in place to manage issues related to the provision of multiple awards to the same company, and in general new entrants receive a substantial share of DoE SBIR/STTR funding.[11]

   - New participants: New companies accounted for greater than 30 percent of companies applying for Phase I funding in almost all the years of the study period. New companies accounted for between 20 to 25 percent of awards and 25 to 30 percent of FY 2005-2013 applications during the study period. The access provided for new entrants to the program is appropriate.
   - Multiple award winners: The top 20 award winners at DoE accounted for 7.7 percent of Phase I SBIR/STTR awards and 8.1 percent of Phase I funding. They accounted for 9.6 percent of awards and 8.1 percent of funding for SBIR/STTR Phase II awards. This level of concentration is lower than that for other agencies. For example, at the Department of Defense (DoD) the top 20 winners accounted for 14.4 percent of awards and 14.3 percent of Phase I SBIR funding.

8. DoE has successfully shortened the gap between Phase I and Phase II funding, primarily by rearranging the schedule of solicitations and providing for dedicated contracts staff. As a result, DoE now meets the SBA guidelines for awarding and contracting Phase I and Phase II SBIR/STTR awards.[12]

B. DoE has not addressed some other important recommendations from the National Academies' 2008 report.

1. Funding between DoE programs and divisions has not been reallocated, which leads to significant imbalances in the program.[13]

   - Currently, funding for SBIR/STTR is allocated more or less in proportion to the extramural funding by division and program, on which the SBIR/STTR funding is based.

[10]See section on "Phase 0" in Chapter 3 (DoE Initiatives).
[11]See section on "New Entrants into the SBIR/STTR Programs and Multiple-Award Winners" in Chapter 4 (SBIR and STTR Awards and DoE).
[12]See section on "Improved Process Timelines" in Chapter 3 (DoE Initiatives).
[13]See Chapter 2 (Program Management).

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- This leads to equivalence between programs that operate in areas of considerable commercial opportunity and programs that focus on DoE's science missions.
- Because of an imbalance between the share of possible applicants and the share of available funding, EERE has eliminated "open" topics and narrowed the scope of its published technical topics, to limit the number of applicants. This is not best practice for the program, because it permanently excludes potentially important technologies.

2. Activities related to Phase III. The National Academies' 2008 report recommended that DoE consider implementing a match-making program of some kind, perhaps modeled on the Navy Opportunity Forum.

   - The SBIR/STTR Program Office continues to see its responsibilities essentially ending at the conclusion of Phase II (or Phase IIB).[14]
   - A number of pilot or fully realized projects at other agencies could be the basis for more effective activity in this area.

3. The procedure for developing topics could be improved.[15]

   - The problem of noncommercial topics: DoE topics and subtopics are primarily the responsibility of technical staff within the science divisions and applied programs, each of which has its own procedures for validating topics.
   - There is a contradiction between the selection of topics by the science divisions in particular and the emphasis placed on commercialization. The science divisions primarily focus on SBIR/STTR to address their own technical needs; there is little evidence that they have any interest or expertise in identifying commercially important topics even within the relatively less commercial domains within which they operate.[16]
   - Unfunded topics: DoE's current practice is to prioritize awards *after* all applications have been received.[17] This places a substantial burden on companies responding to unfunded topics.
   - All projects within a division essentially compete with each other (or even across divisions—see above). As a result, some topics are not funded, even if applications for those topics are marked as fundable.
   - Some companies also complain that the same topics are regularly unfunded, which suggests that these topics are low priority and should

[14]See section on "Beyond Phase II" in Chapter 2 (Program Management) and section on "Support for Improved Commercialization Outcomes" in Chapter 3 (DoE Initiatives).
[15]See Chapter 2 (Program Management).
[16]See Chapter 2 (Program Management).
[17]See Chapter 2 (Program Management).

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be eliminated immediately to avoid imposing an unfair burden on applicants.[18]

C. The DoE application review system can be improved.

1. Case studies, survey responses, and discussions with agency managers all indicated that, although the DoE application review system is highly regarded and has many positive characteristics, it is not serving the SBIR/STTR community as well as it could.
2. DoE reviewers act independently. They do not meet and no consensus view of a proposal is developed. Often only two reviewers are used, and about 40 percent of all reviewers are staff from the National Laboratories. This can lead to inaccurate reviews.

    - The lack of a consensus-making process means there are no checks or balances imposed on individual reviewers by other reviewers, leaving this to be provided in some cases by the topic manager.[19]
    - The impact of missing internal cross checks is multiplied because there is no formal procedure for resubmission whereby applicants can correct misunderstandings or provide additional data as needed. This contrasts for example with the NIH resubmission process or with the iterative approach utilized by most peer-reviewed scientific journals.[20]
    - The impact is also multiplied by the tight competition for awards, which means that a bad score on one criterion from one reviewer is likely enough to doom a proposal.
    - The scoring system is a blunt instrument. Each application is scored on each of the four criteria as "not acceptable," "acceptable," or "outstanding." This leaves no room for a more nuanced appraisal.

3. Because DoE reviews are not sufficiently transparent, the end results are sometimes viewed as unfair by applicants.[21]

    - Considerably more applications are graded as "outstanding" and therefore fundable than there are sufficient funds. As a result, 16 percent of "fundable" SBIR applications were not funded in FY 2015.
    - The process of selecting which "fundable" applications to actually fund is opaque to the applicant, because divisions apply their own priority criteria, which are not published and, in fact, may not exist in written form.

[18]See Appendix E (Case Studies).
[19]See Chapter 2 (Program Management).
[20]See Chapter 2 (Program Management).
[21]See Chapter 2 (Program Management).

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D. The DoE SBIR/STTR programs provide companies some flexibility, but can offer more.[22]

1. DoE provides small amounts of supplementary funding (Phase IIA) when the completion of Phase II research plans can be accomplished with a minor increase in support.
2. DoE will normally extend the timeline for an award.
3. DoE could however offer greater flexibility to make the program more useful to small innovative companies.

- Multiple Solicitations: Currently, DoE releases only one annual solicitation for each division-program, which means that there is one annual window through which a promising technology might be funded through SBIR/STTR.
- Support between Phase I and II: DoE does not at present provide support between Phase I and Phase II. Even if funding is not available, other tools available could provide additional support. For example, NIH reimburses companies for work completed during this gap period if they eventually win a Phase II award.
- Preference for lower cost proposals: Although only maximum funding amounts are set, the selection process does not give preference to companies that seek to perform research at lower cost. As a result, almost all DoE awards are made at the maximum allowable amount.
- Gap funding program: DoE does not offer a gap funding program, such as those offered by some components at DoD. However, DoE is funding more Fast Track awards, which can solve the gap issue for those projects.
- "Open" topics at EERE: Currently, there are no open topics in this area in an effort to limit the number of applications. Adding open topics would substantially increase the programs flexibility in accepting applications covering a wider set of technologies.

E. DoE is seeking ways to improve its data collection and tracking of SBIR/STTR project outcomes.

1. DoE recognizes that longer term tracking of outcomes is essential for effective program management: without outcomes data and analysis it is impossible to determine what is and is not working.
2. DoE has collected outcomes data from companies for some years through a survey of award recipients. The survey is deployed periodically (although not annually) and is web based. DoE did not share these survey results with the National Academies on privacy grounds.

[22]See Chapter 2 (Program Management).

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3. DoE has hired a data analyst to track outcomes, with primary responsibilities in this area. In addition, DoE is also improving access to its own Portfolio Analysis and Management System for analytic purposes.
4. However, DoE does not have a plan to determine which areas should be prioritized for analysis and how this analysis should be integrated into program management.

II. Commercialization

The focus at DoE has primarily been on the commercialization of SBIR- and STTR-funded projects and on the development of technologies that help to meet the agency's mission (discussed separately below). The committee recognizes that issues related to commercialization are complex.[23] For DoE, commercialization objectives are primarily met when projects are commercially successful in private-sector markets. The key findings are as follows:

A. Nearly half of the respondents to the National Academies' 2014 Survey reported some sales, and a further 23 percent reported anticipating future sales.

1. Forty-nine percent of SBIR and STTR respondents reported some sales at the time of the survey.[24] By comparison, 39 percent of the National Academies' 2005 Survey respondents reported some sales.[25]
2. An additional 23 percent of respondents reported that they anticipate future sales,[26] which is greater than the 16 percent figure found in the 2005 Survey.[27]
3. Of those respondents reporting some sales, 25 percent had sales less than \$100,000. Six percent had sales over \$10 million, and an additional 26 percent had sales over \$1 million.[28] The large number of companies with small-scale revenues suggests that although many companies reach the market, few can be described as successful in commercial terms. This finding reflects a deeper understanding of the limitations of the available data on successful commercialization.

[23]See the discussion on "Defining 'Commercialization'" in Appendix F.
[24]See Figure 5-1.
[25]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008, p. 143.
[26]See Figure 5-1.
[27]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008, p. 143.
[28]See Figure 5-2.

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B. Commercialization of DoE SBIR/STTR projects takes place primarily in the domestic private sector.[29] Among surveyed projects reporting sales—

1. An average of 39 percent of project sales were to domestic private-sector customers.[30]
2. An average of 24 percent of project sales were to export customers.[31]
3. An average of 29 percent of sales were to the public sector (primarily state and local governments or other federal agencies).[32]
4. Only an average of 6 percent of reported sales were to DoE.[33]

C. Subsequent investment in DoE SBIR/STTR projects is an indicator that they are seen as having the potential for commercial value even if they have not yet reached the market. [34] The 2014 Survey shows that:

1. Seventy-eight percent of 2014 Survey respondents reported receiving additional investment funding in the technology related to the surveyed project.[35]
2. Overall, the median amount of additional investment was $300,000, and the mean was $814,000. Three out of 245 projects reported additional investments of at least $5 million.[36]
3. The most likely sources of additional investment (other than their own company and personal funds) were non-SBIR/STTR federal funds and the U.S. private sector (reported by 40 percent and 39 percent of respondents respectively). The latter included funding from strategic investors (reported by 20 percent of respondents), angel investors (reported by 5 percent of respondents), and venture capital sources (reported by 2 percent of respondents).[37]

D. Direct job growth from DoE SBIR/STTR awards is in general limited, though some awardees reported large employment gains. [38]

1. The median size of firms responding to the 2014 Survey remained flat at 10 employees between the time of award and the time of the survey.[39] All other things being equal, larger employment gains are more

[29]See Table F-3.

[31]See Table F-3.
[32]See Figure 5-3.
[33]See Figure 5-3.
[34]See Table 5-2.
[35]See Table 5-2.
[36]See Table 5-2.
[37]See Table 5-3.
[38]See Tables F-4 and F-5.
[39]See Tables F-4 and F-5.

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typically associated with the long-term commercialization phase of the resulting innovation, rather than with the research phase.

2. Few firms reported large employment gains: mean employment grew only from 23 to 29.[40]

E. SBIR/STTR funding makes a substantial difference in determining project initiation, scope, and timing. The 2014 Survey data show that:

1. Seventy-one percent of respondents reported that the project probably or definitely would not have proceeded without SBIR/STTR funding.[41]
2. Seventy-four percent of projects that would likely have proceeded anyway would have been narrower in scope.[42]
3. About one-third of projects that would likely have proceeded anyway would have been delayed by at least 1 year.[43]

F. Venture capital funding plays only a modest role for DoE SBIR/STTR firms.

1. Although 78 percent of companies raised additional funds for the technology related to the surveyed project,[44] only 2 percent received funds from venture capitalists (VCs).[45]
2. Energy technologies featured in DoE SBIR/STTR projects typically do not meet the narrow criteria sought by VC firms, including a short timeline to market exit and limited size of funding required.

III. Fostering the Participation of Women and Other Underserved Groups in the SBIR/STTR Programs

A. Current data show that the objective of fostering the participation of women and underserved minorities has not been met by the DoE SBIR/STTR programs.

1. DoE awards data reveal that the participation of woman-owned firms is low and not growing:

    - Woman-owned firms accounted for less than 9 percent of Phase I SBIR and STTR awards in FY 2005-2015.[46] The average success

[40]See Tables F-4 and F-5.
[41]See Table 5-1.
[42] See section on "Project Go-ahead Absent SBIR/STTR Funding" in Chapter 5 (Quantitative Outcomes).
[43]2014 Survey, Question 26. N=27.
[44]See Table 5-2.
[45]See Table 5-3.
[46]See Figure 6-3.

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rates for Phase I applications by firms owned by woman and white males were 15.7 percent and 18.9 percent, respectively, during this period.[47]

- Applications from woman-owned firms accounted for an average of 10 percent of all Phase I applications during FY 2005-2015.[48]
- Among respondents to the 2014 Survey, women accounted for 5 percent of SBIR PIs and 10 percent of STTR PIs.[49]

2. The participation of minority-owned small businesses is low and not growing.

- Minority-owned firms accounted for less than 7 percent of Phase I SBIR and STTR awards during FY 2005-2015.[50]
- The average success rates for Phase I applications by firms owned by minorities and white males were 13.2 percent and 18.9 percent during this period.[51]
- Applications from minority-owned firms accounted for 5.8 percent of all Phase II applications during FY 2005-2015.[52]
- Among respondents to the 2014 Survey, the vast majority of "minority" firms were in fact owned by Asians. Firms owned by Blacks, Hispanics, and American Indians accounted for 2 percent of all responses (including zero Black-owned and American-Indian owned firms).[53]
- Among respondents to the 2014 Survey, minorities accounted for 11 percent of SBIR PIs and 10 percent of STTR PIs. However, no PIs were Black or American Indian, and only 2 percent overall were Hispanic.[54]

B. DoE efforts to "foster and encourage" the participation of woman-owned and minority-owned small businesses are not adequate.[55]

1. DoE outreach efforts have focused more heavily on attracting participation from low-award states than from women-owned and minority-owned small businesses.

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[47]See Figure 6-5.
[48]See Figure 6-1.
[49]See Table 6-5.
[50]See Figure 6-4.
[51]See Figure 6-6.
[52]See Figure 6-8.
[53]See Table 6-4.
[54]See Table 6-5.
[55]See Chapter 6 (Participation of Women and Minorities).

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- The SBA-sponsored Road Show is a primary outreach activity but focuses on low-award states.
- The DoE Annual Report to SBA for FY 2014 mentions a considerable catalog of outreach activities—but mentions underrepresented groups only as a part of one activity.
- Most DoE outreach is conducted in conjunction with other partners. This means that DoE has limited capacity to modify these events to address its own needs. DoE is working to improve reporting on outreach activities with these partners, especially in relation to women and minorities.

2. DoE is developing outreach activities focused on women and minorities. In particular, DoE is planning to work more closely with organizations serving female and minority professionals.

C. DoE is making efforts to understand the patterns of woman and minority participation in the SBIR program, but more is needed. [56]

1. DoE maintains no separate data on small businesses owed by Black Americans, Hispanic Americans, or Native Americans beyond those collected by Dawnbreaker for Phase 0.
2. DoE has not reviewed application and award patterns for women and minorities in detail. These patterns could show differences between woman and minority applications and other applications on a variety of metrics.
3. DoE has sought to contextualize observed trends and patterns of participation by woman- and minority-owned firms against larger patterns of participation in the energy sector. This can help DoE determine whether low participation rates are a function of the energy sector, the SBIR/STTR programs, the financial and business communities, or a combination of these factors.
4. DoE prepared a white paper on the population of woman- and minority-owned businesses in research-heavy sectors—as categorized by the North American Industry Classification System (NAICS)—in 2013.
5. The DoE SBIR/STTR Program Office is undertaking an innovative analysis that utilizes company records in the System for Awards Management (SAMS) database in order to better identify specific NAICS codes relevant to the energy sector. Once complete, this analysis will allow DoE to cross-reference Census business establishment data for these sectors in order to determine the percentages of woman- and minority-owned firms within these

[56]See Chapter 6 (Participation of Women and Minorities).

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NAICs codes. This may turn out to be a valuable project and to provide a methodology that may be applicable to other agencies.

6. However, this work aims only to develop appropriate benchmarks. It does not improve outreach; and focuses only on existing firms, which means that it does not address the need to find applicants who have not yet formed companies, a population that is important in the context of SBIR/STTR.

IV. Stimulating Technological Innovation and Meeting Agency Mission Needs

DoE's agency mission is to enhance "America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions."[57] The twin objectives of using small business to meet federal agency needs and to stimulate technological innovation are closely intertwined and therefore discussed together in this section.

A. The DoE SBIR/STTR programs support the development and adoption of technological innovations that advance the agency's mission.

1. SBIR/STTR topics are initially generated by DoE technical staff (Technical Topic Managers, or TTMs) based on their perception of the technical needs of the programs in which they work.[58]
2. In some cases, topics are designed to generate technologies that are for DoE's direct use, usually in the National Laboratories.
3. "Open" topics, which permit submission of applications that are not limited to problems and technologies described in the DoE solicitations is now standard practice for all DoE science divisions and applied programs except the Office of Energy Efficiency and Renewable Energy (EERE). This approach helps to ensure that potentially important innovations are not excluded by the topic structure, and open topics account for about 7 percent of awards.
4. DoE scoring selects for innovation.[59]

    - The first criterion used in selection scoring for individual projects is "the significance of the technical and-or economic benefits of the proposed work, if successful."
    - Qualitative research confirms that, in practice, SBIR/STTR review focuses heavily on, and provides detailed critiques of, the technical quality of proposals.

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[57] See http://energy.gov-mission. Accessed February 25, 2016.
[58] See section on "Solicitation Topics" in Chapter 2 (Program Management).
[59] See section on "The Review Process" in Chapter 2 (Program Management).

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- However, no explicit criteria focus solely on the innovative characteristics of the proposal. The relevant criterion is only one of four such, and calls for review based on innovation and/or economic impact.

B. The DoE SBIR/STTR programs connect companies to universities and research institutions.

1. Faculty and student participation: Among SBIR awardees responding to the 2014 Survey,

   - 43 percent reported a link to a research institution related to the surveyed project;
   - 26 percent reported that faculty worked on the project (not as a PI);
   - 21 percent employed graduate students for the project; and
   - 29 percent used universities and research institutions as subcontractors for the surveyed project.[60] These percentages are broadly similar to those reported for the 2005 Survey.[61]

2. Research institutions are important project partners: 79 different research institutions were identified by 2014 Survey respondents as partners in 148 total projects; 15 were mentioned by three or more respondents.[62]
3. More than two-thirds of companies responding to the 2014 Survey reported at least one academic founder,[63] and just under one-third reported that the most recent prior employer of a founder was at a research institutions.[64]

C. DoE SBIR/STTR projects generate substantial knowledge-based outputs, such as patents and peer-reviewed publications.

1. Patents: Patenting remains an important component of knowledge diffusion (and protection).

   - Sixty-eight percent of companies responding to the 2014 Survey reported receipt of at least one patent related to any SBIR/STTR-funded technology.[65]

[60]See Table F-13.
[61]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, 153.
[62]See Appendix D (List of Research Institutions Involved in Surveyed DoE SBIR/STTR Awards).
[63]See Table F-15.
[64]See Table F-16.
[65]See Table F-10.

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- Thirty-nine percent of SBIR/STTR respondents reported receipt of at least one patent related to the surveyed technology.[66]

2. Peer-reviewed publications: The 2014 Survey shows that DoE SBIR/STTR firms continue to pursue and achieve scientific publication.

- Seventy-one percent of SBIR respondents and 88 percent of STTR respondents indicated that an author at the surveyed company had published at least one related scientific paper.[67]
- Overall, 39 percent of respondents reported publishing three or more related papers.[68]
- Many of the case study companies reported a great deal of pride in the number of peer-reviewed publications developed by their scientists and engineers, both inside and outside of the SBIR/STTR programs.[69]

D. The DoE SBIR/STTR programs fund some projects that have high scientific or social value, but are unlikely to generate significant market outcomes in the short-term.

1. Small markets: The science divisions of the Department of Energy, in particular, sponsor projects that are not likely to generate large-scale commercial returns. For example, only a few high-energy physics facilities exist in the world, so technologies to support them offer little commercial return despite substantial social and/or scientific impact.
2. Long-cycle research: DoE SBIR/STTR helps support the development of innovations that will take many years to reach the market. Although these projects may hold great potential for positive impact, the time to get to market can be a major barrier for commercial investors. This has been as important characteristic of innovation in energy markets.

E. SBIR/STTR funds the development of research tools, multiplying the impact of the award.

1. Case studies show that the impact of awards can be multiplied if SBIR/STTR technologies are used to develop innovative tools and services for researchers.[70]
2. XIA, for example, produces instruments that are critical to the effective functioning of large accelerators such as the Stanford Linear Accelerator Center (SLAC). Without the relatively modest production of these

[66]See Table F-11.
[67]See Table F-12.
[68]See Table F-12.
[69]See Appendix E (Case Studies).
[70]See Appendix E (Case Studies).

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instruments, these accelerators would be far less efficient, and some experiments could not be run at all.[71]

V. Fostering Innovative Companies

A. The DoE SBIR/STTR programs encourage new firm start-up.

1. Forty-five percent of companies responding to the 2014 Survey indicated that the company was founded entirely or in part because of the SBIR/STTR programs.[72]
2. For some case study companies, SBIR/STTR funding permitted the shift from an exploratory to a professional operation. For some STTR companies in particular, funding permitted university faculty to retain their positions while building the company.[73]

B. DoE SBIR/STTR funding helps small innovative companies in a variety of ways.

1. Early stage: Several survey respondents and case study companies explained that DoE SBIR/STTR funding was provided at a stage when the project was simply too risky for commercial sources of funding. Once the project proceeded further, the risk diminished and additional funding could be acquired.[74]
2. Support for core technology development: DoE SBIR/STTR funding supports technology development, which can be supported through commercial funding further downstream. SBIR/STTR is particularly important for funding proof of concept for new technologies, as described in several case studies as well as in survey responses.[75]
3. Validation and certification effects: DoE SBIR/STTR funding has itself provided important validation for companies seeking further investments, according to discussions with representatives from case study companies and survey responses. The strength of the selection process and growing understanding of SBIR/STTR among both equity and strategic investors may be strengthening this effect.[76]
4. Exploit technology platforms: In some cases, companies use SBIR/STTR funding to build off existing platform technologies specifically to enter new markets. This platform-driven approach is used for example by some companies highlighted in the case studies.[77]

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[71]See XIA, LLC case study in Appendix E.
[72]See Table F-17.
[73]See Appendix E (Case Studies).
[74]See Chapter 7 (Insights from Case Studies and Survey Responses).
[75]See Chapter 7 (Insights from Case Studies and Survey Responses) and Appendix E (Case Studies).
[76]See Chapter 7 (Insights from Case Studies and Survey Responses).
[77]See Appendix E (Case Studies).

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C. Most DoE SBIR/STTR awardees surveyed report positive impacts on their company.

1. Sixty-one percent of respondents to the 2014 Survey indicated that the DoE SBIR/STTR programs "had a highly positive or transformative effect" on their company. Another 35 percent said that it "had a positive effect."[78]
2. Box 8-1 lists the many types of impacts, summarized from the 217 detailed comments received in response to the 2014 Survey.

D. Company dependence on the DoE SBIR/STTR programs is limited.

1. DoE limits the number of applications from a single company to 10 per solicitation, which is similar to the approach taken by the National Aeronautics and Space Administration.[79]
2. Awards are spread widely across the applicant pool.[80]
3. The company's commercialization track record is of growing importance. For example, Dr. Johnson (Muons Inc.) explained that his company's poor commercialization record made it ineligible for DoE SBIR/STTR awards; after becoming more commercial, it started to receive awards again. Clearly, DoE's commercialization requirements have some teeth.[81]
4. Most DoE firms are not dependent on SBIR/STTR awards. Only 25 percent of companies responding to the 2014 Survey reported that SBIR/STTR accounted for greater than one-half of revenues for the most recent fiscal year at the time of the survey, while greater than one-quarter had zero SBIR/STTR-related revenues for the same period.[82] However a considerable number of surveyed firms reported in textual responses that SBIR/STTR was the most important funding source prior to reaching the market.
5. DoE SBIR/STTR projects at many companies do not proceed directly from Phase I to Phase II to commercialization and, as a result, additional funding—which often includes further SBIR/STTR funding—may be needed to reach the market.

[78]See Table F-22.
[79]See Chapter 2 (Program Management).
[80]See Chapter 2 (Program Management).
[81]See case study of Muons, Inc. in Appendix E.
[82]See Table F-19.

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BOX 8-1
Different Ways in Which SBIR/STTR Awards Helped to Transform Companies

A. Unique Source of Seed Funding

- Provided first dollars
- Funded areas where venture capital and other funders were not interested
- Funded new companies and kept companies in business that would not exist without SBIR/STTR funding
- Supported projects with longer time horizons-long sales cycles
- Funded projects in niche markets that are still valuable, and where a company can be sustainable

B. Introduced New Stakeholders and Validated Company Technology

- Opened doors to many potential stakeholders in specific technologies, including agencies, prime contractors, investors, suppliers, subcontractors, and universities
- Gave companies added credibility because SBIR/STTR research is peer reviewed
- Supported adaptation of technologies to new uses, markets, and industry sectors

C. Funded New Technologies

- Funded technology development
- Funded disruptive technologies
- Funded proof of concept
- Supported feasibility testing for high-risk-high-payoff projects

D. Reduced Risk and Costs

- Enabled projects with high levels of technical risk
- Reduced technological risk
- Helped address needs that require high tech at low volume and relatively low cost

E. Encouraged Innovative Firms to Focus on Commercialization

- Provided the basis for spin-off companies
- Encouraged R&D companies to transition into manufacturing
- Provided significant mentoring especially for new businesses

SOURCE: Analysis of company responses to the 2014 Survey. For each bullet multiple responses indicated its importance for surveyed projects and firms.

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- Sixty-three percent of 2014 Survey respondents reported at least one additional SBIR/STTR Phase II award related to the surveyed project.[83]
- Twenty-eight of respondents reported at least two additional Phase II awards related to the surveyed project.[84]

VI. STTR

A. STTR is meeting the program objectives defined in the Small Business Administration's Policy Guidance for STTR.

1. STTR is stimulating technological innovation, as evidenced by the substantial knowledge effects identified in Chapter 5 and the relevant case studies referenced in Chapter 7.
2. STTR fosters cooperative R&D between universities and other research organizations and industry.

   - Thirteen percent of STTR awardees responding to the 2014 Survey reported that the PI was a faculty member at the partnering research institution.[85]
   - Some companies profiled in this report as case studied indicated that STTR helped to bridge the gap between research laboratories and commercial activities.[86]

3. STTR at DoE is meeting the objective of supporting the commercialization of federally funded technologies.

   - Thirty-three percent of STTR awardees responding to the 2014 Survey reported sales from the surveyed project, and a further 43 percent anticipated sales in the future.[87]
   - More DoE STTR awardees than SBIR awardees responding to the 2014 Survey reported additional investment in the technology aside from program funds (86 percent and 78 percent, respectively).[88]

B. At DoE, the STTR program is administered as an adjunct to the much larger SBIR program.[89]

[83]See Table F-21.
[84]See Table F-21.
[85]See Table F-13.
[86]See, for example, case study of Calabazas Creek Research in Appendix E.
[87]See Table F-1.
[88]See Table 5-2.
[89]See Chapter 2 (Program Management).

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1. Discussions with DoE staff confirm that the agency jointly operates the SBIR and STTR programs, with minor differences in participation rules.

   - Solicitations for STTR and SBIR are announced jointly.
   - Companies can apply jointly for both programs.
   - The agency does not have different strategic objectives for the two programs.

C. Outcomes from STTR are broadly similar to those from SBIR, but there were some differences that should be noted.

1. Based on 2014 Survey data, STTR shows substantially greater levels of connection to research institutions than does SBIR, across most categories.[90]
2. Regarding commercialization outcomes, STTR awardees responding to the 2014 Survey were less likely than SBIR awardees to claim that products had already reached the market (33 versus 52 percent). At the same time, they were more likely to claim that the product would reach the market in the future (43 versus 20 percent).[91]
3. Regarding knowledge effects, SBIR awardees responding to the 2014 Survey reported fewer patents related to any SBIR or STTR award received by the company than did responding STTR awardees (66 percent compared with 86 percent).[92]

D. In some cases, companies utilize STTR and SBIR differently.

1. STTR permits PIs to spend less than 51 percent of their time on the funded project. SBIR does not. As a result, PIs who wish to retain a half-time position or more at a research institution find STTR to be a preferable option.
2. STTR also permits subcontracting a larger share of the award to the research institution, which is useful when a company requires specialized equipment or skill sets.

E. The DoE SBIR and STTR programs are not sufficiently integrated with the DoE National Laboratories.

1. Collaborating with the National Laboratories can be challenging for small innovative businesses.

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[90]See Table F-13.
[91]See Table F-1.
[92]See Table F-10.

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- Analysis of STTR in particular suggests that National Laboratories generally do not make good formal partners for small business concerns; their administrators do not prioritize SBIR/STTR because the funding amounts are small; and small businesses have limited leverage if the Laboratories fail to meet their obligations.
- The Laboratories are viewed as bureaucratic and unsympathetic to the needs of small businesses.
- The Laboratories also present difficulties from an IP perspective, because their culture is dominated by open academic exchange, which may not accommodate SBC desire to protect commercially important information.[93]
- Even though National Laboratories staff play a significant role in developing topics for SBIR/STTR, the Laboratories have no formal process for utilizing SBIR/STTR technologies, and some companies say that selling into the Laboratories is difficult.[94]

2. There is potential for more fruitful collaboration between SBIR and STTR awardees and the National Laboratories.

    - A substantial share of STTR awards are made to collaborations that include the National Laboratories.
    - Case study evidence suggests that there can be fruitful collaborations between small business concerns and the National Laboratories, especially when company founders have deep understanding of and connection to the Laboratories.[95]
    - Several companies reported successful engagements with the Laboratories when the latter acted as subcontractor for SBIR awards.[96]
    - Collaborations can be driven by the SBC, which requires expertise or equipment from the Laboratory, or by the Laboratory, which seeks to commercialize a new technology. Although there are no hard data, evidence from case studies suggests that the former is the dominant kind of arrangement.[97]

3. The DoE SBIR and STTR programs have not made sufficient efforts to enhance collaborations between the National Laboratories and small innovative firms.

    - There is no program in place to connect SBIR and STTR companies to other opportunities at the National Laboratories, even though National

[93]See, for example, case study of XIA, LLC in Appendix E.
[94]See, for example, case study of Vista Clara in Appendix E.
[95]See, for example, case study of Muons, Inc. in Appendix E.
[96]See, for example, case study of Calabazas Creek Research in Appendix E.
[97]See Chapter 2 (Program Management).

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Laboratories staff are often the source of topics for which funding was provided.[98]

- The National Academies' 2008 report on the DoE SBIR program recommended increased use of National Laboratories as subcontractors and improved tracking of linkages between SBIR/STTR and the National Laboratories. These recommendations have not yet been adopted.

RECOMMENDATIONS

Although the DoE SBIR/STTR programs generate substantially positive outcomes, the committee has identified a series of recommendations to improve their processes and outcomes. The order of these recommendations reflects the relative emphasis of the committee. The first set of recommendations addresses improving monitoring, evaluation, and assessment. The second set addresses the challenge of drawing more woman- and minority-owned companies into the programs. The third set of recommendations focuses on ways to improve the commercialization of SBIR/STTR projects, followed by recommendations related to the National Laboratories, and then to program management more generally. A detailed description follows the summary of key points below.

Summary of Recommendations

I. Improving Monitoring, Evaluation, and Assessment

A. DoE should improve current data collection approaches and methodologies.
B. DoE should ensure that the outcomes data it now collects are systematically employed to guide program management.
C. DoE should prepare a comprehensive SBIR/STTR Annual Report that replaces current reporting requirements and provides a clear picture of program operations to the Secretary of Energy, Congress, and the public.

II. Addressing Underserved Populations

A. Quotas are not necessary.
B. DoE should accelerate its efforts to develop new benchmarks and metrics.
C. DoE should develop an outreach and education program focused on expanding participation of underserved populations.
D. DoE should review selection procedures and remove any identified biases in the selection process.

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[98]See Chapter 2 (Program Management).

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III. Improving Commercialization Outcomes

A. DoE should support the commercialization of SBIR and STTR supported technologies beyond the completion of Phase II.
B. DoE should review the effectiveness of its commercialization support and training initiatives.

IV. Improving Linkages to National Laboratories

A. DoE should seek to develop programs linking Laboratories' procurement actions with relevant SBIR/STTR projects.
B. DoE should seek ways to ensure that Laboratories fully understand and respect the intellectual property (IP) provisions of SBIR/STTR.
C. DoE should examine from a strategic perspective how the relationship of SBIR/STTR with the National Laboratories works today.

V. Improving Program Management

A. DoE should improve its topic development process.
B. DoE should change the balance of funding to better reflect innovation and commercialization opportunities in the private sector.
C. Although commercialization is an important program objective, DoE should not treat it as the only objective of the SBIR/STTR programs.
D. DoE should review and possibly rethink the relationship between the National Laboratories and SBIR/STTR.
E. DoE should improve its application review system and monitor the profile of applicants.
F. DoE should further address the funding gap between Phase I and II awards.

I. Improving Monitoring, Evaluation, and Assessment

The development of more monitoring and more sophisticated analysis of key variables is necessary to improve program outcomes. Although DoE recognizes the need for better data and is working to improve tracking mechanisms, more remains to be done in this area.

A. DoE should improve current data collection approaches and methodologies.[99]

1. DoE should improve data collection and organization.

- Data collection should be ongoing rather than periodic.

[99] See Finding I-E.

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- Data collection should address the entire range of congressionally mandated outcomes, not just commercialization, and should be extended to other aspects of the program, including demographic data for applicants and awardees.

2. DoE should expand tracking of commercialization outcomes.

- DoE should track commercialization outcomes drawing on a complement of metrics in order to provide a deeper and more nuanced basis for analysis.
- The data collection effort now under way at SBA may provide DoE with additional capabilities.

3. DoE should collect enhanced demographic data.

- DoE should take immediate steps to improve its collection of demographic data about PIs. Although DoE has explained that the provision of such data is voluntary under current federal mandates, DoE can encourage applicants to provide these valuable data.
- DoE should extend its collection of the demographics of company ownership to show which of SBA's socially and economically disadvantaged categories an applicant company belongs to. Although the provision of these data is also voluntary, in this case, some data is better than no data. DoE does collect these data through Dawnbreaker in relation to the pilot Phase 0 program.

4. DoE should also develop and adopt a more systematic and critical approach to the use of detailed case studies and success stories.

- Case studies—written by DoE staff or third parties—can describe the roles played by SBIR/STTR awards, the challenges faced by small businesses, insights into needed improvements in process, lessons learned, and other important information not available elsewhere about program impacts. Currently, the available case studies are limited in number and scope and do not provide an effective review of program successes.
- Success stories—provided by the companies—can provide inspiration and promote interest in the program, but should not be regarded as evidence of program effectiveness.

5. DoE should take advantage of modern information management and data visualization tools to communicate with companies about program activities and operations and to facilitate networking of program participants.

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- DoE should explore ways to use new technology such as social media to collect more current data. SBIR/STTR companies—like "customers" in other markets—are an important source of information about program strengths and weaknesses. This knowledge is currently not systematically included in internal program evaluation by the DoE SBIR/STTR programs.

6. DoE should develop appropriate feedback tools for applicants and awardees. Although DoE program staff talk to participating companies daily, it has not collected systemic feedback. DoE should develop pathways for companies to provide feedback about program activities and operations. These should include various electronic communication tools.

B. DoE should ensure that the outcomes data it now collects are systematically employed to guide program management.[100]

1. DoE should develop a plan for data analysis: The agency should seek to develop a more sophisticated approach to analyzing and applying the data that are already collected, to ensure that congressional objectives are being met, provide a data-driven basis for program improvements, and analyze outcomes from pilot initiatives.
2. DoE should in particular seek data that will help to identify factors that tend to encourage successful transitions between Phases, into Phase IIB, and then into full-scale commercialization.
3. These more comprehensive data can be the basis for addressing a range of key program management issues, such as:

- What is the long-term impact of commercialization training, partnership programs, and other commercialization supports?
- Is Phase IIB simply selecting successful companies or is it at least, in part, causing companies to be successful?
- Are some National Laboratories better partners than others? Are there Laboratories that could provide best practices in this area?
- How well do DoE selection processes predict eventual successful projects?
- How well do commercialization plans presented in applications track in outcomes? Are they related, and, if not, then should the plan be changed or even eliminated (for either Phase I or Phase II)?
- How effectively do initiatives such as direct to Phase II, Phase 0, and Phase IIB improve outcomes?

[100]See Finding I-E.

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- How do applications from woman- and minority-owned firms transition through the SBIR/STTR pipelines into eventual commercialization? How does this compare to other applications?

4. DoE should recognize the impacts of effective data collection and analysis. In some cases, simply measuring something more closely can provoke needed action. For example, closely tracking the participation of women and minorities could help assure a fair process and surface problem issues early, when they can be most easily corrected.

C. DoE should prepare a comprehensive SBIR/STTR Annual Report that replaces current reporting requirements and provides a clear picture of program operations to the Secretary of Energy, Congress, and the public.[101]

1. New annual report: The imposition of new reporting burdens on the DoE SBIR/STTR programs does not come without cost; however, an annual report to Congress could improve transparency and provide a coherent point of discussion for stakeholders.
2. Although the precise details should be left to the agency, DoE should consider discussion of the following areas of program operations in the annual report:

   - Program Inputs: Budget and related resources input at the program's front end.
   - Program Outputs: Initiatives developed, outreach conducted, competitions-solicitations held, applications-proposals received, awards and contracts made.
   - Program Results:

     - Early outcomes: Progress measures such as attraction of additional funding by awardees, formation of partnerships, early sales, patents, publications, and licensing agreements.
     - Intermediate outcomes: Resulting company growth in sales, employment, and knowledge benefits through the citation of patents and publication.
     - Long-term outcomes: Measures of the economic return on investment, improvements in national innovation capacity, gains in strength of small businesses attributed to the programs, and growth in the numbers and percentage of women and minority businesses comprising the SBIR/STTR client base.

[101]See Finding I-E.

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  - Qualitative review, based on improved use of case studies, as well as success and failure stories and social media.

- Impact assessment, focused on the extent to which DoE meets congressional objectives for the program.
- Summary conclusions, including prospective views on program activities and improvements for the coming year.

3. Congress should take steps to support this development by consolidating existing reporting demands into the proposed new framework. The new Annual Report should replace all existing reporting required from the program.

II. Addressing Underserved Populations

In light of the data presented in Chapter 6 and summarized in section III of the findings above, DoE should immediately extend past and current efforts to foster the participation of underserved populations in the SBIR/STTR programs, develop an outreach and education program focusing on these populations, and create benchmarks and metrics to relate the impact of such activities.[102]

A. Quotas are not necessary.[103] While DoE should strive to increase participation of under-represented populations in the SBIR/STTR programs, it should not develop quotas for that purpose.

B. DoE should accelerate its efforts to develop new benchmarks and metrics.[104]

1. Improve participation metrics: DoE should complete and publish its current work on mining the System for Award Management (SAM) database to define appropriate NAICs codes, which can then be matched to Census data to estimate the population of woman- and minority-owned firms that constitute the pool of potential SBIR/STTR applicants.

   - DoE's previous work provides a useful basis for the current effort.
   - If successful, the work now under way may have applications for other agencies.
   - DoE should ensure that its data collection and analysis apply to all congressional objectives, not only commercialization.

[102]See Finding III.
[103]See Box 6-3.
[104]See Finding III-C.

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2. Disaggregate benchmarks: Measures of the participation of socially disadvantaged groups should be disaggregated by race or ethnicity, and attention should be focused on the congressional intent to support "minority" participation. The current SBA definition of "socially and economically disadvantaged" is not 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. Benchmarks should address the following metrics, all of which should include both absolute levels and trends over time:

    - Shares of applications from companies owned by women and minorities.
    - Shares of applications with woman and minority PIs.
    - Shares of Phase I awards to companies owned by women and minorities.
    - Shares of Phase I awards with female and minority PIs.
    - Shares of Phase II awards to companies owned by women and minorities.
    - Shares of Phase II awards with female and minority PIs.

4. Track related program operations: Metrics should also track related program operations including outreach efforts (see below).

C. DoE should develop an outreach and education program focused on expanding participation of underserved populations.[105]

1. DoE's new Phase 0 program is a promising initiative. However, its initial focus on supporting existing applicants and on under-served states is not sufficient to meet the need for enhanced outreach.
2. Develop enhanced outreach strategy: DoE should develop a coherent and systematic outreach strategy that provides for cost-effective approaches to enhance recruitment of woman- and minority-owned companies, as well as female and minority PIs, developed in conjunction with other stakeholders and experts in the field. Outreach should aim to expand SBIR/STTR awareness among potential applicants from underserved demographics.
3. Add-ons to existing outreach activities are not sufficient. There is no evidence that a panel at the national SBIR conference has attracted significant numbers of new participants from target demographics (or indeed any demographics) into the program. The SBA Bus Tour is

[105]See Finding III-B.

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targeted more at reaching potential applicants in underserved states than attracting women and minorities to the program. Focused and extensive outreach activities will be needed.

4. Provide management resources: DoE should provide significant management resources, because these outreach efforts are likely to be difficult and long term, and should consider designating a senior staff member to work exclusively on outreach to women and minorities to improve reporting and deployment of the new initiatives.

D. DoE should review selection procedures and remove any identified biases in the selection process.[106]

1. Review selection processes: DoE should review internal award and selection data and processes to address questions arising from disparities between Phase I and Phase II success rates for woman- and minority-owned firms and firms not in those categories. The goal is to ensure that there are no biases in the selection process that adversely affect the selection of women and minorities.
2. Monitor selection processes: DoE should ensure that patterns of applications, awards, and success rates are monitored and reported out annually.
3. DoE should ensure that reviewers include appropriate numbers of women and minorities. One additional reason to increase the number of reviewers is to expand this pool.

III. Improving Commercialization Outcomes

The DoE SBIR/STTR programs are fulfilling their commercialization mission despite the substantial barriers to commercializing innovative research. However, possible improvements are worth consideration.

A. DoE should support the commercialization of SBIR and STTR supported technologies beyond the completion of Phase II.[107]

1. DoE is well positioned to support company commercialization efforts. Without undertaking resource-intensive efforts, it is still possible to develop programs that support companies in this critical area. For example:

   - DoE could undertake its own version of the Navy Opportunity Forum to connect SBIR/STTR companies with investors and strategic

[106]See Finding III-B.
[107]See Finding I-B.

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partners, or find ways to work with existing conferences as appropriate (as, for example, NIH does with BIO conferences).

- DoE could adopt the online approaches used by the Air Force and NASA to develop attractive and searchable databases of companies and technologies, which could be publicized to potential investors and partners.

B. DoE should review the effectiveness of its commercialization support and training initiatives.[108]

1. While DoE should be commended for providing commercialization support on a regular basis to both Phase I and Phase II SBIR/STTR awardees, it should consider whether current commercialization support is effective. By the time the Dawnbreaker contract expires in March 2017, DoE should have developed and implemented a methodology for assessing the impact of Dawnbreaker's work.
2. More generally, the DoE SBIR/STTR Program Office should review initiatives to assess apparent successes for potential expansion and to learn from failures.
3. More broadly, DoE should consider whether its current approach to require cost sharing for downstream demonstration (non-SBIR/STTR) projects outside the Office of Science is appropriate for small innovative firms. High cost-sharing requirements are a barrier to participation for these firms.

IV. Improving Linkages to National Laboratories[109]

The National Laboratories perform multiple functions in relation to SBIR/STTR. Their staff generate many of the topics, account for about 40 percent of reviewers, provide important access to expertise and equipment for both SBIR and STTR projects, are formal partners for many STTR projects; and are significant customers for some SBIR/STTR technologies. The following recommendations are predominantly for DoE senior management, rather than SBIR/STTR Program Office staff.

A. DoE should seek to develop programs linking Laboratories' procurement actions with relevant SBIR/STTR projects.

1. Significant sole sourcing advantages of SBIR/STTR awards should be highlighted to Laboratory management and contracts officers.
2. DoE should review DoD procedures for ensuring that SBIR/STTR topics are sponsored by acquisition elements of the agency. Although this will

[108]See Finding I-B.
[109]Recommendations in this section are based on the analysis summarized in findings in section VI-E.

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not always—or even most often—be the case at DoE, the Laboratories should be positioned to ensure that SBIR/STTR technologies developed at the instigation of Laboratories staff are fully considered for purchases downstream.

B. DoE should seek ways to ensure that Laboratories fully understand and respect the intellectual property (IP) provisions of SBIR/STTR.

1. Although formal IP clauses are always part of STTR partnerships agreements, and are often part of SBIR subcontracts, DoE should ensure that staff acting as technical points of contact for these agreements understand and agree with these provisions.
2. DoE should review its procedures in cases when IP is covered by an agreement with an SBC but is not treated appropriately.

C. **DoE should examine from a strategic perspective how the relationship of SBIR/STTR with the National Laboratories works today**.

1. The review should explore how these relationships could be improved.
2. Should DoE conclude that the relationships incurs more costs than benefits, it should seek to reduce the relationship along several dimensions (e.g. using more external reviewers, reducing incentives to partner with National Laboratories, reducing the use of SBIR/STTR to serve the specific scientific objectives of Laboratories' staff at the expense of commercialization).

V. Improving Program Management

The following recommendations are designed to improve program operations in ways that should enhance the program's ability to address some or all of its objectives.

A. DoE should improve its topic development process.[110] The current topic development process has been criticized by companies from a number of perspectives. DoE should make the following changes:

1. Unfunded subtopics: Although the current process allows DoE to prioritize subtopics after proposals are received, this approach ignores the cost to applicants. DoE should seek to ensure that all published topics are funded. Non-funded topics should be a rare event—for example, when for unexpected reasons no fundable applications were received.
2. Recurring subtopics: Although subtopics rotate more often than topics, DoE should seek to ensure that the same subtopics do not recur regularly,

[110]See Finding I-B and Finding I-D.

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unless it has a specific reason to seek a technology that it has not yet found.

3. Noncommercial topics: DoE should enhance its cross-checks of subtopics to ensure that they meet DoE's own definition of an appropriate internal rate of return for projects. It is not appropriate to write a subtopic for technology that is designed for use in a handful of National Laboratories and to then expect applicants to meet rigorous commercialization standards. More generally, DoE should clarify selection guidelines so that reviewers are clear on the appropriate balance between agency need and commercialization potential, which may vary by topic.
4. Because "open" subtopics provide funding opportunities for important projects that go beyond the areas defined in specified subtopics, they should be used for topics selected by EERE.

B. DoE should change the balance of funding to better reflect innovation and commercialization opportunities in the private sector.[111] In recent years, DoE has sharply limited opportunities in EERE, partly by eliminating open topics and partly by narrowing the published topics and subtopics. This action is a direct result of the way funds are allocated within DoE, with each program receiving more or less a pro rata amount of funding based on its overall extramural expenditures.

1. DoE should allocate funding based on the needs of the agency, not the individual divisions or programs.
2. Funding decisions should be data-driven, guiding funding toward opportunities that maximize the return to DoE's investment (return on investment should be considered as a broad concept, not simply as revenue from commercialization).
3. DoE should consider reallocating funds in part based on a division or program's willingness to work with SBIR/STTR to DoE should ensure that its solicitation is designed to meet all program objectives.

C. Although commercialization is an important program objective, DoE should not treat it as the only objective of the SBIR/STTR programs.[112]

1. DoE should ensure that a commercialization filter for applications is not only appropriate, but also used judiciously and does not result in insufficient levels of innovation or risk within the program. DoE will therefore need to develop mechanisms to identify and encourage high-risk/high-reward projects.

[111]See Finding I-B.
[112]See Finding I-B.

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D. DoE should review and possibly rethink the relationship between the National Laboratories and SBIR/STTR.[113]

1. DoE should consider creating a task force to review the role of the National Laboratories in the SBIR/STTR program. Such a review is overdue and could lead to significant and positive improvements. As part of the review, DoE should seek to develop mechanisms for improving and strengthening the links between National Laboratories and SBIR/STTR. These could include:

   - Mandatory training in SBIR/STTR for DoE contracting officers with National Laboratories responsibilities
   - Incentives for utilizing SBIR/STTR technologies (e.g., prioritizing topics from National Laboratories staff with a track record in adopting such technologies)

2. Alternatively, DoE should consider ways to reduce linkages between the National Laboratories and SBCs, as the currently relationship may on balance be dysfunctional.

E. DoE should improve its application review system and monitor the profile of applicants.[114]

1. DoE should consider whether its current requirements for Phase I commercialization plans are appropriate.

   - DoE should consider whether a formal commercialization plan is appropriate for Phase I. There is evidence that early attention to commercial possibilities is important for eventual success, but many technologies find applications not envisaged accurately at early stages of development.
   - DoE should determine through post facto review whether Phase I commercialization plans have any correlation with commercialization activities after Phase II. If not, such plans simply add noise to the signal.

2. DoE should review the use of commercialization plans for Phase II.

   - DoE should undertake a detailed review to determine whether the Phase II plans submitted are useful predictors of eventual commercial outcomes.

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[113]See Finding VI-E.
[114]See Finding I-C.

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- DoE should consider whether a less burdensome set of requirements would provide sufficient information about company commercialization plans (which are in any event highly likely to change during Phase II).

3. DoE should ensure that the selection criteria are fully transparent.

- If the final decision is based on DoE priorities, rather than application quality, then these priorities should be made public before the solicitation is published.
- If however the final decision is based on application quality (rather than agency priorities), then DoE should consider adopting a scoring system that makes these differences transparent.

4. DoE should consider moving to a system in which reviewers arrive at a consensus score.

- Such a system would require some one-to-one interaction between reviewers, which some companies observed would substantially improve the quality of reviews by making sure that the views of individual reviewers are challenged. Companies noted that NIH uses such a process, with success.
- Despite the additional costs involved, DoE should consider adopting best practice from other agencies and competitions and add more reviewers. Two reviewers are simply too few to ensure that the review is fair.

5. DoE should find ways to allow companies to rebut poor-quality reviews and to elucidate their approach where necessary.

- One option is for DoE to use available electronic tools to allow for a limited company rebuttal prior to selection.
- Another option, which is used at NIH, is to permit companies to formally resubmit an application. This approach makes failures in the review process less definitive. DoE could consider adopting a formal resubmission process, although the single annual solicitation makes this a less promising alternative.

6. DoE should monitor the percentage of multiple awards and the composite age of company applicants (e.g., ratio of startups to mature companies) who are applying for and receiving awards.[115]

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[115]See Finding I-A-7.

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- Careful monitoring and study should inform the question of whether "small" or "young" companies are more effective in generating state-of-the-art technology and innovation in the context of SBIR.
- This evidence can be used by Congress to determine if encouraging participation by younger firms furthers the missions of the SBIR program.

F. DoE should further address the funding gap between Phase I and II awards.

1. DoE should permit companies to "work at their own risk." Under this approach, used at the NIH SBIR program, companies can be paid for work completed during the gap period if they eventually receive a Phase II. This adds no risk to the agency and could shorten time to commercialization.
2. DoE should consider additional ways to provide financial support during funding gaps. For example, such support might be available to top scoring Phase II proposals as a supplement to their Phase I award, using an approach similar to that used at several DoD components.

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APPENDIXES

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Appendix A

Overview of Methodological Approaches, Data Sources, and Survey Tools

This report on the Small Business Innovation Research (SBIR) and Small Business Technology Transfer programs at the Department of Energy (DoE) is a part of a series of reports on SBIR and STTR at the National Institutes of Health (NIH), Department of Defense (DoD), NASA, and National Science Foundation (NSF). Collectively, they complement and earlier assessment of the SBIR program by the National Academies of Sciences, Engineering, and Medicine, completed in 2009.[1]

The first-round assessment of SBIR, conducted under a separate ad hoc committee, resulted in a series of reports released from 2004 to 2009, including a framework methodology for that study and on which the current methodology builds.[2] Thus, as in the first-round study, the objective of this second-round study is "*not* to consider if SBIR should exist or not"—Congress has already decided affirmatively on this question, most recently in the 2011 reauthorization of the program.[3] Rather, we are charged with "providing assessment-based findings of the benefits and costs of SBIR . . . to improve public understanding of the program, as well as recommendations to improve the program's effectiveness." As with the first-round, this study "will *not* seek to compare the value of one area with other areas; this task is the prerogative of the Congress and the Administration acting through the agencies. Instead, the study is concerned with the effective review of each area."

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[1]Effective July 1, 2015, the institution is called the National Academies of Sciences, Engineering, and Medicine. References in this report to the National Research Council or NRC are used in an historic context identifying programs prior to July 1, 2015.
[2]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, Washington, DC: The National Academies Press, 2004.
[3]National Defense Authorization Act of 2012 (NDAA) HR.1540, Title LI.

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These areas refer to the four legislative objectives of the SBIR program:[4]

- Expand the U.S. technical knowledge base
- Support agency missions
- Improve the participation of women and minorities
- Commercialize government-funded research

The parallel language for STTR from the SBA's STTR Policy Directive is as follows:

> *(c) The statutory purpose of the STTR Program is to stimulate a partnership of ideas and technologies between innovative small business concerns (SBCs) and Research Institutions through Federally-funded research or research and development (R/R&D). By providing awards to SBCs for cooperative R/R&D efforts with Research Institutions, the STTR Program assists the small business and research communities by commercializing innovative technologies.*[5]

The SBIR/STTR programs, 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 these programs presents formidable challenges. Among the more difficult are the following:

- **Lack of data.** Tracking of outcomes varies widely across agencies, and in no agency has it been successfully implemented into a fully effective tracking system. There are no successful systematic efforts by agencies to collect feedback from awardees.
- **Intervening variables.** Analysis of small businesses suggests that they are often very path dependent and, hence, can be deflected from a given development path by a wide range of positive and negative variables. A single breakthrough contract—or technical delay—can make or break a company.
- **Lags.** Not only do outcomes lag awards by a number of years, but also the lag itself is highly variable. Some companies have sales within 6 months of award conclusion; others take decades. In addition, often the

[4]The most current description of these legislative objectives is in the Policy Guidance provided by the Small Business Administration (SBA) to the agencies. SBA Section 1.(c) SBIR Policy Directive, October 18, 2012, p. 3.

[5]Small Business Administration, Office of Investment and Innovation, "Small Business Technology Transfer (STTR) Program— Policy Guidance," updated February 24, 2014.

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biggest impacts take many years to peak even after products have reached markets.

ESTABLISHING A METHODOLOGY

The methodology utilized in this study of the SBIR/STTR programs builds on the methodology established by the committee that completed the first-round study of the SBIR program.

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.[6]

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.*[7]

[6]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, 2.
[7]National Research Council, *An Assessment of the Small Business Innovation Research Program: Project Methodology*, 2.

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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; initial public offering	Patent counts and other intellectual property/employment growth, number of new technology firms	Agency procurement of products resulting from SBIR work
Tools	Case studies, agency program studies, study of repeat winners, bibliometric analysis	Phase II surveys, program manager surveys, case studies, study of repeat winners	Phase I and Phase II surveys, case studies, study of repeat winners, bibliometric analysis	Program manager surveys, case studies, agency program studies, study of repeat winners
Key Research Challenges	Difficulty of measuring quality and of identifying proper reference group	Skew of returns; significant interagency and inter-industry differences	Measures of actual success and failure at the project and firm levels; relationship of federal and state programs in this context	Major interagency differences in use of SBIR to meet agency missions

NOTE: Supplementary tools may be developed and used as needed. The committee notes that while sales is a legitimate indicator of progress toward commercialization, it is not a reliable measure that commercial success has occurred.
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.

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TOOLS UTILIZED IN THE CURRENT STUDY

Quantitative and qualitative tools being utilized in the current study of the SBIR/STTR programs include the following:

- **Case studies.** The committee commissioned in-depth case studies of 12 SBIR and STTR recipients at DoE. These companies are geographically diverse, demographically diverse, and funded by several different DoE programs, and they are at different stages of the company life cycle.
- **Workshops.** The committee convened a number of workshops to allow stakeholders, agency staff, and academic experts to provide unique insights into the program's operations, as well as to identify questions that need to be addressed.
- **Analysis of agency data.** A range of datasets covering various aspects of agency SBIR/STTR activities were sought from DoE and other sources. The committee has analyzed and included the data that was received as appropriate.
- **Survey of award recipients**. All PIs that received a Phase II SBIR or STTR award from DoE between FY 2001 and FY 2010 were surveyed by a contractor for the National Academies. Details are discussed below.
- **Open-ended responses from SBIR/STTR recipients.** For the first time, the committee solicited textual responses, drawing more than 200 observations from DoE SBIR/STTR respondents (respondents were asked to describe in their own words significant long-term impacts of the SBIR/STTR programs on their company).
- **Agency interviews.** Agency staff was consulted on the operation of the SBIR/STTR programs, and most were helpful in providing information both about the program and about the challenges that they faced.
- **Literature review.** In the time period since the start of our research in this area, a number of papers have been published addressing various aspects of the SBIR program. In addition, other organizations, such as the Government Accountability Office (GAO), have reviewed particular parts of the SBIR program. These works are referenced in the course of this analysis.

Taken together with our committee deliberations and the expertise brought to bear by individual committee members, these tools provide the primary inputs into the analysis.

We would stress that, for the first-round study and for our current study, multiple research methodologies feed into every finding and recommendation. No findings or recommendations rest solely on data and analysis from the survey; conversely, data from the survey are used to support analysis throughout the report.

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COMMERCIALIZATION METRICS AND DATA COLLECTION

Congressional discussions of the SBIR program in the context of the 2011 reauthorization reflected strong interest in the commercialization of technologies funded through SBIR. This enhanced focus is understandable: the investment made should be reflected in outcomes approved by Congress.

However, no simple definition of "commercialization" exists.[8] Broadly speaking, in the context of the program it means funding for technology development beyond that provided under Phase II SBIR funding. At DoE, most commercialization occurs outside the agency, mostly in the private sector (as survey results indicate).

In the 2009 report on the DoE SBIR program[9] the committee charged with that assessment held that a binary metric of commercialization was insufficient. It noted that the scale of commercialization is also important and that there are other important milestones both before and after the first dollar in sales that should be included in an appropriate approach to measuring commercialization. The committee carrying out the current study further notes that while sales is a legitimate indicator of progress toward commercialization, it is not a reliable measure that commercial success has occurred.

Challenges in Tracking Commercialization

Despite substantial efforts at DoE, described below, significant challenges remain in tracking commercialization outcomes for the DoE SBIR/STTR programs. These include the following:

- **Data limitations.**
- **Linear linkages.** Tracking efforts usually seek to link a specific project to a specific outcome. Separating the contributions of one project is difficult for many companies, given that multiple projects typically contribute to both anticipated and unanticipated outcomes.
- **Lags in commercialization.** Data from the extensive DoD commercialization database suggest that most projects take at least 2 years to reach the market *after the end of the Phase II award*. They do not generate peak revenue for several years after this. Therefore, efforts to measure program productivity must account for these significant lags.
- **Attribution problems.** Commercialization is often the result of several awards, not just one, as well as other factors, so attributing company-level success to specific awards is challenging at best.

[8]See Chapter 5 (Quantitative Outcomes) for related analysis of commercialization in the SBIR program.
[9]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2009.

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Why New Data Sources Are Needed

Congress often seeks evidence about the effectiveness of programs or indeed about whether they work at all. This interest has in the past helped to drive the development of tools such as the Company Commercialization Record database at DoD. However, in the long term the importance of tracking lies in its use to support program management. By carefully analyzing outcomes and associated program variables, program managers should be able to manage more successfully.

We have seen significant limitations to all of the available data sources. Unfortunately, DoE declined to share its tracking data on privacy grounds, so we are unable to draw conclusions about the quality or extent of DoE data collection, and the data itself were not made available for our use.

BEYOND COMMERCIALIZATION METRICS

Although Congressional interest has focused primarily on commercialization in recent years, it remains the case that there are four congressionally mandated objectives for the SBIR program, and that commercialization is only one of them. STTR adds additional objectives beyond commercialization. DoE's data collection tools focus almost exclusively on that commercialization; they appear to have limited capabilities for collecting data about the other three SBIR program objectives described in the introduction to this appendix.

OVERVIEW OF THE SURVEY

Our analysis of the SBIR and STTR programs at DoE make extensive use of case studies, interviews, and other qualitative methods of assessment. These sources remain important components of our overall methodology, and Chapter 7 (Insights) is devoted to lessons drawn from case studies and other qualitative sources. But qualitative assessment alone is insufficient.

The Role of the Survey

The survey offers several significant advantages over other data sources, as it

- covers all kinds of commercialization inside and outside of DoE;
- provides a rich source of textual information in response to open-ended questions;
- probes more deeply into company demographics and agency processes;
- addresses principal investigators (PIs), not just company business officials;

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- allows comparisons with previous data-collection exercises; and
- addresses other Congressional objectives for the program beyond commercialization.

At the same time, however, we are fully cognizant of the limitations of this type of observational survey research in this case. To address these issues while retaining the utility and indeed explanatory power of survey-based methodology, this report contextualizes the data by comparing results to those from the survey conducted as part of the first-round assessment of the SBIR program (referred to below as the "2005 Survey"[10]). This report also adds transparency by publishing the number of responses for each question and indeed each subgroup, thus allowing readers to draw their own conclusions about utility of the data.

We contracted with Grunwald Associates LLC to administer a survey to DoE award recipients. This 2014 survey is based closely on the 2005 Survey but is also adapted to lessons learned and includes some important changes discussed in detail below. A methodology subgroup of the committee was charged with reviewing the survey and the reported results for best practice and accuracy. The 2014 Survey was carried out simultaneously with surveys focused on the SBIR programs at NIH, and followed a survey in 2011 of awardees at NASA, NSF, and DoD.[11]

The primary objectives of the 2011 and 2014 surveys were as follows:

- Provide an update of data collected in the National Academies survey completed in 2005, maximizing the opportunity to identify trends within the program;
- Probe more deeply into program processes, with the help of expanded feedback from participants and better understanding of program demographics;
- Improve the utility of the survey by including a comparison group;
- For the first time, survey STTR awardees, and
- Reduce costs and shrink the time required by combining three 2005 survey questionnaires—for the company, Phase I, and Phase II awards—into a single questionnaire.

Box A-1 identifies multiple sources of bias in survey response.

[10]The survey conducted as part of the current, second-round assessment of the SBIR program is referred to below as the "2014 Survey" or simply the "survey." In general, throughout the report, any survey references are understood to be to the 2014 Survey unless specifically noted otherwise.
[11]Delays at NIH and DoE in contracting with the National Academies combined with the need to complete work contracted with DoD NSF and NASA led the committee to proceed with the survey at three agencies only.

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BOX A-1

Multiple Sources of Bias in Survey Response[a]

Large innovation surveys involve multiple sources of potential bias that can skew the results in different directions. Some potential survey biases are noted below.

- **Successful and more recently funded firms more likely to respond.** Research by Link and Scott (2005) demonstrates that the probability of obtaining research project information by survey decreases for less recently funded projects, and it increases the greater the award amount.[b] Nearly 75 percent of Phase II responses to the 2011 Survey (the population for which was awards made FY 1998-2007) were for awards received after 2003, largely because winners from more distant years are more difficult to reach: small businesses regularly cease operations, are acquired, merge, or lose staff with knowledge of SBIR awards. This may skew commercialization results downward, because more recent awards will be less likely to have completed the commercialization phase.
- **Non-respondent bias.** The committee acknowledges that because it was not possible to collect information from non-respondent PIs and because the agencies have minimal information about PIs which could be used to track potential non-respondent biases, we do not have data on which to develop an analysis of non-respondent bias. The committee has concluded that the data are likely to be biased toward PIs who are still working at companies that are still in business as corporate entities (i.e., have not failed or been acquired). However, at the same time, the committee notes that successful PIs who left the original firm to start a new venture, or simply moved to another firm, and PIs who were in successful firms that merged or were bought out by other firms are also excluded from the results, which would bias the results in the opposite direction.
- **Success is self-reported.** Self-reporting can be a source of bias, although the dimensions and direction of that bias are not necessarily clear. In any case, policy analysis has a long history of relying on self-reported performance measures to represent market-based performance measures. Participants in such retrospective analyses are believed to be able to consider a broader set of allocation options, thus making the evaluation more realistic than data based on third-party observation.[c] In short, company founders and/or PIs are in many cases simply the best source of information available.

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BOX A-1 (Continued)

- **Survey sampled projects from PIs with multiple awards.** Projects from PIs with large numbers of awards were underrepresented in the sample, because PIs could not be expected to complete a questionnaire for each of numerous awards over a 10-year time frame, and they were, therefore, asked to complete no more than two. However, PIs with multiple awards may tend to have a greater reliance on the SBIR program, a more favorable view of it, and a greater willingness to complete the survey; furthermore, they may have greater recall about the program from working with it multiple times.
- **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/STTR 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/STTR contribution to project success.** Some firms may be unwilling to acknowledge that they received important benefits from participating in public programs for a variety of reasons. For example, some may understandably attribute success exclusively to their own efforts.
- **Commercialization lags.** Although the 2005 Survey broke new ground in data collection, the amount of sales made—and indeed the number of projects that generated sales—are inevitably undercounted in a snapshot survey taken at a single point in time. On the basis of successive datasets collected from NIH SBIR award recipients, it is estimated that total sales from all responding projects will be considerably greater than can be captured in a single survey, because technologies continue to generate revenue after the date of the survey. These positive outcomes are therefore not included in any single survey result.[e] This underscores the importance of follow-on research based on the now-established survey methodology. Figure Box A-1 illustrates this impact in practice: projects from 2006 onward had not yet completed commercialization as of August 2013.

Finally, the committee suggests that, where feasible, future assessments of the SBIR/STTR programs include comparisons of non-awardees, such as in matched samples (Azouley et al., 2014) or regression discontinuity analysis (Howell, 2015).[f] In addition, future assessments should document the root cause

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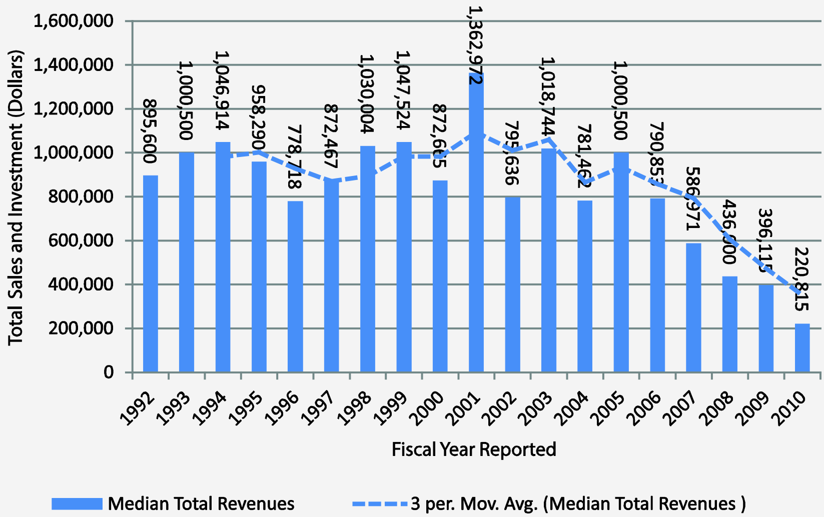

FIGURE Box A-1 The impact of commercialization lag.
SOURCE: DoD Company Commercialization Record database.

of non-responsiveness. For example, determining whether the company is still in business even if the PI is no longer with the firm could provide useful evidence about the effectiveness of the SBIR/STTR award.

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[a] The limitations described here are drawn from the methodology outlined for the previous survey in National Research Council, *An Assessment of the SBIR Program at the Department of Defense*, Washington, DC: The National Academies Press, 2009.
[b] A.N. Link and J.T. Scott, *Evaluating Public Research Institutions: The U.S. Advanced Technology Program's Intramural Research Initiative*, London: Routledge, 2005.
[c] While economic theory is formulated on what is called "revealed preferences," meaning that individuals and companies reveal how they value scarce resources by how they allocate those resources within a market framework, quite often expressed preferences are a better source of information, especially from an evaluation perspective. Strict adherence to a revealed preference paradigm could lead to misguided policy conclusions because the paradigm assumes that all policy choices are known and understood at the time that an individual or firm reveals its preferences and that all relevant markets for such preferences are operational. See (1) G. G. Dess and D. W. Beard, "Dimensions of Organizational Task Environments," *Administrative Science Quarterly*, 29: 52-73, 1984; (2) A.N. Link and J.T. Scott, *Public Accountability: Evaluating Technology-Based Institutions*, Norwell, MA: Kluwer Academic Publishers, 1998.
[d] Link and Scott, *Evaluating Public Research Institutions*.
[e] Data from the assessment of the SBIR program at NIH indicate that a subsequent survey taken 2 years later would reveal substantial increases in both the percentage of firms reaching the market and in the amount of sales per project. See National Research Council, *An Assessment of the SBIR Program at the National Institutes of Health*, Washington, DC: The National Academies Press, 2009.
[f] Pierre Azoulay, Toby Stuart, and Yanbo Wang, Matthew: Effect or Fable?. *Management Science*, 60(1), pp. 92-109, 2014. Howell, Sabrina, "DoE SBIR Evaluation: Impact of Small Grants on Subsequent Venture Capital Investment, Patenting, and Achieving Revenue." Paper presented at the National Academy of Sciences, Engineering, and Medicine Workshop on the Economics of Entrepreneurship, June 29, 2015.

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Survey Characteristics

In order to ensure maximum comparability for a time series analysis, the survey for the current assessment was based as closely as possible on previous surveys, including the 2005 Survey and the 1992 GAO survey.

Given the limited population of Phase II awards, the starting point for consideration was to deploy one questionnaire per Phase II award. However, we were also aware that the survey imposes burdens on respondents. Given the detailed and hence time-consuming nature of the survey, it would not be appropriate to over-burden potential recipients, some of whom were responsible for many awards over the years.

An additional point of consideration was that this survey was intended to add detail on program operations, rather than the original primary focus on program outcomes. Agency clients were especially interested in probing operations more deeply. We decided that it would be more useful and effective to administer the survey to PIs—the lead researcher on each project—rather than to the registered company point of contact (POC), who in many cases would be an administrator rather than a researcher.

The survey was therefore designed to collect the maximum amount of relevant data, consistent with our commitment to minimize the burden on individual respondents and to maintain maximum continuity between surveys. Survey questionnaires were to be sent to PIs of all projects that met selection characteristics, with a maximum of two questionnaires per PI. (The selection procedure is described in section on "Initial Filters for Potential Recipients".)

Based on reviewer feedback about the previous round of assessments, we also attempted to develop comparison groups that would provide the basis for further statistical analysis. This effort was eventually abandoned (see section on "Effort at Comparison Group Analysis").

Key similarities and differences between the 2005 and 2014 Surveys are captured in Table A-2.

The 2014 Survey included awards made from FY 2001 to FY2010 inclusive. This end date allowed for completion of Phase II awards (which nominally fund 2 years of research) and provided a further 2 years for commercialization. This time frame was consistent with the 2005 Survey, which surveyed awards from FY 1992 to FY 2001 inclusive. It was also consistent with a previous GAO study, published in 1992, which surveyed awards made through 1987.

The aim of setting the overall time frame at 10 years was to reduce the impact of difficulties generating information about older awards, because some companies and PIs may no longer be in place and because memories fade over time. Reaching back to awards made before FY 2001 would generate few additional responses.

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TABLE A-2 Similarities and Differences: 2005 and 2014 Surveys

Item	2005 Survey	2014 Survey
Respondent selection		
Focus on Phase II winners	✓	✓
Inclusion of Phase I winners	✓	✓
All qualifying awards		✓
Respondent = Principal Investigator (PI)		✓
Respondent = Point of Contact (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		✓

Determining the Survey Population

Following the precedent set by both the original GAO study and the first-round study of the SBIR program, we differentiated between the total population of awards, the preliminary survey target population of awards, and the effective population of awards for this study.

Two survey response rates were calculated. The first uses the effective survey population of awards as the denominator, and the second uses the preliminary population of awards as the denominator.

From Total Population of Awards to Effective Population

Upon acquisition of data for the 2014 Survey from the sponsoring agencies (NIH and DoE) covering record-level lists of awards and recipients,

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initial and secondary filters were applied to reach the preliminary survey population and ultimately the effective survey population. These steps are described below.

Initial Filters for Potential Recipients: Identifying the Preliminary Survey Population

From this initial list, determining the preliminary survey population required the following steps:

- 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 [DoE and then NIH in that order], then by year [oldest], and finally by random number); and
- elimination of records for which there were significant missing data—in particular, where emails and/or contact telephone numbers were absent.

This process of excluding awards either because they did not fit the protocol agreed upon by the committee or because the agencies did not provide sufficient or current contact information, reduced the total award list provided by DoE from an initial list of 1,325 to a preliminary survey population of Phase II SBIR and STTR awards of 1,077 awards.

Secondary Filters to Identify Recipients with Active Contact Information: Identifying the Effective Population

This preliminary population still included many awards for which the PI contact information appeared complete, but for which the PIs were no longer associated with the contact information provided and hence effectively unreachable. This is not surprising given that there is considerable turnover in both the existence of and the personnel working at small businesses and that the survey reached back 13 years to awards made in FY 2001. PIs for awards may have left the company, the company may have ceased to exist or been acquired, or telephone and email contacts may have changed, for example. Consequently, two further filters were utilized to help identify the effective survey population.

1. PI contacts were eliminated—and hence the awards assigned to those PI contacts were eliminated—for which the email address bounced twice. Because the survey was delivered via email, the absence of a working email address disqualified the recipient PI and associated awards. This eliminated approximately 30 percent of the preliminary population (320 awards).

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SBIR/STTR at the Department of Energy

2. Efforts were made to determine whether non-bouncing emails were in fact still operative. Email addresses that did not officially "bounce" (i.e., return to sender) may still in fact not be active. Some email systems are configured to delete unrecognized email without sending a reply; in other cases, email addresses are inactive but not deleted. So a non-bouncing email address did not equal a contactable PI. In order to identify not contactable PIs, we undertook an extensive telephone survey. Telephone calls were made to every PI with an award among the preliminary survey population of awards at DoE and who did not respond to the first round of questionnaire deployment. On the basis of responses to the telephone survey, we were able to ascertain that 263 further PIs could not be contacted even though their email addresses did not formally bounce.

There was little variation between agencies or between programs in the quality of the lists provided by the agencies, based on these criteria.[12]

Following the application of these secondary filters, the effective population of DoE Phase II awardees was 494.

Deployment

The survey opened on December 3, 2014, and was deployed by email, with voice follow-up support. Up to four emails were sent to the PIs for the effective population of awards (emails were discontinued once responses were received or it was determined that the PI was non-contactable). In addition, two voice mails were delivered to non-responding PIs of awards in the effective population, between the second and third and between the third and fourth rounds of email. In total, up to six efforts were made to reach each PI who was sent an award questionnaire.

After members of the data subgroup of the committee determined that additional efforts to acquire new responses were not likely to be cost effective, the survey was closed on April 7, 2015. The survey was therefore open for a total of 18 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

[12]The share of preliminary contacts that turned out to be not contactable was higher for this survey than for the 2005 Survey. We believe this is primarily because company points of contact (POCs) to which the 2005 Survey was sent have less churn than do principal investigators (PIs) (often being senior company executives).

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evidence from the literature shows.[13] Under these circumstances, the inability to contact and obtain responses always raises questions about potential bias of the estimates that cannot be quantified without substantial extra efforts requiring resources beyond those available. (See Box A-1 for a discussion of potential sources of bias.)

The lack of detailed applications data from the agency, beyond the name and address of the company, makes it impossible to estimate the possible impact of non-response bias. We therefore have no evidence either that non-response bias exists or that it does not. For the areas where Academy surveys have overlapped with other data sources (notably DoD's mandatory CCR database), results from the survey and from the DoD data are similar. Table A-3 shows the response rates at DoE, based on both the preliminary study population and the effective study population after all adjustments.

The 2014 Survey primarily reached companies that were still in business: overall, 97 percent of PIs responding for an award in the effective population indicated that the companies were still in business.[14]

Effort at Comparison Group Analysis

Several readers of the first-round reports on the SBIR program suggested inclusion of comparison groups in the analysis. There is no simple and easy way to acquire a comparison group for Phase II SBIR or STTR awardees especially at the agency level. These are technology-based companies

TABLE A-3 2014 Survey Response Rates at DoE

Overall Population of Awards (all awards made)	1,325
Preliminary Population of Awards	1,077
Awards for which the PIs Were Not Contactable	
No Email	320
No Phone Contact	263
Effective Population of Awards	494
Number of Awards for which Responses Were Received	269
Response Rate: Percentage of Effective Population of Awards	54.5
Response Rate: Percentage of Preliminary Population of Awards	25.0

SOURCE: 2014 Survey.

[13]Many surveys of entrepreneurial firms have low response rates. For example, Aldrich and Baker (1997) found that nearly one-third of surveys of entrepreneurial firms (whose results were reported in the academic literature) had response rates below 25 percent. See H. E. Aldrich and T. Baker, "Blinded by the Cites? Has There Been Progress in Entrepreneurship Research?" pp. 377-400 in D. L. Sexton and R. W. Smilor (eds.), *Entrepreneurship 2000,* Chicago: Upstart Publishing Company, 1997.

[14]2014 Survey, Question 4A.

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at an early stage of company development, which have the demonstrated capacity to undertake challenging technical research *and* to provide evidence that they are potentially successful commercializers. Given that the operations of the SBIR/STTR programs are defined in legislation and limited by the Policy Guidance provided by SBA, randomly assigned control groups were not a possible alternative.

As part of the our 2011 Survey of DoD, NSF, and NASA SBIR and STTR award recipients, efforts to identify a pool of SBIR-like companies were made by contacting the most likely sources (Dun & Bradstreet and Hoovers), but these efforts were not successful, as insufficiently detailed and structured information about companies was available.

In response, we sought to develop a comparison group from among Phase I awardees that had not received a Phase II award from the three agencies surveyed in 2011 Survey during the award period covered by the survey (FY 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.

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Appendix B

Major Changes to the SBIR and STTR Programs Resulting from the 2011 SBIR Reauthorization Act, P.L. 112-81, December 2011

1) **The SBIR program received an increased share of federal agencies' extramural budgets:**[1]

   a. Congress increased the SBIR/STTR share from 2.5 percent to 2.6 percent in FY 2012 and by 0.1 percent per year thereafter through FY 2017, 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 FY 2011, 0.35 percent in FY 2012 and 2013, 0.40 percent in FY 2014 and 2015, and 0.45 percent in 2016 and 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.

[1]U.S. Congress, P.L. 112-81, Sec. 5102 (a)(1)(a).
[2]Sec. 5102(b).
[3]Sec. 5103.

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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 for SBIR:[6]

a. The requirement that a company be invited by the agency before it could propose work for Phase II is now eliminated.

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) For SBIR. 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.

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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.

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12) **The commercialization readiness pilot at DoD was converted to a permanent program—the Commercialization Readiness Program (CRP).** Details include in particular the following:[12]

  a. An SBIR Phase III insertion plan is now required for all DoD acquisition programs with a value of $100 million or more.
  b. SBIR/STTR Phase III reporting is now required from the prime contractor for all such contracts.
  c. The Secretary of Defense (SecDef) is now required to set goals for the inclusion of SBIR/STTR Phase II projects in programs of record and fielded systems and must report on related plans and outcomes to the SBA Administrator.
  d. The legislation explicitly requires the SecDef to develop incentives toward this purpose and to report on the incentives and their implementation.

13) **CRP may be expanded to other agencies:**[13]

  a. Other agencies may spend up to 10 percent of their SBIR-STTR program funds on commercialization programs.
  b. CRP awards may be up to three times the maximum size of Phase II awards.
  c. CRP authority expires after FY 2017.

14) **Phase 0 pilot partnership program at NIH was enabled:**[14]

  a. NIH is permitted to use $5 million to establish a Phase 0 pilot program.
  b. The funding must go to universities or other research institutions that participate in the NIH STTR program.
  c. These institutions must then use the funding for Phase 0 projects for individual researchers.

15) **Data collection and reporting were enhanced:**[15]

  a. Overall, the legislation calls for substantially increased data collection for individual recipients and for much more detailed reporting from agencies to SBA and to Congress.
  b. Specific areas for improved reporting include:

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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.

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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 for SBIR;
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.

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Appendix C

National Academies of Sciences, Engineering, and Medicine

2014 SBIR/STTR Survey

Introduction

Welcome to the National Academies SBIR/STTR Survey. Thank you for participating. This survey seeks responses related to the Phase II project entitled [insert project title], funded by [insert agency name], at [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.

Finally, please use the navigational buttons within the survey. The back and forward buttons on your browser will not work.

Privacy and Confidentiality Policy

Responses to this survey will be held in confidence by the survey team. No identifiable information will be provided to other Academy staff or to the Public Access File which provides researchers with access to project data.

In order to implement this commitment, the following steps have been taken, covering three areas:

a) Data in the published report
b) Management of raw data files
c) Additional review of textual (open-ended) responses

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a) Data in the published report.

All data except for text responses will be presented only in aggregated form in the report; no individually identifiable cells will be published.

b) Managing raw data.

In order to provide researchers with access while meeting the confidentiality commitment, the following steps will be taken by the Contractor prior to providing an expurgated data set to the Academy for inclusion in the Public Access File:

1) Replace company name with a new company ID
2) Replace PI name with a new PI ID
3) Delete the following fields:

    a. Agency record ID
    b. Company address except for State field
    c. Project title
    d. Project abstract
    e. Flag for woman owned business
    f. Flag for minority owned business

The raw (unexpurgated) data set will be retained by the Contractor for two years after publication of the report. All copies of the raw data will then be destroyed. The expurgated data set will be retained indefinitely in the Public Access File related to the project.

c) Review of textual responses.

Two independent reviewers will analyze open ended responses with a view to redacting material that could provide clues as to the identity of the respondent prior to their inclusion in the Public Access File. In particular, this review will redact all company names, product names, and PI or other company official names, as well as other potential identity clues.

Do you approve the privacy and confidentiality policy as shown above?
[Yes/No. If no, jump to page 55.]

This information is required only to determine your current status, and to ensure that we have accurate contact information. Your information will be strictly private and will not be shared with any private entity or government agency; aggregated data will be shared in a published report.

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1. For the project referenced above, were you (during the time period covered by this award) …*

   Select all that apply.
   a. A Principal Investigator (PI) on this project
   b. The CEO
   c. A company founder
   d. Senior researcher (other than PI)
   e. Not CEO but a senior executive with the company identified above
   f. None of the above (exit questionnaire)

Part 1. Information About You.

2. 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.

   First name: [Text box]
   Last name: [Text box]
   Current email address: [Text box]
   Current work telephone number (for follow up questions if necessary): [Text box]

Part 2. Company Information Section

3. Have you already completed a questionnaire about another SBIR or STTR project for this National Academy survey related to [insert company name]?*
   [Yes/No. If yes, skip to Part 3: PI/Senior Executive Information]

4. Is [insert company name] still in business?
   [Yes/No]

5. Thinking about the number of founders of the company, what was…?

   Min = 0 Max = 20 Must be numeric

   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) [number box]
   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 [number box]

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6. 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. Research institution
   d. FFRDCs or National Labs
   e. Other

7. Was the company founded because of the SBIR/STTR program?

   Yes
   In part
   No

8. What was the company's total revenue for the most recent fiscal year?

   $0
   Under $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 or more

9. What percentage of the company's revenues during its most recent completed fiscal year was Federal SBIR/STTR funding (Phase I and/or Phase II)?

   0%
   1-10%
   11-25%
   26-50%
   51-75%
   76-99%
   100%

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10. What percentage of the company's total R&D effort (man-hours of scientists and engineers) was for SBIR/STTR activities during the most recent fiscal year?

    0%
    1-10%
    11-25%
    26-50%
    51-75%
    76-100%

11. Which if any of the following has the firm experienced since your first SBIR/STTR award?

    Select all that apply.
    Made an initial public offering
    Established one or more spin off companies
    Been acquired by/merged with another firm
    Planning to make an initial public offering in the next two years
    Entered into strategic partnership with major industry player
    None of the above

12. How many patents have resulted, at least in part, from the company's SBIR/STTR awards?

    Min = 0 Max = 999 Must be numeric
    Whole numbers only
    Positive numbers only

    [number box]

13. Does the company have one or more full time staff for marketing or business development?
    [Yes/No]

14. Number of company employees (including all affiliates):

    Min = 0 Max = 99999 Must be numeric
    Whole numbers only
    Positive numbers only

    a. At the time of the award in [pipe in award year] [Number box]
    b. Currently [Number box]

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15. What was the ownership status of the company at the time of the award?

Select all that apply.

a. Woman-owned
b. Minority-owned
c. Neither of the above

If the answer is "Minority-owned," please indicate the ethnic minority group[s] that company owners [at the time of the award] belonged to.

Select all that apply.

Asian-Indian
Asian-Pacific
Black
Hispanic
Native American
Other [Text box]

Part 3. PI/Senior Executive Information

16. The Principal Investigator for this [SBIR/STTR] Award was a …

Select all that apply.

a. Woman
b. Minority
c. Neither of the above

If the answer is "Minority," please indicate the ethnic minority group[s] the Principal Investigator for this award belongs to.

Select all that apply.

Asian-Indian
Asian-Pacific
Black
Hispanic
Native American
Other [Text box]

17. At the time of the award, the age of the leading PI was…

[Under 25, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65+]

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18. 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 [Text box]

19. 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/STTR funded research.
    b) Efforts at this company have been discontinued. No sales or additional funding resulted from this project.
    c) Efforts at this company have been discontinued. The project did result in sales, licensing of technology, or additional funding.
    d) Project is continuing post-award technology development.
    e) Commercialization is underway.
    f) Products/Processes/Services are in use by target population/customer/consumers.
    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).

20. If the answer is either b) or c), did the reasons for discontinuing this project include any of the following?

    Select one of the reasons as the Primary Reason. Select all that apply as Other contributing reasons.

    Another firm got to the market before us
    Level of technical risk too high
    Principal Investigator left
    Technical failure or difficulties
    Inadequate sales capability
    Project goal was achieved (e.g. prototype delivered for federal agency use)
    Licensed to another company
    Market demand too small
    Company shifted priorities
    Other (Please specify in comments box below)

    Comments
    [Text box]

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Part 4. Project status information

21. Please select the technology sector or sectors that most closely fit(s) the work of the SBIR/STTR project.

Select all that apply.

Aerospace and Defense
- Aerospace
- Defense-specific products and services

Energy and the environment
- Renewable energy production (solar, wind, geothermal, bio-energy, wave)
- Energy storage and distribution
- Energy efficiency
- 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
- Materials (including nanotechnology for materials)

Medical technologies
- Pharmaceuticals
- Medical devices
- Biotechnology (including therapeutic, diagnostic, combination)
- Health IT (including mobile, big data, training modules)
- Research tools
- Other medical products and services

Other (please specify) [Text box]

22. Did you experience a gap between the end of Phase I and the start of Phase II for this award?

    [Yes/No. If no, skip to question 25]

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23. During the funding gap between Phase I and Phase II for this award, which of the following occurred?

    Select all answers that apply.
    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 gap funding between Phase I and Phase II.
    e. Company ceased all operations during funding gap
    f. Other (specify) [Text box]

24. In your opinion, in the absence of this SBIR/STTR award, would the company have undertaken this project?

    a. Definitely yes [Answer questions 25-27.]
    b. Probably yes [Answer questions 25-27.]
    c. Uncertain
    d. Probably not
    e. Definitely not

25. If you had undertaken this project in the absence of SBIR/STTR, this project would have been …
    a. Broader in scope
    b. Similar in scope
    c. Narrower in scope

26. In the absence of SBIR/STTR funding… (Please provide your best estimate of the impact)

    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 similar goals and milestones, the project would be…
       1) ahead
       2) the same place
       3) behind

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27. Did this award require matching funds or other types of cost sharing in the Phase II Proposal?
    [Yes/No. If No, skip questions 28-39.]

28. Matching or co-investment funding proposed for Phase II was received from ...

    Select all that apply.
    Non-SBIR/STTR federal funds
    a. **Private investment: U.S. Sources**
        i) venture capital (VC)
        ii) U.S. angel funding or other private equity investment (not VC)
        iii) Friends and family
        iv) Strategic investors/partners
        v) Other sources
    b. **Foreign investment**
        i) Financial investors
        ii) Strategic investors/partners
    c. **Other sources**
        (1) State or local governments
        (2) Research institutions (such as colleges, universities or medical centers)
    d. **Internal sources**
        (1) Your own company (Including money you have borrowed)
        (2) Personal funds

29. How difficult was it for the company to acquire the funding needed to meet the matching funds requirements?

    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

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Part 5. Project outcomes

30. To date, what has been the total additional developmental funding for the technology developed during this project?

None $0
Under $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 or more

31. What have been the sources of additional development funding?

Select all that apply.

Non-SBIR/STTR federal funds

a. **Private investment: U.S. Sources**
   i) venture capital (VC)
   ii) U.S. angel funding or other private equity investment (not VC)
   iii) Friends and family
   iv) Strategic investors/partners
   v) Other sources
b. **Foreign investment**
   i) Financial investors
   ii) Strategic investors/partners
c. **Other sources**
   (1) State or local governments
   (2) Research institutions (such as colleges, universities or medical centers)
d. **Internal sources**
   (1) Your own company (Including money you have borrowed)
   (2) Personal funds

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32. 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 questions 33-39.]
    b. No sales to date, but sales are expected. [Skip to question 33-39.]
    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.)

33. 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/STTR awards contributed to the ultimate commercial outcome, report only the share of total sales appropriate to this SBIR/STTR project.

    For the company [Pulldown with choices from 1990-2014]
    For any licensees [Pulldown with choices from 1990-2014]

34. For the company, what is the approximate amount of total sales dollars of product(s), process(es) or services to date resulting from the technology developed during the [name of project]?

    [Pulldown with choices:
    None $0
    Under $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 or more]

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35. What is the approximate amount of other total sales dollars (e.g. rights to technology, sale of spin-off company, etc.) to date resulting from the technology developed during the [name of project]?

    [Pulldown with choices:
    None $0
    Under $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 or more]

36. To date, approximately what percent of total sales from the technology developed during this project have gone to the following customers?

    Round percentages. Answers required to add to 100%.
    a. Domestic private sector [Number box]
    b. Export Markets [Number box]
    c. Department of Defense (DoD) [Number box]
    d. NASA [Number box]
    e. Prime contractors for DoD [Number box]
    f. Prime contractor for NASA [Number box]
    g. Agency that awarded the Phase II (if not NASA or DoD) [Number box]
    h. Other federal agencies [Number box]
    i. State or local governments [Number box]
    j. Other [Number box] (Specify below, if applicable)

    If applicable please specify what "other" types of customers you have sold to as a result of this project.
    [Text box]

37. Please list any significant commercial partnerships (including licensing agreements) based on the SBIR/STTR-funded technology.
    [Text box]

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38. Please give the number of patents, copyrights, trademarks received and articles published in scientific publications for the technology developed as **a result of** [name of project].

Enter numbers. If none, enter 0 (zero).
Patents [Number box]
Copyrights [Number box]
Trademarks [Number box]
Published articles [Number box]

39. How many SBIR and/or STTR awards has the company received that are related to the project/technology supported by this award?

a. Number of related Phase I awards [Text box]
b. Number of related Phase II awards [Text box]

NIH Only

40. Does your product require FDA approval before it can be marketed?
[Yes/No. If no, skip to question 47]

41. What is the current status of the project with regard to the FDA process?

Process abandoned
Preparation under way for clinical trails
IND granted
In Phase 1 clinical trials
In Phase 2 clinical trials
In Phase 3 clinical trials
Completed clinical trials

42. What sources of funding have been employed in relation to the FDA process?

Select all that apply.
SBIR Phase II
SBIR Phase IIB
Other NIH Funding
BARDA funding
Internal company and personal funding
Angel Funding
Venture funding
Funding from other companies
Other (specify) [Text box]

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43. For projects still in process, when approximately – assuming all goes well with clinical trials – do you anticipate completing the FDA certification process?

    [Text box]

44. What non-financial support in relation to FDA approval have you received from NIH before and during the clinical trials process?

    [Text box]

45. If applicable, how useful was this support?

    Extremely useful (5)
    4
    3
    2
    Not useful at all (1)

    Comments
    [Text box]

46. How much difference did Phase IIB funding make to the eventual outcome of the project (or its current status if research is not completed)?

    A tremendous difference (5)
    4
    3
    2
    It made no difference at all (1)

    Comments
    [Text box]

47. Was the additional funding sufficient to allow you to complete any of the following?

    Select all that apply.

    Preclinical trial preparation
    Phase 1 trials
    Phase 2 trials
    Phase 3 trials
    No/None of the above

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48. What additional measures should NIH take to support companies like yours during the process?

    [Text box]

Part 6. SBIR Process and Recommendations

49. Many agencies offer commercialization assistance in connection with SBIR or STTR awards. Did you (or another company staff member) participate in a technical assistance related to this award that was offered by your funding agency?

    [Yes/No. If no, skip questions 50-73.]

    Phase I
    Phase II
    Both

50. What company provided assistance to you?

    Dawnbreaker
    LARTA
    Foresight
    Other (specify) [Text box]

51. How valuable was the commercialization assistance?

    Extremely valuable
    Very valuable
    Somewhat valuable
    Not very valuable
    Not at all valuable

52. New rules permit companies to use up to $10,000 of SBIR/STTR funding for their own marketing purposes, outside the agency program.

    Would you…

    Continue to use the agency's program
    Use the funding for your own marketing consultant
    Neither

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53. In comparison to other Federal awards or Federal funding, how would you rate the process of applying for Phase II funding? Applying for SBIR/STTR Phase II funding was...

    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

54. How adequate was the amount of money you received through SBIR/STTR Phase II funding for the purposes you applied for? Was it...

    a. More than enough
    b. About the right amount
    c. Not enough

55. Congress recently increased the standard limit on awards to $1 million for SBIR/STTR. Should the size of Phase II awards be increased even if that means a proportionately lower number of Phase II awards are made?

    a. Yes
    b. No
    c. Not sure

56. Overall, would you recommend that the SBIR/STTR 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)

57. To what extent did the SBIR/STTR funding significantly affect long term outcomes for the company?

    a. Had a highly positive or transformative effect
    b. Had a positive effect

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c. Had no effect
d. Had a negative effect
e. Had a highly negative or disastrous effect

58. Can you explain these impacts in your own words?
[Text box]

Part 7. Working with Project Managers

This section seeks information about your interactions with your agency point of contact, who for the purposes of this survey is referred to as a "Project Manager."

59. How often did you engage with your Project Manager in the course of your award?
a. weekly
b. monthly
c. quarterly
d. annually

60. How valuable was your Project Manager on a scale of 1-5, with 1 being no help and 5 being invaluable?

Invaluable (5)
4
3
2
No help (1)

61. How knowledgeable was your Project Manager about the SBIR/STTR program. Were they able to guide you effectively through the SBIR/STTR process?

a. Not at all knowledgeable
b. Quite knowledgeable
c. Somewhat knowledgeable
d. Extremely knowledgeable

62. 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]

a. Providing direct technical help
b. Finding markets for our technology or products/services
c. The Phase II application process
d. Introducing us to university personnel or government labs that could

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contribute to the project

e. Introducing us to other firms that could provide technical expertise

63. How closely did you work with your Project Manager as you pursued additional funding beyond Phase II?

    a. The officer provided a lot of guidance during the application process
    b. We discussed the application in detail
    c. Not much
    d. Not at all
    e. We did not apply for additional agency funding

64. How effective was the Project Manager in connecting the company to sources of Phase III funding (such as acquisition programs or venture/angel funding)?

    Very helpful
    Somewhat helpful
    Not very helpful
    Not at all helpful

65. How easy was it to reach your Project Manager when you had questions or concerns?

    Very easy
    Easy
    Hard
    Very hard

66. Was your Project Manager replaced during the course of your award?
    [Yes/No]

67. How do you see the time allocated for your Project Manager to work on your project?

    More than sufficient
    Sufficient
    Insufficient

68. Additional comments on working with your Project Manager
    [Text box]

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69. Is a Federal System or Acquisition Program using the technology from this award?

    Yes (Answer question 70)
    No (Skip to question 71)

70. Please provide the name of the Federal System or Acquisition Program that is using the technology.
    [Text box]

71. This questions address any relationships between your firm's efforts on this project and any partnering Research Institution (RI) (including universities, medical centers, Federal research labs).

    Select all that apply.

    a. The PI for this project was at the time of the project an RI faculty member
    b. The PI for this project was at the time of the project an RI 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 an RI
    f. The technology for this project was originally developed at an RI by one of the participants in this project
    g. An RI was a subcontractor on this project
    h. None of the above [Skip questions 72-73.]

72. Which research institution (or institutions) worked with your firm on this project?
    [Text box]

73. If you worked with an FFRDC or a National Lab as part of this project, please briefly describe this aspect of the project, and add any further comments based on this aspect of the project.
    [Text box]

Part 8. STTR

74. To what extent did your STTR award change your relationship with the research institution?

    a. Substantially enhanced it

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b. Somewhat enhanced it
c. Made no real difference
d. Made it somewhat worse
e. Made it substantially worse

If you have additional comments and/or recommendations about working with a research institution in the context of SBIR/STTR, please enter them here.

75. Did you collaborate with this research institution before receiving this STTR award?
    [Yes/No]

76. Have you ever received a Small Business Innovation Research (SBIR) award?
    [Yes/No. If no, skip to question 80]

77. Have you had prior SBIR awards in which you collaborated with a research institution?
    [Yes/No]

78. From your perspective, are there significant differences between SBIR and STTR awards?
    [Yes/No. If no, skip to question 80.]

79. Please explain these differences in your own words.
    [Text box]

80. If you have received both SBIR and STTR awards, did you find that

    a. STTR is easier to manage than SBIR
    b. They are about the same
    c. STTR is harder to manage than SBIR

81. Do you think that the funding proportion that can be allocated to the research institution should be increased?

    a. Strongly agree
    b. Somewhat agree
    c. Neither agree nor disagree
    d. Somewhat disagree
    e. Strongly disagree

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82. Have you tried to switch an STTR Phase I award to an SBIR Phase II award, or the other way around?
    [Yes/No]

83. Are these specific ways in which outcomes from your SBIR/STTR awards as a company have helped meet the mission of the funding agency?
    [Text box]

84. Other comments or recommendations based on your experience with the STTR program?
    [Text box]

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Appendix D

List of Research Institutions Involved in Surveyed DoE SBIR/STTR Awards[1]

Name of Research Institution	Number of Respondent Mentions
Argonne National Laboratory	5
Arizona State University	2
Boston College	2
Brigham Young University	1
Brookhaven National Laboratory	6
California State Polytechnic University	1
Case Western Reserve University	2
Center for Catalytic Science & Technology in University of Delaware	1
Clemson University	1
Colorado State University	1
Duquesne University	1
Fermi National Accelerator Laboratory	5
Florida A&M University	1
Florida State University	2
Georgia Institute of Technology	2
Harvard University	1

[1]Based on responses to 2014 Survey, Question 72. Survey covered awards made FY 2001-2010.

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Illinois Institute of Technology	2
Kansas State University	1
LANL	1
Lawrence Berkeley National Laboratory	10
Lehigh University	2
Maine Maritime Academy	1
Massachusetts Institute of Technology	3
Michigan State University	1
Michigan Tech	1
Montana State University	3
Montana Technological University	1
National High Magnetic Field Laboratory	1
Naval Research Laboratory	1
National Instiute of Standards and Technology	1
North Carolina State University	2
National Renewable Energy Laboratory	1
Oak Ridge National Laboratory	2
Ohio State University	6
Old Dominion University	3
Oregon State University	1
Oak Ridge National Laboratory	1
Pacific Northwest National Laboratory	2
Pennsylvania State University	2
Princeton Plasma Physics Laboratory	3
Purdue University	1
Rensselaer Polytechnic Institute	1
Rice University	1
Rutgers University	2
Sandia National Laboratories	1
Smithsonian	1

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Spallation Neutron Source	1
Stanford Linear Accelerator Center	3
Stanford University	1
Stony Brook University	1
TEES/TAMU	1
Thomas Jefferson National Accelerator Facility	3
University of California, Berkeley	2
University of California, Davis	1
University of California, Los Angeles	4
UDRI	1
University of Akron	1
University of Arizona	2
University of Central Florida	1
University of Colorado	7
University of Connecticut	1
University of Florida	1
University of Hawaii	1
University of Illinois	3
University of Maine	3
University of Maryland	1
University of Massachusetts, Lowell	2
University of Michigan	2
University of Nebraska	1
University of New Hampshire	1
University of South Florida	1
University of Texas	2
University of Toledo	1
University of Washington	2
Virginia Polytechnic Institute	1
Wake Forest University	1

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Washington State University	1
Yale University	1
Total	148

SOURCE: 2014 Survey, Question 72.

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Appendix E

Case Studies

To complement its review of program data, the committee commissioned case studies of 12 companies that received Phase II Small Business Innovation Research (SBIR) and or Small Business Technology Transfer (STTR) awards from the Department of Energy (DoE). These case studies were undertaken in 2015-2016. Case studies were an important source of data for this study, in conjunction with other sources such as agency data, the survey, interviews with agency staff and other experts, and workshops on selected topics. The impact of SBIR/STTR funding is complex and often multifaceted, and although these other data sources provide important insights, case studies allow for an understanding of the narrative and history of recipient firms—in essence, providing context for the data collected elsewhere.

The committee studied a wide range of companies (see Box E-1). They operated in a wide range of technical disciplines and industrial sectors. Some firms focused solely on serving the national labs, while others focused on commercialization through the private sector. Overall, this portfolio sought to capture many of the types of companies that participate in the SBIR/STTR programs. Given the multiple variables at play, the case studies are not presented as any kind of quantitative record, and only a limited number of case studies were completed as part of this study. Rather, they provide qualitative evidence about the individual companies selected, and although they are not intended to be statistically representative of DoE SBIR/STTR award winners or their award outcomes, they are, within the limited resources available, as representative as possible of the different components of the awardee population. The featured companies have verified the case studies presented in this appendix and have permitted their use and identification.

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BOX E-1
Directory and Profile of Case Studies

Company Name	Year Founded
Adelphi Technology, Inc.	1984
Calabazas Creek Research , Inc.	1994
Compact Membrane Systems, Inc.	1993
Creare, Inc.	1961
Diversified Technologies, Inc.	1987
LI-COR Biosciences, Inc.	1971
Muons Inc.	2002
Nanosonic, Inc.	1998
Physical Sciences, Inc.	1973
Vista Clara, Inc.	1997
Woodruff Scientific Incorporated	2005
XIA, LLC	1988

ADELPHI TECHNOLOGY, INC.[1]

Adelphi Technology, Inc. is a private company founded in 1984 as sole proprietorship by Melvin Piestrup and incorporated 2 years later in 1986. The company produces a range of high energy neutron sources for industrial and research applications. Adelphi is headquartered in Redwood City, CA. For its first ten years, the company focused on the research aspects of SBIR/STTR awards, followed by a further ten years in which it was seeking to identify and develop commercial products.

Dr. Charles K. Gary, Vice President for Operations for Adelphi said that his company, in recent years, has completed its evolution from a research-oriented company into a more product-focused company, and at the same time has focused its attention increasingly on the development and then sale of compact neutron generators (CNGs).

CNGs have a number of advantages over isotopes as sources for neutrons: they can be turned on and off, which makes them in practice safer to handle. They eliminate the significant bureaucratic requirements involved in using isotopes, which for instance require a radioactive materials license while CNGs do not. There are no materials handling issues. CNGs can be provided with a relatively small footprint. And isotopes must be replaced much more

[1]Primary sources for this case study are the interview with Dr. Charles Gary, August 18, 2015, and a review of the Adelphi website (http://www.adelphitech.com) and related company documents.

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frequently, for which there are disposal costs. So while the cost of the raw source is much higher for CNGs, the overall life cycle cost is lower.

Reduced bureaucratic costs are especially attractive to academics, according to Dr. Gary, as they do not have the resources easily available to ensure compliance. Hence academic labs have been an important initial market.

The focus on CNGs also opens the door to broader use of neutron scattering techniques in research and wider commercialization of neutron-based technologies in both new markets (for Adelphi) such as medicine (as an oncology therapy) and security (as a non-invasive sensing technology).

Adelphi operates an onsite neutron laboratory facility at its headquarters in Redwood City. The laboratory supports Adelphi's own research and development into new generator designs and neutron related applications. The laboratory is also available to customers so they can get first-hand experience with Adelphi neutron sources as they consider incorporating them into their own products.

Adelphi is recognized for its innovative work in the design and development of neutron generators. In 2012, in collaboration with Berkeley's Lawrence Livermore Laboratory, it won an R&D 100 award for its work developing the company's DD100 Series of High Output Neutron Generators. In 2013, in collaboration with the University of Florida, Adelphi won a second R&D 100 award for its DD109X High Flux Fast Neutron Source.[2]

Adelphi maintains research relationships with a broad range of academic, government, and corporate organizations such as the University of California, Berkeley, the University of Florida, Yale University, Indiana University, Rapiscan, Inc., Engility, Inc., and the Savannah River National Laboratory. Adelphi has approximately 10 employees at its headquarters.[3]

Technology: Neutron Sources

Neutron sources are primary used in materials analysis based on neutron scattering. Because neutrons are electrically neutral, they penetrate matter more deeply than electrically charged particles of comparable kinetic energy. They are, therefore, useful sensors of bulk material properties. In scattering experiments, neutrons cause pronounced interference and energy transfer effects. Because they do not interact well with the electron cloud, interference effects stem from neutron-nucleus interactions.

Until the 1990s, special research facilities were required to generate such neutrons fluxes, either research nuclear reactors or spallation reactors.

[2]"R&D Magazine 2012 R&D 100 Winners," *R&D Magazine,* June 7, 2012, http://www.rdmag.com/articles/2012/06/2012-r-d-100-award-winners; "R&D Magazine 2012 R&D 100 Winners," *R&D Magazine,* July 8, 2013, http://www.rdmag.com/award-winners/2013/07/2013-r-d-100-award-winners.

[3]"Our Teammates," http://www.engilitycorp.com/seaport-e/team-members.

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Researchers applied for beam time to run their experiments at a small group of about 20 research institutions (RIs) globally. The neutron sources developed by Adelphi have much lower capital and operational costs and, although lacking the flux density of these research reactors, are enabling broader use of neutron scattering in research and in industrial applications.[4]

Adelphi neutron sources contain compact linear accelerators that produce neutrons by fusing isotopes of hydrogen together. Deuterium (D), tritium (T), or a mixture of these two isotopes of hydrogen is accelerated into a metal hydride target also containing deuterium, tritium or a mixture. The hydrogen atoms fuse resulting in the formation of helium and a neutron. The energy of the neutrons depends on types of hydrogen isotopes that fused.

The Adelphi technology can produce sufficiently high levels of energetic neutrons for many research and industrial applications. The flux rates of Adelphi's neutron sources are controllable. Also, the flux is monochromatic (if both the accelerated and target isotopes are the same). For example, deuterium atoms fired at tritium targets produce neutrons with uniform kinetic energies of 14.1 MeV.

The principal industrial applications of neutron scattering are in healthcare and security. In healthcare, boron neutron capture therapy (BNCT) is potentially a new therapy for radiation oncologists. In BNCT, boron-10 is delivered to the tumor, either directly via injection or using antibodies. The tumor is irradiated with a neutron beam. The beam does not interact appreciably with tissue. In the tumor, however, boron-10 transforms into boron-11 which is radioactive and kills the tumor cells. Adelphi has already developed proprietary designs for neutron sources in oncology facilities.[5]

Adelphi is also partnering with government and private entities on neutron-based scanning systems for application such as border security, airline-cargo inspection, and investigation of unknown packages. Because fast neutrons (> 1 MeV) have deep penetration of most materials—usually more than 1 meter—they have significant advantages over x-rays in non-destructive, non-contact scanning.

Business Model

Adelphi Technology has supported operations by performing SBIR research and selling products and services. The company generates approximately $1.5 million annually from the provision of products and services related to the design and development of CNGs, including some SBIR/STTR funding.

Adelphi was initially quite dependent on SBIR funding. However, in recent years as more products have reached commercialization, the SBIR/STTR

[4]Hammoud, "Introduction to Neutron Scattering," National Institute of Standards and Technology, http://www.ncnr.nist.gov/staff/hammouda/distance_learning/chapter_6.pdf.
[5]"The Basics of Boron Neutron Capture Therapy," http://web.mit.edu/nrl/www/bnct/info/description/description.html.

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share of total revenue has declined. SBIR/STTR now accounts for about one third of company revenues, according to Dr. Gary, down from well over 50 percent in the early years of the company. He anticipates that this percentage will fall further as markets for CNGs mature, and that Adelphi will receive zero SBIR/STTR funding in 2016.

Adelphi typically sells four to five CNG systems annually primarily to academic customers and government research labs, including significant interest abroad. According to Dr. Gary, units cost approximately $200,000-$300,000 although highly customized models can reach $400,000.

Adelphi is also working closely with potential security and healthcare customers to design Adelphi sources as OEM (Original Equipment Manufacturer) parts in their customers' systems.

Products

Adelphi has designed and developed neutron sources, producing sources with neutron energies ranging up to 14 MeV and output levels of up to 10^{10} neutrons per second. Recently, the company has added neutron detectors to its product line for use in security and healthcare applications.

Deuterium—Deuterium Sources

The deuterium—deuterium (DD) reaction produces neutrons sufficiently energetic (2.5 MeV) for non-destructive elemental identification in a wide range of analytic applications. Like the deuterium—tritium sources, these systems consist of an accelerator head, a power supply (2kW) and control rack, and a heat exchanger/chiller. Because deuterium is non-radioactive, Adelphi's DD generators source a continuous supply of deuterium gas from an external tank, resulting in a tube head with almost unlimited lifetime. Other internal components can be easily exchanged by the user as needed due to damage or excessive wear. "These generators make excellent fast epithermal and thermal neutron sources for laboratories and industrial applications that require neutrons with safe operation, small footprint, low cost and small regulatory burden."[6]

Deuterium—Tritium Sources

Deuterium—tritium (DT) sources produce much more energetic neutrons (14.1 MeV) than deuterium—deuterium sources. Thus, DT neutrons penetrate further into objects, for more effective screening and imaging. The DT reaction is 100 times more efficient than the DD reaction, so DT sources have substantially lower operating costs. However, both capital and maintenance

[6]See http://www.adelphitech.com/products/dd109-dd110.html.

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costs are higher, and higher energy neutrons require heavier shielding to protect users. Furthermore, because tritium itself is radioactive, the tube head is sealed for user safety. The tritium inside is consumed, and eventually the source must be returned to Adelphi for periodic maintenance, typically after several thousand hours of operation. Also, the customer must register DT sources with the Nuclear Regulatory Commission.

Detectors

Adelphi's detector work has been motivated mostly by the opportunity presented in security applications where the goal is not only to produce neutrons but also to detect their interactions with matter in real time. Detector projects include liquid Argon large volume detectors, a large area scintillation camera, particle imaging, and phoswich detectors for neutron discrimination.

Patents and Other Intellectual Property

Adelphi Technology is the assignee for the U.S. patents listed in Table E-1.

Adelphi Technologies and SBIR/STTR

Between 1984 and 2014, SBIR/STTR funded 91 projects with Adelphi Technology, Inc. amounting to nearly $19.7 million in funding. Of this, DoE accounted for approximately 41 percent, NIH 25 percent, and NSF 17 percent, with the remaining 17 percent from the DoD, NASA, the Department of

TABLE E-1 Adelphi Technology Patents

Patent Number	Patent	Year
7,177,389	X-ray tomography and laminography	2007
6,992,313	X-ray and neutron imaging	2006
6,765,197	Methods of imaging, focusing and conditioning neutrons	2004
6,674,583	Fabrication of unit lenses for compound refractive lenses	2004
6,545,436	Magnetic containment system for the production of radiation from high energy electrons using solid targets	2003
6,269,145	Compound refractive lens for x-rays	2001
6,201,851	Internal target radiator using a betatron	2001
5,107,508	X-ray laser	1992
5,077,774	X-ray lithography source	1991
4,951,304	Focused x-ray source	1990

SOURCE: U.S. Patent and Trademark Office.

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Homeland Security, and the Department of Transportation. Dr. Gary observed that typically 30 percent of SBIR funding and 40 percent of STTR funding is used for subcontracts.

Adelphi has extensive experience with the DoE SBIR/STTR program. Dr. Gary observed that DoE SBIR/STTR topics were in some cases clearly derived from the research-oriented interests of topic managers, while in others there was a commercial interest as well. Adelphi had initially won a series of more science-oriented awards but as a result of increasing internal focus on commercialization was now more selective in the topics to which it applied. However, some recent awards on neutron optics were in topics that showed limited commercial potential given market realities for that technology.

Dr. Gary was concerned that some topics were simply not funded at all. He believed that DoE should be careful to ensure that topics were excluded from the solicitation if there was no track record of funding. He also suggested that DoE consider funding broader topics. Currently, too many topics are tightly defined technically, which meant that potentially valuable ideas were not considered.

Dr.Gary said that the topic development process at DoE was quite opaque, and he suspected that for a number of topics the process was largely driven by research scientists within DoE. While this resulted in interesting science, he believed that it lacked alignment with commercial opportunities: not all good science is commercially viable.

DoE currently provides one solicitation annually for each broad area of interest; Dr. Gary said that agencies providing more than one solicitation—such as DoD and NIH—were better attuned to the speed of technical development, and that DoE should consider adding at least one additional deadline for solicitations annually.

More generally, Dr. Gary said that connections with DoE staff were very limited. Project liaisons appeared to have other more pressing responsibilities, and in most cases there was almost no contact between the DoE staff and the PI or company representatives beyond the resolution of contracting issues.

In particular, DoE staff were said to be of little help in finding potential markets for the technology within DoE. This contrasts for example with Homeland Security, which clearly considers itself a potential customer for SBIR/STTR products and hence pays quite close attention to progress on the award. Overall, Dr. Gary said that it was very rare to find a DoE program manager who was interested in the funded project; in most cases they simply sought to ensure that no fraud was being perpetrated and that the science was good.

So far as the review process was concerned, Dr. Gary felt that insufficient information was being provided to applicants—in particular, too many applications were graded as excellent but not funded. It would be helpful

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to have a more granular review that effectively identified weaknesses when projects were not selected.

Dr. Gary was also a strong proponent of better review feedback more generally. He noted that NIH provides an online resource (ERA Commons) where applicants can find all of their applications and all reviews. In contrast, DoE applicants must apply to have a review sent to them, and the window for this application is limited. This substantially reduced the value of the process for the company and imposed unnecessary burdens.

Finally, Dr. Gary wanted to underscore his appreciation for the DoE payments system, which he believed was the best of all the SBIR/STTR agencies. Funding was available immediately and could be pulled in any amount at any time against work and need. This was extremely helpful for a small business, and contrasted very favorably with other agencies that used a milestone-based system.

STTR

Dr. Gary noted that Adelphi typically works with research institutions that are seeking ways to bring their technology to market. In some cases, Adelphi has identified opportunities. In others—for example a current STTR project—the driver is the university where the researcher is the PI. The work in this case is in a fairly esoteric field with minimal commercial potential, but the project has been highly successful technically.

Dr. Gary said that he was a strong supporter of the STTR program, and believed that companies were best placed to determine whether a project should be SBIR or STTR, based on the needs of the project. He observed that a separate solicitation for STTR was likely to generate poor quality partnerships put together primarily to find funding, and that SBIR/STTR should provide a single opportunity for funding.

So far as funding amounts were concerned, Adelphi would certainly consider applying for less funding if there was some benefit for doing so—for example, a higher likelihood of success. As this was not the case for most agencies. The company instead designed the project to meet the funding available.

CALABAZAS CREEK RESEARCH, INC.[7]

Calabazas Creek Research (CCR) is a private company founded in 1994 by Dr. R. Lawrence Ives, who remains as its president. The company specializes in the design and development of high power electron beam devices, including electron guns and RF sources. In addition to product and service

[7]Primary sources for this case study are an interview with Dr. Ives on August 21, 2015, and a review of the Calabazas Creek Research website (http://www.calcreek.com) and related company documents.

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offerings, CCR also licenses software tools for the design of electron beam devices and waveguide components. These software packages simulate particle trajectories, electromagnetic fields, RF fields, thermal performance and RF radiation.

Dr. Ives founded CCR after previously working for a large defense contractor. While an employee, he reviewed SBIR proposals, and, after starting his company, immediately sought SBIR funding, winning two DoE projects. In both cases, Phase II's were subsequently awarded and provided a foundation for the company in both financial and technical terms—the technology developed for one of the awards is still the most advanced in the world, according to Dr. Ives. The projects also provided a commercial return, with about six sales of devices for testing high-powered gyrotrons, at approximately $120,000 each.

CCR is primarily a research and development firm, developing high power electron beam devices and components for clients working in communications, defense, and particle physics research. CCR employees prototype designs in a laboratory leased from Communications & Power Industries, a $350 million manufacturer of components for the defense and telecommunications sectors.[8]

CCR is a virtual company. Aside from the lab space noted above, it rents or owns no office space. Two employees work in the laboratory and the remaining staff, located across the country, work from home offices. Dr. Ives said that the company's very low cost structure substantially reduces its overhead rate (to slightly more than 20 percent), which allows it to pay wages that are considerably higher than the industry standard. The company offers no paid leave and relies on what Dr. Ives believes to be a much more comfortable and productive environment for its staff.

In addition to providing innovative designs for components in medical and defense systems, CCR provides technology to high energy physics research scientists. For example, CCR partnered with the SLAC National Accelerator Laboratory to improve the performance of cavity resonators in linear accelerators. Stronger electric fields within the resonators allow shorter accelerators, potentially saving millions of dollars in construction costs.[9]

CCR has received substantial recognition for its work. In 2011 the company received an R&D 100 Award for developing Controlled Porosity Reservoir Cathodes that significantly improve cathode performance and lifespan. CCR leadership has also been deeply involved in strengthening the SBIR program. In 2012, Dr. Ives received the Champion of Small Business

[8]Bill Silverfarb, "It is rocket science," *The Daily Journal*, August 15, 2011, http://archives.smdailyjournal.com/article_preview.php?id=165168.

[9]"SLAC Partners with Small Businesses to Put Technology to Good Use: DoE-funded Program Benefits Companies, the Lab and Society," July 29, 2014, https://www6.slac.stanford.edu/news/2014-07-29-slac-partners-small-businesses-put-technology-good-use.aspx.

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Innovation award for his part in 2011's campaign for the long-term reauthorization of SBIR program funding from Congress.[10]

Because CCR produces world leading technology, its products are in demand outside the United States as well. CCR products can be found in Germany, England, India, Japan, Korea, and China. The company is also developing products to meet DoE's obligations for the ITER project in France.

Technology and Products

Electron Beam Devices

Although semiconductors have displaced vacuum tubes in many logic and communications applications, there remain important niche applications in television transmitters, satellite communications, material processing, defense, and particle accelerators. CCR designs and develops a broad range of high power, short wavelength devices and components for these applications.

The principal devices produced by CCR include traveling-wave tubes, klystrons, gyrotrons and keystrokes. They operate by modulating a beam of electrons using a mixture of electromagnetic fields and resonance phenomena to generate high power, high frequency RF waves. Although related, these technologies vary in their characteristics and applications.

Much of CCR's work is in the development of klystron and gyrotron technologies. In a klystron, cavity resonators modulate a high energy electron beam with an input signal and convert the resulting modulated beam into an output signal. High performance klystrons operate at power levels to 10s of MW and frequencies up to approximately 100 GHz.[11] CCR has designed RF sources producing RF power from a few milliwatts to 200 MW and at frequencies from a few hundred MHz to 1 THz.

Gyrotrons also feature a cavity resonator. The resonator operates in combination with strong magnetic fields to transfer electron beam energy into RF radiation. This radiation can be formed into a beam and emitted at right angles to the direction of the original electron beam. High performance gyrotrons operate in the 1-2 MW CW range and up to 250 GHz.[12]

As in other electron beam devices, the power of a gyrotron is determined by the energy of the electron beam. Consequently, CCR personnel are skilled in designing different components in these devices (such as electron guns, circuits, collectors, RF windows, *etc.*). Indeed, one of CCR's most

[10] "SBTC Honors "Champions of Small Business Innovation,'" February 7, 2012, http://www.nsba.biz/content/printer.4422.shtml.

[11] "How do klystrons work?" Berkeley Lawrence Livermore Laboratory, http://www2.lbl.gov/MicroWorlds/ALSTool/ALS_Components/RFSystem.

[12] "What is a gyrotron?" Bridge 12, http://www.bridge12.com/learn/gyrotron; E. Borie, "Review of Gyrotron Research," Institut für Technische Physik, August 1991, http://bibliothek.fzk.de/zb/kfk-berichte/KFK4898.pdf.

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successful innovations—the sintered wire cathode, which CCR licensed to Ceradyne—is a sub-component in an electron gun.

Corrosion Mitigation

CCR is now actively working on using atomic layer deposition (ALD) to dramatically improve the corrosion resistance of copper cooling channels (the company has long experience in designing cooling circuits). A current Navy STTR program is focused on this effort, and Dr. Ives believes that this may provide a breakthrough technology with many applications.

This STTR is in partnership with North Carolina State University, and Dr. Ives noted that these kinds of arrangements allow a small company such as CCR to enter entirely new technology areas by tapping into university expertise and equipment. ALD requires equipment that CCR does not have and could not afford, even with a Phase II STTR award, but that is readily available at NC State.

Design Services

CCR provides design and development services for many electron beam devices. Additionally, it also licenses simulation and computational tools that CCR has developed to design such devices more effectively.

Design and Development

CCR offers a range of services related to the design of electron beam devices. Broadly, they are: (1) hardware design, (2) software development, (3) thermomechanical analysis, (4) electromagnetic analysis, and (5) CAD and other design services. Testing and support services are provided by Communications & Power Industries (CPI)[13] in Palo Alto, California.

Software

CCR markets intuitive, user-friendly software for a broad range of electromagnetic and particle simulations to the microwave research community.

Patents and Other Intellectual Property

CCR has historically used patents to protect its intellectual property (IP). (See the list of CCR assigned patents in Table E-2). However, Dr. Ives is

[13]Bill Silverfarb, "It is rocket science."

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TABLE E-2 CCR Patents

Patent Number	Patent	Year
9,013,104	Periodic permanent magnet focused klystron	2015
8,963,424	Coupler for coupling gyrotron whispering gallery mode RF into HE11 waveguide	2015
8,686,910	Low reflectance radio frequency load	2014
8,664,853	Sintered wire cesium dispenser photocathode	2014
8,547,006	Electron gun for a multiple beam klystron with magnetic compression of the electron beams	2013
7,545,089	Sintered wire cathode	2009
7,313,226	Sintered wire anode	2007
7,102,459	Power combiner	2006
6,987,360	Backward wave coupler for sub-millimeter waves in a traveling wave tube	2006
6,919,776	Traveling wave device for combining or splitting symmetric and asymmetric waves	2005
6,847,168	Electron gun for a multiple beam klystron using magnetic focusing with a magnetic field corrector	2005
6,768,265	Electron gun for multiple beam klystron using magnetic focusing	2004
6,411,263	Multi-mode horn	2002
5,949,298	High power water load for microwave and millimeter-wave radio frequency sources	1999
5,780,970	Multi-stage depressed collector for small orbit gyrotrons	1998

SOURCE: U.S. Patent and Trademark Office.

concerned that the rising costs of patents, particularly maintenance fees, means that CCR will have to become much more selective about which technologies it seeks to patent.

Dr. Ives was also a strong supporter of the recent DoE initiative to permit companies to spend up to $10,000 per Phase II award for patenting costs. He noted that recent proposed changes in Congress impacting the patenting process would have a highly negative effect on small innovative companies like CCR.

Business Model

CCR is not reliant on SBIR/STTR for revenues. Currently, SBIR/STTR provides about 50 percent of annual revenues, according to Dr. Ives. Its customers have included the U.S. Department of Defense, Department of Energy, the National Aeronautics and Space Administration, Raytheon Company, Titan Pulse Sciences, Inc., NexRay, Inc., KLA-Tencor, Inc.,

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Forschungszentrum Karlsruhe (FZK) (Germany), Communications & Power Industries, LLC., TMD Technology, Inc. (United Kingdom), Japan Atomic Energy Association (JAEA), Stanford Linear Accelerator Center, Naval Research Laboratory, Q-Dot, Inc., ARINC, Inc. Heatwave Laboratories, Inc., Surebeam Corporation, Macrometalics, E-Beam, Inc., Omega-P, Inc., MDS Company, Altair, Inc., H.V. Systems (India), and Samsung (Korea). CCR is also working as a subcontractor to provide an electron gun for a major classified defense program.

CCR is also successful in licensing intellectual property developed through SBIR funding. In 2010, Ceradyne acquired the intellectual property rights for "sintered wire" technology that enables the production of a tungsten, reservoir, dispenser cathode with applications in electronic counter measures (ECM), telecommunications, medical devices, defense, and scientific research. The licensed technology improved the cathode current density by a factor of ten and extended cathode lifespan by a factor of two to four times (U.S. Patent #: 7,545,089).[14]

CCR also generates income by providing design services to the microwave R&D community. Technical services have been provided to numerous organizations, including Karlsruhe Institute of Technology (Germany), Communications & Power Industries, LLC, (USA) Northrop Grumman Corp. (USA), Samsung (Korea), Japanese Atomic Energy Agency (Japan), and SLAC National Accelerator Laboratory (USA).

Collaborations

CCR is strongly oriented toward collaboration, particularly with academic research partners. It maintains research relationships with various academic laboratories, such as the Massachusetts Institute of Technology, North Carolina State University, University of Maryland, and Rensselaer Polytechnic Institute. CCR also works with several industrial organizations, including Ron Witherspoon, Inc. and HeatWave Labs, Inc. Its list of recent collaborators includes:

- University of California, Berkeley
- Rensselaer Polytechnic Institute
- North Carolina State University
- University of Maryland
- University of Wisconsin
- Old Dominion University

[14] "Ceradyne, Inc.'s Semicon Associates Division Acquires New Ceramic Impregnated Dispenser Cathode Technology," July 26, 2010, http://www.ceradyne.com/news/newsreleasedetails.aspx?id=192.

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- SLAC National Accelerator Laboratory
- Fermilab
- Sandia National Laboratory
- General Atomics
- Los Alamos National Laboratory
- Communications & Power Industries, LLC

SBIR/STTR

Between 1995 and 2014, SBIR/STTR funded 119 projects with CCR, amounting to nearly $31.4 million. Of this, DoE provided about 75 percent, DoD provided 23 percent, and the balance came from NASA and NSF.

STTR

CCR sees STTR as an enormously helpful program and finds that, in some cases, it is a better vehicle for company initiatives than SBIR (in which the company also participates extensively).

Dr. Ives noted that STTR provides an appropriate structure for partnering with research institutions and also offers access to the creativity and enthusiasm of graduate students. A recent STTR with North Carolina State University led to student-developed designs being incorporated into CCR products.

CCR had differing experiences with universities. Some, such as NC State, were said to have offered realistic licensing terms and welcomed collaboration with small companies. Others reportedly did not appear to understand the limited resources of small businesses and required unrealistic up front licensing fees and royalties. Similarly, there are often complexities in dealing with university technology transfer offices that limit commercialization.

Partnering with research institutions was said to result in other challenges. In particular, universities and students want to publish their research. It was therefore, in Dr. Ives' view, important to understand this need and provide opportunities to publish without compromising company intellectual property. Dr. Ives believes this can be accomplished, as the record of publications related to CCR-university collaborations shows.

Dr. Ives said that when he sees interesting topics in a solicitation that are outside the company's range of expertise, he seeks possible collaborators through his extensive network of technical experts and is often able to identify appropriate collaborators.

Recommendations for SBIR/STTR

Dr. Ives said that none of CCR's major accomplishments would have been possible without SBIR and STTR. He then offered a number of comments

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and recommendation related to SBIR/STTR, and in particular the DoE SBIR/STTR program, from which CCR has received most of its SBIR/STTR funding.

Topic Development. Dr. Ives noted that the wording of topics in some cases did not change from year to year, which in his view suggested that the agency was not interested in these areas.

Unfunded Topics. According to Dr. Ives, some agencies appear to publish topics in areas that are unlikely to be funded. These are often topics that appear year after year with no awards being made. This is a waste of time for companies that apply. Topics that are systematically not funded should be eliminated.

Phase III. Dr. Ives observed that most agencies do not have a Phase III policy in place that supports commercialization of technology developed in the SBIR/STTR program. Recent experience with a national laboratory suggests that operations within agencies are not following the Phase III directives in the current SBIR law. Phase III is currently not seen as a responsibility of the SBIR/STTR Program Office, and it does not appear that it is the responsibility of any other office within the agencies. Dr. Ives said that an exception is the U.S. Navy, which established a Phase III policy and insures it is followed by its operational offices.

More Recent Focus on Commercialization. Dr. Ives said that historically, some agencies appeared to have little interest in commercialization, and that most topics were focused more on addressing technology needs rather than development of commercial products. CCR previously applied for many such topics, and received awards, but realized that it was difficult to build a sustainable business on 6-7 percent profit margins. The company has become much more selective about which SBIR/STTR awards it applies for, with a greater emphasis on commercialization potential.

SBA Commercialization Benchmarks. Dr. Ives supports the new SBA commercialization benchmarks for awardees with a minimum number of awards. He believes that this will encourage firms to take a more commercial view of their activities.

Letters of Intent. Dr. Ives said that the letter of intent (LOI) process provided a good opportunity for companies to explore possible applications without committing substantial resources.

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COMPACT MEMBRANE SYSTEMS, INC.[15]

Compact Membrane Systems, Inc. (CMS) is a private company founded in 1993 by Stuart Nemser. Prior to creating CMS, Mr. Nemser worked in a range of engineering and management positions at Dupont and acquired the right to a set of Dupont patents related to certain membrane and thin film technologies. For over 20 years, CMS has developed these pervaporative fluoropolymer membranes and thin films technologies. CMS is headquartered in Wilmington, Delaware, and has approximately 25 employees.[16]

Having received over 200 SBIR/STTR grants worth nearly $50 million, CMS successfully developed various pervaporative membranes. CMS now owns a portfolio of effective, differentiated, separation technologies with broad commercial applications. The membranes are composed of highly fluorinated polymers with unusual gas transport properties. Also, they have extremely high thermal and chemical stability.

SBIR provided the first funding for the company, and in subsequent years permitted CMS to explore a range of possible applications, according to Mr. Nemser. That exploratory period is now over, and CMS uses SBIR in a much more targeted fashion (see below). He noted that the solicitation-based character of SBIR helped the company target its energies better—the solicitations at least indicated applications in which the government was interested.

CMS came to focus initially on applications related to the chemical industry and in particular developed expertise in using membranes for dehydration purposes. Subsequently the company developed applications in mining, marine, power generation, wind power, coal conveyers, and paper mills. It also generates significant sales through exports, especially to Asia.

CMS recently hired as President a senior executive from McKinsey's pharmaceutical and medical products practice to commercialize these technologies more aggressively. Although CMS has developed a broad range of potential applications of this technology, its initial go-to-market strategy is focusing on two particular separation problems: dehydrating lubricants and solvents, separating olefins from paraffins.

At present, the company focuses on customers with large, industrial, capital-intensive operations in the petrochemical, maritime, power generation, and aerospace industries. CMS markets its systems to help customers lower cost, increase efficiency, and operate with lower levels of environmental pollution compared to current technologies.

[15]Primary sources for this case study are the interview with Stuart Nemser, company founder, and a review of the Compact Membrane Systems, Inc. website (http://www.compactmembrane.com) and related company documents.
[16]Environmental Expert, "Company Membrane Systems, Inc." http://www.environmental-expert.com/companies/compact-membrane-systems-inc-8184.

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In addition to SBIR funding, CMS also sells pervaporative membrane-based separation equipment to customers in the petrochemical, heavy equipment, power generation, and aerospace sectors.

Technology

CMS membrane technology uses a physical process called pervaporation to separate two or more components in a chemical flow. Different rates of diffusion through a membrane enable highly efficient extraction of contaminants such as water or organic compounds from a flow. This technology is broadly applicable and can be utilized in a range of systems and processes, including lubrication systems (in marine vessels, power plants, mining, milling), solvent systems (e.g., in paint manufacture, semiconductor manufacture), and pharmaceutical ingredient manufacture.

In pervaporation, two components in a flow are separated using a thin polymer membrane. By maintaining a concentrate and vapor pressure difference across the membrane, one component—the permeate—will preferentially diffuse through the membrane. "A vacuum applied to the permeate side is coupled with the immediate condensation of the permeate vapors." [17] There are two requirements for success. First, the membrane must be designed for high selectivity to the permeate component, and, second, the permeate must be a vapor at the expected operating temperature of the process.

Because of the low temperatures and pressures required, pervaporation often has cost and performance advantages in separating mixtures of liquids not easily separated using distillation. Pervaporation "can be used for the dehydration of organic solvents or the removal of organics" from aqueous streams. Pervaporation is a good process for separating heat sensitive products.[18] Finally, pervaporative membranes work with liquids across a broad range of viscosities and tend to resist fouling.

Compared to other dehydrating technologies, the CMS pervaporative membrane technology has a number of competitive advantages. It is extremely effective, maintaining very low moisture levels in lubricants, oils, and solvents. In industrial environments, CMS membrane systems have been shown to remove 100 percent of free and emulsified water, reduce dissolved water to well below 100 ppm, and, under certain conditions, remove dissolved air. The system runs with minimal oversight and management, and fewer moving parts than other purification systems.

[17]"Pervaporation: An Overview," CheResources.com: Your Chemical Engineering Community (November 8, 2010), http://www.cheresources.com/content/articles/separation-technology/pervaporation-an-overiew.

[18]"Products," Compact Membrane Systems, Inc." http://www.environmental-expert.com/companies/compact-membrane-systems-inc-8184/products.

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Products

CMS has developed membrane systems for four different applications targeting the petrochemical, heavy equipment, power generation, and aerospace sectors. Other applications—such as the elimination of fault gases in high voltage electrical transformers or the removal of NO_x emissions from diesel exhaust—are feasible, but CMS is currently focusing on the following applications of its technology.[19]

Oil Dehydration

Water in lubrication oil inhibits the oil's capacity to enable performance and prevent damage to moving parts. The presence of water—whether in a free, emulsified, or dissolved state—degrades lubricity and accelerates component degradation that shortens the life of gears, bearings, and other elements in lubrication and hydraulic systems. CMS membranes manage water ingress in challenging environments such as power plants, paper mills, steam turbines, wind turbines, and various marine systems. Importantly, CMS technology dehydrates lubricating oil without removing performance additives.

Solvent Dehydration

In printing, electronics, fine chemicals, and other applications, solvents are used to transport a target substance. Some solvents are easily recovered and reused, but others—such as many alcohols—are simply discarded because of the cost of recovering and purifying them. CMS membranes can dehydrate solvents like alcohols. Applied in series with distillation and other technologies, CMS membranes can dehydrate alcohols (such as isopropyl alcohol) to a purity of greater than 99.5 percent at a fraction of the cost of purchasing new solvents.

Environmentally Acceptable Lubricants Dehydration

The release of lubricants into aquatic ecosystems during shipping operations is equivalent globally to over one Exxon Valdez disaster annually. Environmentally Acceptable Lubricants (EAL) are lubricants demonstrated to meet standards for biodegradability, toxicity, and bioaccumulation that greatly reduce the impact lubricants on aquatic environments. Shipping companies and ship builders are slowly adopting these new lubricating materials.[20]

To meet EAL standards for biodegradability, EALs are often designed to be water soluble and attract an unusually high concentration of water

[19]Ibid.
[20]"Environmentally Acceptable Lubricants," United States Environmental Protection Agency, EPA 800-R-11-002 (November, 2011), http://nepis.epa.gov/Exe/ZyPDF.cgi/P100DCJI.PDF?Dockey=P100DCJI.PDF.

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compared to mineral oil-based lubricants. Adoption of EALs requires the implementation of EAL dehydration systems in real time to avoid corrosion. CMS provides systems that dehydrate reducing and maintaining water concentrations to ppm levels for a wide range of EALs including polyalkylene glycols, synthetic esters, and polyalphaolefins.

Olefin-Paraffin Separation

Olefin-Paraffin separations are a core process in the petrochemical industry. Outputs from these separations include polypropylene, polyethylene, polyester, polyvinyl chloride (PVC), rubber, nylon, and are more worth about $300 billion annually. Nearly every industry—from manufacturing and construction to electronics and pharmaceuticals—use these inputs to make consumer products. These separations are extremely energy intensive industrial processes, using an estimated 250 trillion BTU/year.[21]

Distillation is currently the method of choice for separation of olefins such as ehthylene or propylene from paraffins such as ethane or propane. Retrofitted to existing propylene/propane splitter units, the CMS hybrid membrane/distillation process can significantly reduce energy costs and increase yield (by 15 percent) compared to the energy-intensive distillation currently used. For initial, smaller applications, the CMS systems costs less than $1 million to install, less than $500,000/yr to operate, and has an estimated IRR of 150 percent.

Markets

Given the wide range of industry verticals in which CMS technologies could be applied, CMS decided that it made little sense to build distribution networks in each vertical industry and instead opted to find license or distribution partners better positioned to attack these markets. These partners can leverage their own brands and reputations, market access, and customer insight. This was especially important during the early days of CMS when the company, according to Mr. Nemser, lacked visibility and credibility among downstream customers.

Today, CMS has delivered more than 3,000 systems to these different markets. The company has its own well regarded brand, especially among original equipment manufacturers (OEMs) even if the CMS brand is still not widely recognized among end users.

The company is now strategically focused on growth in a number of sectors, including marine, where it plans to use a current EPA/Coastguard

[21] "SBIR/STTR Success: Compact Membrane Systems," https://www.sbir.gov/sites/default/files/SBAsuccess_CompactMembraneSystemsFINAL.pdf.

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initiative aimed at encouraging the use of better and more hydrophilic lubricants. A major advantage is that this initiative could allow CMS to start selling completed systems, rather than components or partner with a major service provider in the marine market to bring the product to market at a much larger scale than CMS could achieve alone. Mr. Nemser said that CMS now has the IP and the knowhow in making membranes, as well as the manufacturing capacity, to make a successful product. The key strategic question is how to best approach each market to maximize likelihood and magnitude of success. For example, should the company move downstream or indeed upstream to capture more value. One model being explored was to develop branded components as part of a partnership with players dominant in their sectors.

Patents and Other Intellectual Property

CMS is the assignee for five key patents since 1999. CMS has many other patents, and a number of recent applications. Many of these were under Compact Membrane Technology Holdings. The two companies were merged at the end of 2015.

SBIR/STTR

Between 1993 and 2015, SBIR/STTR funded 210 projects with CMS, amounting to over $49.9 million in R&D support. 43 percent was provided by DoE, 31 percent by NIH, and 8 percent by the U.S. Department of Agriculture. The balance derives from the NSF, DoD, NASA, and Commerce. SBIR awards account for 92 percent of the total by value.

Over the past five years, CMS has reduced its dependence on SBIR/STTR funding. The three year moving average for 2014 (the most recent year for which we have complete data) is $1.5 million, down 54 percent from the $3.3 million reported in 2010. Considering that the number of employees has grown slightly over the same period (going from 22 in 2010 to 25 in 2014), CMS appears to be shifting to a commercial business model based on product revenues.[22]

Mr. Nemser said that changes made to the DoE SBIR/STTR programs had been a significant improvement. The program appeared now to be focusing further downstream, away from basic science, and CMS strongly supports the introduction of Phase IIA and Phase IIB at DoE, especially as CMS believes that a single Phase II award is often insufficient to develop a marketable product. Phase IIB provides up to one-third of Phase II funding to support getting the product to market. CMS has also participated in the introductory accelerator program.

[22] "COMPACT MEMBRANE SYSTEMS, INC." https://www.sbir.gov/sbirsearch/detail/130036.

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CMS also strongly supports the letter of intent (LOI) process. Mr. Nemser observed that while he never like being rejected, he would much rather be rejected on a one-page document than a 20-page proposal.

In addition, CMS supported the limit of 10 proposals per solicitation from any one company. This had in fact limited CMS applications, which had peaked at 17 in one year before the limit was put in place.

CMS has also used the “other” category within the DoE solicitation. Initial discussions with a topic manager has clarified that the CMS proposal would not be deemed responsive to a specific topic, but the topic manager suggested that CMS apply instead under the “other” category.

Mr. Nemser noted that the responsiveness of topic managers varied widely, and did not always compare favorably with responses at other agencies—he found managers at EPA and the USDA to be especially responsive. He also noted that it’s worth being creative in seeking funding: he said that NIH in fact has more funding available for environmental topics than EPA, and that NIH will fund ideas that might seem better aligned to the EPA’s goals and mission.

Ms. Nemser noted that this is especially important in light of the company’s focus on the current EPA/Coastguard initiative related to marine lubricants. EPA/Coastguard have announced that all 200,000 ships operating in U.S. waters must use hydrophilic lubricants. The CMS system is uniquely positioned to address this need by separating lubricating fluids from water. At a panel convened at the International Workboat Show, CMS, the EPA, and several manufacturers discussed lubricant options and provided guidance to vessel owners and operators.

Overall, Mr. Nemser observed that DoE uses Phase I and Phase II very effectively to advance technology that supports its technological objectives. He went on to say that CMS has been able to conduct research and develop products that would not otherwise reach the market. However, companies need to be aware that overcoming technical hurdles is just a first step. Companies will still need to face major challenges on the road to commercial success, which are out of the scope of grants. These typically include market and user insight, customer network and access, user awareness and feedback. He noted that companies that address these too late (i.e., in sequence after grants) or underinvest their own funds can find themselves facing the "valley of death" on their own. He noted that VCs understand the need to double down on their investments to get through this period before products are introduced into the market, but that DoE has no capacity in place to do so, and has made no real effort to help in this area. Best practice in new product development call for early discussions between marketing and commercialization teams on one side and the scientific and engineering team to influence product design at a stage when adjustments are inexpensive, and when the company can focus some energy on building a network of early adopters, as well as a preliminary set of

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marketing decisions (which might for example include identification of key conferences). Ms. Nemser noted that this model of product development was mandatory in the pharmaceutical sector.

SBIR forces companies to undertake very high risk work, which makes it difficult to attract any kind of venture funding unless the product is targeting a very large market.

Topics are sometimes science oriented, but others can be very practical. They also support longer sequences of work that develop platform technologies and then permit a range of applications. For example, the Phase III accelerator program helped CMS launch its oil dehydration systems. Their success underpinned further grants focused on solvent dehydration, a technology which is now being commercialized by capitalizing on the existing infrastructure and manufacturing capability.

Recommendations

[The following recommendations were provided jointly by Ms. Nemser and Mr. Nemser on behalf of CMS]

Downstream Funding. The top priority for CMS is to see DoE find ways to shift more funding to downstream questions to help with commercialization. This is a key concern given the difficulties of finding outside money for further product development prior to revenue.

Direct to Phase II. Under current guidelines, direct to Phase II excludes work completed under a previous Phase I—the program only supports work completed by the company without SBIR/STTR Phase I funding. This simply seems an unnecessary barrier—previous Phase I work may have entirely novel applications but is currently excluded from the program. More flexibility is needed.

Proposal Review. CMS strongly prefers application systems that generate quantitative scores. That allows companies to see the funding line and to understand how close they were. DoE's program would be improved by clearer scoring, although CMS noted that DoE provides strong technical feedback.

CMS also supported ideas that would help address errors or omissions in the review process. The company supported the resubmission approach adopted by NIH, and also recommended that DoE explore ways to provide feedback from the company before reviews were finalized—ideally through some version of face-to-face defense, to the extent that is possible.

STTR. CMS notes that there are always difficulties in dealing with research institutions. The latter do great work, but do not operate on the same timeline as an SBC. Their involvement is usually needed because they have a unique skill. Overall, CMS would not oppose the notion of folding STTR into SBIR, although it is also not a strong supporter. STTR is really just a vehicle to do joint work.

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National Labs. So far as the National Labs are concerned, CMS has worked with the Labs on occasion (e.g. Sandia), and noted that recent program changes have excluded NETL from the SBIR/STTR program. CMS used to have an active program with NETL, and strongly believes it would be helpful to include the lab back into the program.

CREARE, INC.[23]

Creare LLC is a private company founded in 1961 by Robert Dean. Dr. Dean was an Assistant Professor of Mechanical Engineering at MIT in the Gas Turbine Laboratory, the Head of Advanced Engineering at Ingersoll-Rand Company, and an Associate Professor and later Professor of Engineering at Thayer School of Engineering at Dartmouth, prior to starting Creare. Dr. Dean is now Professor of Engineering, emeritus. The company is an engineering research and development company, which both acts as an engineering consultancy and commercializes proprietary technologies through licensing or through the creation of independent product companies. Creare is headquartered in Hanover, New Hampshire, and has approximately 150 employees.

Creare is a partnership. It has seven principal engineers who own and operate the company. According to Creare's Principal Engineer, Dr. Rozzi, "for someone who wants to get their technology implemented and see their ideas manifested in the world, it's the ideal place to work—an engineering Disney Land."

The company originally provided expertise in fluid dynamics, serving the turbine machinery and nuclear industries during the 1960s and 1970s. In the 1980s, Creare branched out into the energy, aerospace, cryogenics, and materials processing industries. The 1990s brought growth in software, controls, and biomedical applications. Typical deliverables from an engagement with Creare include analysis with results, experimental data, engineering models, design recommendations, software, numerical solutions, prototypes, and hardware designs.

Although Creare's founding precedes the creation of the SBIR/STTR program, it has proven to be one of the most adept participants in the program. Since 1985, Creare has received over 950 awards, \$50 million in SBIR Phase I, \$197 million in SBIR Phase II, \$3.3 million in STTR Phase I, and \$10.2 million in STTR Phase II.[24]

[23]Primary sources for this case study are the interview with Jay Rozzi, Principal Engineer, Dr. Rozzi's presentation at the National Academies' of Sciences, Engineering, and Medicine workshop on STTR, May 2015, and a review of the Creare, Inc. website (http://www.creare.com) and related company documents.

[24]"CREARE LLC" https://www.sbir.gov/sbirsearch/detail/263879; National Research Council, *An Assessment of the Small Business Innovation Research Program*, Washington, DC: The National Academies Press, 2008, p. 268.

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Creare's offices and laboratory facilities cover over 60,000 sq. ft. and are located in Hanover, New Hampshire. The office space includes general seating for engineering, technical, and administrative staff, computer facilities, a dedicated technical library, conference rooms and various community spaces. Over half the facility is dedicated to laboratory space, experimental project rigs, machine shops, and specialized fabrication and test apparatus. These extensive facilities and in-house capabilities have been developed and refined over Creare's 50+ year history to serve its broad range of clients. Creare's capabilities enable projects that span development activities in mechanical systems and prototypes, electronics, advanced manufacturing, chemical engineering, nuclear engineering, bioengineering, space-qualified systems, materials development, acoustics, cryogenics, etc. Creare's laboratories are supplied with standardized buses for electric power and pressurized air that enable a broad range of general experimental work. Extensive clean room facilities enable fabrication, assembly, and testing of space-qualified hardware. Its in-house fabrication capabilities are supported by an extensive machine shop and a fully equipped electronics laboratory. To support clients that require qualified and documented hardware, Creare also maintains a quality assurance program and state-of-the-art inspection facilities. Creare's labs are staffed with approximately 40 highly skilled electrical and mechanical technicians, machinists and support staff who typically support approximately 100 concurrent experimental projects in its laboratories.

Creare also maintains research relationships with a broad range of university, government, and corporate R&D organizations. As an example, the list of industry partners working with Creare in the area of advanced manufacturing is both long and notable. Creare has strong relationships with machine equipment companies like KMT, MAG IAS, Fives, Harris Aerostructures, Saint-Gobain, Guhring, Iscar, AMETEK/Precitech, among many others. At the same time, it also works with these numerous prime contractors including LMACo, NGC, BHT, ATK, P&W[25] as well as Tier 1 suppliers.

Engineering Services

Creare provides engineering services to a diverse, international customer base, including both government and industrial clients, in a broad range of industries. At present, disciplinary foci include biomedical and human systems, cryogenics, fluid and thermal systems, sensors and controls, advanced manufacturing, and power systems. The following provides a sense of the disciplinary breadth of Creare's engineering work.

[25] Jay Rozzi, "Cryogenic Machining," p. 6.

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Cryogenics

Creare is well known in the areas of miniature high-speed turbomachinery and gas film bearings for cryogenic applications. These specialties are supported by the company's overall expertise in heat and mass transfer, thermal system design and analysis, and the fluid dynamics of multiphase and multi-component flow systems.

Cryogenics projects have included the development of probes for cryosurgical treatment of cancer, superconducting electrical buses for the space station, shipboard liquefaction of helium to cool advanced propulsion systems, and cryogenic cooling systems and packaging for superconducting electronics. Creare also designed, built, and delivered to NASA the cryocooler that fixed the malfunctioning infrared imaging system on the Hubble space telescope. This cryocooler was installed in 2002 and is directly responsible for the over 10-year revival of the NICMOS camera on the Hubble.

Fluid and Thermal Systems

The original disciplinary focus of Creare was fluid dynamics applied to turbines. Long experience in this area provides expertise suitable to any situation, including stationary or rotating machinery, coupled fluid flow, heat, and mass transfer; and chemically reacting flows.

Projects in this area include maintaining uniform temperatures during integrated circuit operation, evaluating the flow fields at the joints in the Space Shuttle solid rocket motors after the Challenger disaster, developing gas lifts for transporting solids mined in the deep oceans, among many, many others.

Sensors and Controls

Creare projects have included a wireless activity monitor for evaluating movement by patients with certain medical conditions, active noise reduction for communications headsets, and next generation catapult slot width measuring systems for U.S. Navy aircraft carriers.

Advanced Manufacturing

Creare develops advanced materials processing and component fabrication techniques, both as end products for clients and as means to build components for other projects. The main focus is to augment current processes to increase overall affordability and product quality. This work again blends strengths in fluid flow and heat transfer, control systems, hardware, and fabrication. Creare's Advanced Manufacturing Center (AMC) facilities at

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Creare consist of machine tools, lasers, tool wear measurement systems, tooling, and other associated hardware.

Creare's focus is not only on the development of innovative solutions, but their implementation in a real-world manufacturing environment. In doing so, Creare provides innovative, yet practical solutions for hat enable sustainable quality improvements and substantial cost savings. These key partnerships enable Creare to develop innovative, implementable, advanced manufacturing solutions for U.S. industry. They have designed programs for laser-assisted consolidation of F-35 thermosetting composites (Air Force Phase II SBIR) and laser-based curing of thermoplastics (Army Phase II SBIR). Currently, Creare is working on a large-scale program with the Air Force to transition laser-assisted consolidation to F-35 Wing Skin production. In addition, they have worked with Lockheed, the F-35 program and other key partners to transition Cryogenic Machining for the affordable machining of titanium components for the JSF.

Power Systems

Creare works across the full scale of power systems and related technologies, from detailed design and prototyping of individual components to overall system analyses with thermodynamic analysis of alternative system configurations. This disciplinary area merges corporate competencies in fluid flow, heat transfer, combustion, cryogenics, machine design, and power electronics.

Examples include design and testing of gas turbines based on a recuperated Rankine cycle, design of evaporators and condensers for thermal-to-electric conversion cells, and development of heat exchanger technology for a pressurized-air energy storage system.

Biomedical and Human Systems

Building on core capabilities in precision fabrication, software development, signal and image processing, sensor design, control systems, and thermal/fluid technology, Creare has undertaken various multidisciplinary projects for biomedical clients. Creare frequently works with clinicians at nearby Dartmouth-Hitchcock Medical Center, a 400-bed teaching and research hospital, and at other institutions such as Harvard Medical School, Memorial Sloan-Kettering Cancer Center, and Duke University.

Creare has developed various biomedical technologies including innovative signal processing algorithms and software for cardiac electrophysiology, cryogenic probes for the surgical treatment of cancer, aerosol technologies for mass vaccinations, and robotic control software for performing telesurgery.

As described above, Creare uses its capacity to integrate core capabilities across multiple disciplines. Two technologies described below

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illustrate Creare's ability to combine capabilities in cryogenics, heat flow, and fluid dynamics.

Cryogenic Cooling of Hubble Infrared Imaging Device

Creare began developing technical capabilities related to cryogenic coolers in the early 1980s, based on one of the company's first SBIR projects. Over 20 years, Creare received more than a dozen additional SBIR/STTR projects to develop the technology further. Over the same period, the U.S. government and other clients purchased additional engineering services from Creare that totaled 10 times the magnitude of the initial SBIR funding in this area.

The failure of the cooling system for the infrared imaging device on the Hubble telescope provided an opportunity to demonstrate practical application of this body of technical knowledge. According to NASA, "The Hubble team developed the NICMOS Cryocooler—a state-of-the-art, mechanical, cryogenic cooler that has returned NICMOS to active duty. Using nonexpendable neon gas as a coolant, this closed system delivers high cooling capacity, extremely low vibration and high reliability. It employs a miniature cryogenic circulator to remove heat from NICMOS and transport it to the Cryocooler. The system uses a tiny turbine turning at up to 400,000 rpm (over 100 times the maximum speed of a typical car engine). The NICMOS Cryocooler is virtually vibration-free—which is very important for Hubble. Vibrations could affect image quality in much the same way that a shaky camera produces blurred pictures."[26]

Cryogenically Cooled Machine Tools

Creare has a long history of developing systems for advanced manufacturing. For example, one of its early spin-out companies, Creonics, manufactured controllers for high performance computer numerical control (CNC) machine tools. Linking to its expertise in heat management and cryogenics, Creare developed an integrated system that enabled the effective, indirect cooling of cutting tools with very small flow rates of liquid nitrogen. Implemented in partnership with MAG-ISA Gbmh, this technology enables higher machining speeds (50 percent reduction in cycle time) with equal or improved tool life. For the Air Force F-35 program, Creare estimated potential savings of $300 million from adoption of this technology.[27]

[26]National Aeronautics and Space Administration, "Small Business/SBIR: NICMOS Cryocooler—Reactivating a Hubble Instrument," *Aerospace Technology Innovation*, vol. 10 no. 4, July/August 2002, http://ipp.nasa.gov/innovation/innovation104/6-smallbiz1.html.

[27]Jay Rozzi, "Cryogenic Machining," http://www.nsrp.org/6-Presentations/Joint/100411_Cryogenic_Machining_Background_and_Application_to_Shipbuilding_Rozzi.pdf, p. 18.

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Patents and Other Intellectual Property

Creare is the assignee for 36 patents over the period 1976 to 2015 (see Table E-3).

Business Model

Creare has received extensive support from SBIR/STTR funding. It also generates considerable revenue from engineering service contracts, licensing, and to a lesser extent spin-outs. According to Dr. Rozzi, SBIR/STTR (i.e., non-Phase III work) now accounts for about one-half of Creare revenues. Nearly 40 percent of Creare's total revenues come from Phase III commercialization activities related to past SBIR/STTR programs.

Spin-Offs

Creare has spun out a total of 10 companies in its history. Examples of such companies include the leading supplier of plasma-based metal cutting systems, Hypertherm, as well as a leading computational fluid dyamics software provider, Fluent, which was acquired by ANSYS in 2006. Although Creare remains a small company, these companies generate over 2000 jobs and half a billion dollars annually.[28] Creare has benefited greatly from these companies' successes. As a general rule, Creare management has provided generous terms for the use of its technology in order to maximize the chances of successful commercialization.[29]

Creare has spun off 10 companies during its history, and creating spin-off companies is central to its efforts to commercializing SBIR/STTR developed technologies. Several of the spin-off companies have been purchased by larger firms, e.g., Fluent.

Started in 1983, where Creare used early SBIR funding to develop FLUENT™, a general purpose code for computational fluid dynamics (CFD). Creare says that FLUENT™ became the most widely used CFD code language in the world. The company was spun out in 1988, and was purchased by Ansys in 2006.

The most recent Creare spin-off is Edare, which provides manufacturing and product development services intended to transition innovative technologies into low- and medium-volume production. The objective appears to be to provide a home for Creare technologies once demand

[28] "Cryogenic Machining Technology," http://www.gearsolutions.com/news/detail/7168/cryogenic-machining-technology-from-mag; Jay Rozzi, "Cryogenic Machining Background and Application to Shipbuilding," NSRP All Panel Meeting, October 2011, http://www.nsrp.org/6-Presentations/Joint/100411_Cryogenic_Machining_Background_and_Application_to_Shipbuilding_Rozzi.pdf, p. 4.
[29] National Research Council, *An Assessment of the SBIR Program*, p. 270.

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TABLE E-3 Creare Patents

Patent Number	Patent	Year
8,777,529	Mechanism for delivering cryogenic coolant to a rotating tool	2014
8,656,908	Aerosol delivery systems and methods	2014
8,544,462	Systems and methods for aerosol delivery of agents	2013
8,303,220	Device for axial delivery of cryogenic fluids through a machine spindle	2012
8,215,878	Indirect cooling of a rotary cutting tool	2012
8,061,241	Indirect cooling of a cutting tool	2011
8,021,737	Panelized cover system including a corrosion inhibitor	2011
7,954,486	Aerosol delivery systems and methods	2011
7,759,265	Protective cover system including a corrosion inhibitor and method of inhibiting corrosion of a metallic object	2010
7,699,804	Fluid ejection system	2010
7,561,051	Magnet locating apparatus and method of locating a magnet using such apparatus	2009
7,373,943	Self-contained breathing apparatus facepiece pressure control method	2008
7,225,807	Systems and methods for aerosol delivery of agents	2007
7,189,468	Lightweight direct methanol fuel cell	2007
7,183,230	Protective cover system including a corrosion inhibitor	2006
7,100,628	Electromechanically-assisted regulator control assembly	2006
7,053,012	Flexible corrosion-inhibiting cover for a metallic object	2006
6,874,676	Method and structure for welding an air-sensitive metal in air	2005
6,833,334	Flexible corrosion-inhibiting cover for a metallic object	2004
6,794,317	Protective cover system including a corrosion inhibitor	2004
6,444,595	Flexible corrosion-inhibiting cover for a metallic object	2002
6,397,936	Freeze-tolerant condenser for a closed-loop heat-transfer system	2002
6,379,789	Thermally-sprayed composite selective emitter	2002
6,212,568	Ring buffered network bus data management system	2001
6,170,568	Radial flow heat exchanger	2001
6,023,420	Three-phase inverter for small high speed motors	2000
5,938,612	Multilayer ultrasonic transducer array including very thin layer of transducer elements	1999
5,906,580	Ultrasound system and method of administering ultrasound including a plurality of multi-layer transducer elements	1999
5,748,005	Radial displacement sensor for non-contact bearings	1998
5,399,825	Inductor-charged electric discharge machining power supply	1995
5,145,001	High heat flux compact heat exchanger having a permeable	1992

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	heat transfer element	
5,033,756	Wide temperature range seal for demountable joints	1991
5,029,638	High heat flux compact heat exchanger having a permeable heat transfer element	1991
4,557,611	Gas thrust bearing	1985
4,357,932	Self-pumped solar energy collection system	1982
3,981,540	Rock breaking apparatus	1976

SOURCE: U.S. Patent and Trademark Office.

TABLE E-4 A Sample of Creare Spin-Offs

Company	Year	Spun Out
Hypertherm	1968	Hypertherm was founded to commercialize plasma cutting technology developed at Creare. Still headquartered in New Hampshire, Hypertherm is now the world's largest manufacturer of plasma cutting tools.
Creonics	1982	Creonics develops and manufactures motion control systems for industrial processes. Acquired by Allen-Bradley in 1990, Creonics is now part of Rockwell International.
Spectra	1984	Spectra is a manufacturer of high speed ink jet print heads and ink deposition systems. Formed around a sophisticated deposition technology developed at Creare, Spectra was acquired by Fujifilm in 2006 and renamed Fujifilm Dimatix.[a]
Fluent	1988	Based on Creare's longstanding expertise in computational fluid dynamics, Fluent began marketing comprehensive computational fluid dynamics software. In 2006 ANSYS Inc. acquired Fluent for $565 million.[b]
Mikros	1991	Based on Creare's advanced electric discharge machining technology, Mikros offers precision micro-machining services.
Verax Biomedical	1999	Verax was founded to commercialize technology to detect bacterial contamination of cells and tissues intended for transfusion and transplantation. They have received seven rounds totaling $28.2 million in venture funding.[c]
Edare	2011	Edare provides manufacturing and product development services intended to transition innovative technologies into low- and medium-volume production.[d]

[a] "Dimatix Acquisition by Fuji Reflects Strong Growth Opportunity For Its Innovative Ink Jet Technology," (June 13, 2006) https://www.fujifilmusa.com/press/news/display_news?newsID=880149.
[b] "ANSYS Signs Definitive Agreement to Acquire Fluent; Broadens Capabilities as a Global Innovator of Simulation Software," (February 16, 2006), http://www.prnewswire.com/news-releases/ansys-signs-definitive-agreement-to-acquire-fluent-broadens-capabilities-as-a-global-innovator-of-simulation-so ftware-55340982.html.
[c] "Company Overview," http://veraxbiomedical.com/company/index.asp; "$28.2M in 7 Rounds from 3 Investors," https://www.crunchbase.com/organization/verax-biomedical.
[d] "About Us," http://www.edareinc.com/pages/about.html; "Edare, Inc." http://www.edareinc.com/pages/about.html.

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exists for batch production and beyond. Edare will likely focus on niche products: its first commercial product is VacJac™ Tubing, which provides long life vacuum-insulated tubing primarily. This particular technology does not lend itself to the creation of a standalone spin-off single technology company, nor—because of low volumes—is it well suited to a licensing agreement with a large company. Dr. Rozzi said that the Edare model is therefore focused on building a company that at any one time has two to three programs in production, proving low- to medium-volume manufacturing typically for government clients (although some commercial clients are also anticipated). This low-volume production may be the end of the transition path for some products, but may also be an important way station on the path to larger volume sales or a licensing agreement once the technology has been fully proven and manufacturing processes rolled out. Dr. Rozzi observed that it is a good model for achieving production of 30 to 50 units, which is hard to do in an R&D environment.

Edare will have two new programs in 2016, according to Dr. Rozzi. One will deliver approximately 40 reduced-footprint swaging machine for the Navy, a project for which Creare will be the prime contractor and Edare will build support and sell those systems to the Navy. The second is to provide tools to LMACo for noncontact metrology for configuration on aircraft, initially the F-35 Strike Fighter. The system will provide for very rapid noncontact inspections of items such as filled and unfilled fasteners which impact the radar cross-section of the aircraft, replacing current manual procedures.

Licensing

Creare has licensed significant amounts of technology. For example, Phillips Screw Company, AeroVectRx Corporation, Envelop, and MAG-ISA Gmbh have all licensed technology from Creare. Creare has licensed technologies developed in its laboratories such as the cryogenically cooled cutting tool technology now sold by Fives LLC, an spinoff of the former MAG IAS Gmbh, which was acquired by Fives. The exact number of technologies that the company has licensed and the income generated by these licenses, however, is unknown.

Creare often uses multiple funding streams to create new technologies that can have multiple applications, according to Dr. Rozzi. One good example is the development of tools for cryogenic machining of very hard metals, focused on titanium, which used multiple funding streams primarily from Air Force and Navy (along with some additional funding from Army).

The objective was to develop the capacity to machine titanium twice as fast as the current standard. Create met that objective using a new approach and filed multiple patents. The technology is now being commercialized with a partner retrofitting production machines and using the technology to provide new machines as well. Edare is still supplying some of the key components.

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Dr. Rozzi said that a direct linear path from Phase I to Phase II to a Phase III transition was very rare. Most technologies—especially those supplied to DoD—required more than just a single Phase II prototype. For example, a measurement device of some kind would almost certainly need certification for production, end user input, multiple iterations, and possibly a qualification process.

SBIR/STTR

Between 1985 and 2015, SBIR/STTR funded 959 projects with Creare, Inc., amounting to over $261 million in R&D support. Of the 96 SBIR/STTR projects awarded to Creare in 2013 and 2014, 73 percent (70 projects) were funded DoD, 22 percent by NASA, and 5 percent by DoE. Over the 30 years of SBIR/STTR funding for Creare, STTR awards account for 5 percent of the total by value.

According to Dr. Rozzi, Creare utilizes SBIR and STTR in the same way: Creare only applies for SBIR or STTR awards if the company can see a clear path to transition and/or commercialization. This could mean developing a specialty product—e.g., the cryocooler for Hubble and other space programs, or the turbo pumps developed for the first Mars rovers with NASA SBIR funding, which have now been adapted for other space program at NASA such as the Curiosity Mars rover. While these are specialized technologies, Dr. Rozzi noted that Creare is exploring more commercial applications for these technologies.

Dr. Rozzi said that in the 1980s, SBIR was primarily a research program. TPOCs would have pet technology projects, which would typically have no clear path to transition would usually not generate commercial returns. Beginning in the 1990s, this began to change as Industry research and development (IRAD) budgets began to shrink at DoD and at the prime contractors. As these budgets began to decline, SBIR/STTR came to be seen as a more viable alternative for the development of new technologies and new systems at DoD. The shift in the SBIR/STTR programs was largely completed in the years immediately after 2000.

Creare makes it a high priority to "get the right people in the room as early as possible—as early as P1 proposal development, "according to Dr. Rozzi. Creare tries to develop the entire team as early as possible, bringing together primes, government people, and technologists. This team-oriented approach has led to considerable transition success.

Working with Primes

Creare has done a lot of work with many primes over the years, according to Dr. Rozzi. He noted that he personally knew many of the Lockheed staff working on the F-35, which for all its issues is making wonderful use of SBIR/STTR to develop technologies that are getting into production. Because Lockheed allocates little funding for R&D to support production, they leverage

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SBIR/STTR for that purpose. The work now coming under way at Edare to address non-contract metrology originated in discussions with Lockheed, who had encouraged the Air Force to publish a topic, under which Creare won an award to develop the relevant technology solution.

Creare gets involved in SBIR/STTR solicitations in two ways, according to Dr. Rozzi. In one respect the company has a lot of hammers looking for nails: existing technologies that can be applied to new problems to generate new solutions—the noncontact metrology technology was originally developed for a biomedical MRI application, a new kind of laparoscope to be used for the exact measurement of the location of tumors during surgery.

Alternatively, the solicitation may generate ideas in entirely new areas. For example, Creare recently won a Phase I award from Navy to develop tools for ultra high speed friction stir welding. The traditional approach has been to use big machines operating at low rpms. Creare is now working to develop a much smaller tool (approximately the size of a router) using much higher rpms (a factor of 20-30 increase in rpm). Creare sees a very large market for this tool given the enormous number of stir welds required both by Navy and other ship builders.

STTR

Creare has worked to developed a network of potential academic partners, and is usually aware of who the best RI partner might be. In some cases this is a Federally Funded Research and Development Corporation (FFRDC), although the latter usually want full payment of their contract up front, and require approval of a CRADA.

Dr. Rozzi noted that International Trafficking in Arms Regulations (ITAR) presented particular challenges in relation to STTR. Creare took a very conservative view of ITAR restrictions, and indicated that it could be difficult to ensure that universities understood and accepted the relevant restrictions, particularly when there were a considerable number of foreign students in most high quality engineering departments.

Dr. Rozzi also noted that there had in the past been conflicts over publishing results. RIs, academics, and graduate students all wanted to publish, and that had in some cases led to conflicts. However, he also noted that said there were ways to publish without breaching disclosure limitations.

Creare's STTR partnerships tended to be aligned with schools that were well known to Creare engineers. For example, Purdue was one of the top partners for Creare, and it was also the school from which Dr. Rozzi has received his PhD. The company had also worked closely with MIT in the past, but not so extensively in recent years. Similarly, another engineer had developed a close relationship with the University of Minnesota.

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In most cases, Creare directs the STTR project. However, a number of universities have now set up TTOs and incubators for emergent SBC's. Faculty are being encouraged to form companies and work through the incubator. In these cases, they often seek companies like Creare to partner on STTR proposals, but Creare is very cautious about becoming involved in partnerships where the driver is the faculty member, according to Dr. Rozzi.

Overall, the bar is simply higher for Creare involvement in an STTR as opposed to an SBIR. Dr. Rozzi said that unless the RI is a great partner—and some are—money going to the RI will not generate results that are nearly as efficient as Creare doing the work. STTR works best when Creare is seeking access to unique RI technologies—for example, previous STTR with Purdue provided access to modeling for composites machining. The fact that the RI is not is not fireable and not easily made accountable under STTR means that Creare has to be very careful. Dr. Rozzi noted that an STTR also requires an IP agreement, so if one is not in place, and if Creare does not have existing contacts with the contracts staff at the RI, a considerable amount of work is needed before the proposal can even be advanced. So the partnership really has to be worth it, from Creare's point of view.

Despite these challenges, Creare favors STTR. Working with RIs means that Creare is potentially accessing the best and brightest minds in the United States. Dr. Rozzi sees the program as being like a mini-DARPA, seeking ideas that give the war-fighter an advantage, and believes that STTR has an important role in that over the long term. STTR also offers recruiting benefits, by allowing Creare to work with RI staff and graduate students who are potential employees. Dr. Rozzi said that "we get great people" from these projects.

STTR also differs by agency: Creare did a considerable amount of work for NIH in its early years, especially on hardware of various kinds, but Dr. Rozzi observed that NIH was less interested in hard engineering recently.

Recommendations

Dr. Rozzi said that it might be helpful if the agencies endorsed some of the better model contracts for working with RIs. While some were good to work with, others were very difficult on issues related to IP and payments in particular. He said that this particularly applied to FFRDCs, who were institutionally not interested in SBIR/STTR.

Dr. Rozzi also noted that at DoD in particular, STTR topics tended to be long term and higher technical risk, and that he thought they brought particular value to DoD as a result. Too heavy a focus on immediate commercialization would result in missed opportunities, and he recommended that the agency retain the STTR program and use it to focus on these longer term projects.

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DIVERSIFIED TECHNOLOGIES, INC.[30]

Diversified Technologies, Inc. (DTI) is a private engineering product and services company founded in 1987 by Marcel Gaudreau. Prior to DTI, Dr. Gaudreau worked as the director of the Advanced Projects Group at MIT's Plasma Fusion Center. By the late 1990s, DTI had developed into an industry leader in the application of solid-state devices to high-power, high-voltage switches.

DTI has won over 100 SBIR/STTR awards worth slightly over $30 million. This funding enabled DTI to develop its PowerMod™ technology and to test applications in radar, power conversion, high energy physics, and food and wastewater processing. In the 15 years after receiving its first SBIR contract to study semiconductor switching in 1991, DTI grew to approximately $11 million in revenue of which over 80 percent was generated by PowerMod™ product sales. Since 2008, however, DTI revenue has been flat, and was about $10 million in 2014.

PowerMod™ switches are stacked, semiconductor devices configured for very high voltages. They operate as a single, near ideal switch with extremely short switching times and minimal overshoot. The technology is modular and can be scaled to very high voltages and currents. Solid state transistors offer higher reliability, longer component life, and higher power conversion efficiencies than competing high power vacuum tubes.

SBIR funding was of critical importance to DTI in developing the PowerMod™ technology. SBIR awards from DoE funded the development of DTI's core high power switching technology. Also, a series of SBIR awards enabled DTI to develop applications in radar, high energy physics, and food and wastewater processing. DTI sells high power switches to government agencies at the federal levels (Department of the Navy, to corporations (Kraft, General Mills) and to university laboratories (Stanford Linear Accelerator Center, ASU Arizona Center for Algae Technology and Innovation).

DTI has received recognition for its research. In 1997 and again in 1999, DTI received R&D 100 Awards—for its work on solid state switches and switch modules.[31]

DTI is headquartered in Bedford, Massachusetts and employs approximately 50 staff. Company headquarters include 33,000 square feet of office, lab, and manufacturing space, housing engineering, sales and marketing,

[30]Primary sources for this case study are the interview with Mr.Kempkes, and a review of the Diversified Technologies, Inc. website (http://www.divtecs.com) and related company documents.

[31]"PowerMod High Voltage Pulse Modulator," (1997), http://www.rdmag.com/award-winners/1997/01/powermod-high-voltage-pulse-modulator; "PowerMod Solid State Switch Module," (1999), http://www.rdmag.com/award-winners/1999/01/powermod-solid-state-switch-module.

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and support functions. The company sells its products worldwide, and is represented by local distributors in selected overseas markets.

Company Development

When Marcel Gaudreau founded DTI in his home in 1987, his intention was not to build a product oriented company. DTI was a consulting company to enable Gaudreau's various research activities. Although often unsuccessful, Gaudreau worked with MIT graduate students to write SBIR proposals as a means of focusing on real-world problems. In 1989, DTI won its first SBIR award, and in 1991 it won another to investigate development of a solid state, high power switching device. Completed with a Phase II award in 1992, the technology languished for a number of years after its demonstration.[32]

Although performance, reliability, and cost considerations made semiconductor switches superior to the vacuum tube switches then in use, customers were reluctant to switch without validation of the technology. In 1996, DTI partnered with Communications and Power Industries (CPI)—a leader in the vacuum tube industry, which was a large potential market, to develop a high power test set-up at the CPI campus in Palo Alto, aided by a subsequent SBIR to demonstrate the scalability and practicality of the technology. With CPI as a customer, DTI's standing in the market improved, and other customers began evaluating the DTI PowerMod™ technology.[33]

Subsequently, DTI developed applications for radar, high energy physics, and food and wastewater processing. Each time SBIR funding allowed DTI to extend the capabilities of its technology. In 1998, DTI received SBIR funding from the Navy for an advanced radar system. In 1999, DTI received multiple Phase I and subsequently Phase II awards to assist the Stanford Linear Accelerator Center in adopting solid state switches and sources for the Next Generation Linear Collider (NLC). In 2003, SBIR funding from the Environmental Protection Agency allowed DIT to investigate the application of Pulsed Electric Field (PEF) processing to waste water treatment.[34]

[32]"A Long Pulse, High Power Solid-State Gyrotron Modulator," (1991), https://www.sbir.gov/sbirsearch/detail/147952; "A Long Pulse, High Power Solid-State Gyrotron Modulator," (1992), https://www.sbir.gov/sbirsearch/detail/147834.

[33]National Research Council, *An Assessment of Small Business Innovation Research Program at the Department of Energy*, Washington, DC: The National Academies Press, 2008, pp. 186-189, http://www.nap.edu/catalog/12052.html.

[34]Arntz, Floyd *et. al.* "New Concepts for Pulsed Power Modulators: Implementing a High Voltage Solid-State Marx Modulator," http://www.divtecs.com/data/File/papers/PDF/ILC_Long_Pulse_Marx.pdf; "Advanced Solid State High Repetition Rate Modulator," (1998), https://www.sbir.gov/sbirsearch/detail/147844; "Wastewater Treatment by Pulsed Electric Field Processing," (2003), https://www.sbir.gov/sbirsearch/detail/147910.

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Technology

Trademarked as PowerMod™, these solid state switches are built from series stacks of semiconductor devices (Insulated Gate Bipolar Transitors or IGBTs) configured for very high voltages and operated as a single, near ideal switch.

The technology is modular and scalable which allows designers to build switches with performance requirements up to 500 kV and over 20 kA. Because IGBTs always fail by shorting, PowerMod™ modulators continue to operate even if several IGBTs in the switch fail. Also, because each switch is rated at a lower level than its actual capacity, each switch has additional operating margin and reliability.

PowerMod™ systems are used in two general applications, to condition high voltage DC power and to switch high voltage, high power circuits. For power supply applications, ranging from radar, magnet control, magnetron heating, lasers, electron beams, and RF transmitters, DTI 's technology enables voltage regulation to within ±0.1 percent tolerance and maximum voltage ripple of less than 0.01 percent. High efficiency and a small footprint mean DTI power supplies can significantly reduce space and power costs.

For switch applications, PowerMod™ provide nearly ideal switching behavior. They transition between fully "on" and "off" states in as little 50 nanoseconds. Compared to conventional tube-based approaches, they also have substantially simplified ancillary circuitry. PowerMod™ switches require only 110 VAC power for operation and can accept commands via fiber optic link. Pulsewidths are variable on a pulse-to-pulse basis from 1 microsecond to DC, with pulse repetition frequencies of up to 300 kHz.

PowerMod™ switches perform better than vacuum tube-based modulators because solid state components offer higher reliability and longer component life. Also, they cost less to operate because of significantly higher power conversion efficiency. Because these switches consume less power compared to vacuum tube modulators, electrical costs are substantially lower (as are cooling costs).

Products

DTI has developed four different applications of PowerMod™ technology: radar, power conversion, high energy physics, and food and wastewater processing.

Radar

Radar systems use vacuum tube modulators (thyratrons, switch tubes, etc.) to generate trains of high frequency pulses. These modulators are expensive

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to maintain. Worse still, relatively short operating lifetimes make replacement a significant operational expense. DTI retrofits vacuum based radar systems, upgrading transmitters to DTI's solid state PowerMod™ switches to reduce failure rates and improve system up-time. For example, Navy estimates indicate that retrofits of fire control radar systems with DTI technology would increase the mean time between failure by a factor of over 150, from 300 to 50,000 hours.[35]

Power Conversion

DTI technology enables AC-to-DC and DC-to-DC power conversion. High frequency switching allows output power to be tightly regulated even when driving nonlinear and transient loads. The technology can also be applied to variable frequency power converters such as those needed for synchronous AC motor drives. Applying this technology to higher voltage (tens of kV) and higher power (MWs) enables a variety of applications such as pulsed power systems and high speed utility switching.

High Energy Physics

The DoE's national laboratories and leading universities worldwide use DTI modulators and power supplies in RF power systems for accelerators and fusion systems. Both applications require careful control of voltage, pulsewidth, and pulse repetition frequency at very high power (more than 20 MW) and voltage (more than 100 kV). PowerMod™ switches can also be used to protect sensitive equipment—such as klystrons or gyrotrons—from electrical arcs with only the smallest interruption in operation.

Food and Wastewater Processing

Pulsed Electric Field processing is used in food processing to pasteurize liquids or increase yields in starch and sugar extraction from plants such as sugar beets and to enhance digestion of biomass in wastewater processing. PEF uses a high-energy pulsed electric field to break down vegetative cell walls in a process called "electroporation." Liquids pass through processing chambers and are "pulsed" rapidly with very high voltage electric pulses generated using DTI electronics. PEF processing is a "non-thermal" technology. Because the target is not significantly heated, in food sterilization applications PEF processing maintains the taste, color, anti-oxidant content, and

[35]"Department of the Navy SBIR/STTR Success Stories," (September, 2004), 10, http://www.navysbir.com/docs/NavyBook-04.pdf.

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consistency of fresh food, eliminating the need for chemical or radiation treatment.[36]

Markets and Commercial Development

DTI's commercial perspective has evolved over the years. Initially the company focused on high end modulators for European installations and for National Labs, which cost up to $1 million plus each. This has been a low volume and somewhat variable market over the last 15 years, according to Mr. Kempkes. 20014 and 2015 were good years, but in some years there have been no sales at all into high energy physics.

Predominantly, DTI's sales have in recent years focused on radar modernization. Since 2008, these products have according to Mr. Kempkes been the company's largest and most consistent market, primarily through direct sales to Air Force or Navy, and in addition to government agencies seeking to upgrade air defense radars in other countries.

Mr. Kempkes noted that sales were made directly to agencies, rather than indirectly through prime contractors. He observed that prime contractors are primarily focused on building new systems, which are almost all solid state now, and do not have large TWTs or klystrons in them as did the previous generation. Since new radars are incredibly expensive, and slow to be fielded, their emergence has a by-product generated substantial demand to keep existing radars operational and to extend their anticipated lifecycles. That in turn had created market for DTI, and the company had turned toward that market as a primary focus. Clients needed to extend life cycles for another 10-20 years, and make their radars more reliable, rather than improving their capabilities.

Demand for these products came primarily from the services themselves, rather than from the acquisition programs which are focused on developing new tools and technologies. So while new radar systems are funded by acquisition programs, the improvement and extension of existing systems comes from the services maintenance budgets. This also in part explains the lack of interest from the primes.

DTI has by now developed strong relationships with the radar community, a small and tight-knit group where DTI's reputation continues to generate sales. DTI also works with a few support contractors (e.g., BAE and Harris). The community quickly becomes aware of options for improving existing installations, and DTI has capitalized on this via word of mouth. It is, according to Mr. Kempkes, difficult to really market into this community—it is in general aware of what works and quick to share tools and techniques. This

[36]Bob Sperber, "Milk Processors Work on Making Pasteurization Cool Milk Processors Work on Making Pasteurization Cool," (May 11, 2011), http://www.foodprocessing.com/articles/2011/pasteurization/.

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market is also difficult to enter for other reasons—there are no central acquisition authorities—funding comes from the operational or support budgets.

Finally, it is worth noting that while this market is large enough to sustain DTI, it is essentially a steady state market. Specific products and services are in demand, then eventually become obsolete, but the overall amount of work remains relatively steady. The reliability of DTI's products also works against them to some extent—there is very little ongoing need for repairs or spares for these systems.

At the same time, DTI uses SBIR to find opportunities to develop new technologies into products that can supplement the core business. For example, DTI won an SBIR from NAVAIR to replace a transmitter on a beacon used to land planes on aircraft carriers (a magnetron transmitter). This amounts to an application of the technologies developed for use with radars. Successful Phase I and Phase II awards have led to a Phase III contract from NAVAIR to upgrade every one of the approximately 100 units currently in operation. Mr. Kempkes noted that in this case, Navy had been able to utilize the sole source provisions of SBIR to award DTI the contract directly. He observed that Navy is the best of the agencies in working on sole source procurement—it has even published a booklet that DTI has sent to contracts officers in the Air Force and Army to explain how sole source contracting works under SBIR.

According to Mr. Kempkes, power conversion offers many different markets and opportunities. DTI builds large, high voltage, power supplies. The company still sells a few as a stand-alone power supplies, but it recognized the need to advance the technology further. DTI won an SBIR from NAVSEA to build a more compact power supply, and developed a much more power-dense power unit for the Electromagnetic Rail Gun (EMRG) program. This product is now shipping, with DTI having built four units as part of the Phase II award for the first railgun on a ship. This could turn into a big program with hundreds of units for DTI.

The potential commercial importance of the power-dense HV unit has generated some significant commercialization challenges for DTI, specifically related to ITAR (the unit is currently ITAR-restricted). DTI has identified some possible markets in high energy physics and possibly with the European Spallation Source (ESS), but DTI does not see a clear path forward. It appears that the options are either to apply for an export license or to find a way to redevelop similar technology without Navy (or other DoD) funding.

DTI believes that while the specific product built for Navy is ITAR, that the technology itself is generic and should not be subject to ITAR regulations. There have been some cases in which blanket determinations have been made that for a specific power range/frequency range no export license is needed (e.g., for microwave tubes). However, those determinations are made case by case, and power sources have not yet been addressed.

DTI entered the Pulsed Electric Field (PEF) market some years ago, according to Mr. Kempkes, but is only now just starting to get some traction. PEF went on the market in 2006, and quickly generated a lot of press coverage

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and an award. Unfortunately, the company marketing the product went under after trying to grow too quickly. Since then DTI has sought other partners, but this was delayed by the market crash in 2008. Over the past two years, sales have started to grow again in this area.

Patents and Other Intellectual Property

DTI is the assignee for 24 patents since 1989.

DTI has not taken advantage of the funding that DoE now allows to SBIR awardees for patenting purposes. DTI, as a rule, does not patent any technologies based on DoD contracts unless there is also a large commercial potential for the technology.

Work with DoE is largely based on SBIR awards. Contracting in the DoE sector comes through DTI's work with the National Labs. Mr. Kempkes observed that "for the most part, patents have no meaning for the National Labs." They view all government funded technologies as inherently open.

DTTI typically patents a technology if it believes that it will help to keep a competitor out of that technology, or if it believes that the path forward is to license the technology. The PEF patent will for example likely be licensed, but patents are not really needed for standard direct sales.

The 2011 reauthorization fixed one concern: companies can now extend data rights on the basis of a Phase III contract or equivalent. Now there is a defined methodology under which companies must write a letter to the original contract officer stating that the company considers the data rights to be extended because of this new contract.

SBIR data rights mean little in the real world, Mr. Kempkes said. It was until recently not even possible to prove that the company owned them. Now at least there is a record through this letter to the contracting officer. This provides a contracting trail, which is a substantial improvement. He also suggested that data rights should be extended beyond 5 years—that in terms of product development, this was far too short. For example, DTI had worked on helicopter blades under an Army SBIR contract. It entered negotiations with a helicopter manufacturer, but in the end, the manufacturer simply decided to wait out the 5 years.

SBIR/STTR

Between 1989 and 2015, SBIR funded 111 projects with DTI, amounting to over $31.7 million in R&D support. Of the $31.7 million provided in SBIR/STTR funding, 62 percent was provided by the Department of Energy and 37 percent by the Department of Defense. The National Science Foundation and the Environmental Protection Agency also provided two Phase I grants

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amounting to less than 1 percent of total funding. DTI has never received STTR funding. Overall DTI converts 48 percent of Phase I grants into Phase II awards.

Although DTI continues to receive SBIR funding, the company appears to have successfully transitioned to commercial activities based mostly on other product and service revenues. The Hoovers website reports annual revenue of $9.34 million. Assuming that this number is for 2014, this suggests product revenue was approximately $8.7 million dollars. See Table E-5 for a breakout.[37]

Although DTI has successfully transitioned to a product-based business model, it has not grown substantially over the past decade. DTI revenues were reported at approximately $11 million in 2008.[38]

SBIR/STTR Recommendations

Topics

Mr. Kempkes was critical of the DoE topic development process. He noted that the agency does a poor job of updating the topics, and that many of them remained unchanged from year to year, even after interest in a particular area has waned. He also said that the topics themselves provide insufficient information on which to base a proposal: it was critical to contact the technical staff interested in the topic to find out what was really being sought.

While DoE does publish the contact information for subtopic managers, these are according to Mr. Kempkes in most cases not the technical staffer (usually working at a National Lab) who is really driving the topic. It is often quite difficult to find the right contact who really knows the details; listed points of contact are typically not the right people.

From Mr. Kempkes' perspective, DoE seems to include two distinct types of technologies within SBIR/STTR: generic technologies that possibly might useful someday, and very specific narrow technologies designed for use in existing programs. The agency does not distinguish between these two types of topics.

TABLE E-5 Diversified Technologies Revenue Breakdown, 2014

	Amount of Revenue (Millions of Dollars)
Estimated Product Revenue	8.71
SBIR/STTR Funding	0.63
Total	9.34

SOURCE: Hoovers.

[37]"Diversified Technologies, Inc." http://www.hoovers.com/company-information/cs/revenue-financial.Diversified_Technologies_Inc.8004553a443318fc.html. Hoovers does not report a year; revenue is assumed for 2014.

[38]National Research Council, *An Assessment of Small Business Innovation Research Program at the Department of Energy*, 185.

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Mr. Kempkes said that DoE SBIR topic managers are forthcoming if you can contact them. In his experience, one staffer is often listed as manager for 4-10 subtopics, and as a result they are quickly overwhelmed. Soon after the solicitation is published they will pick up the phone and answer questions; after that it becomes more challenging to contact them. Email responses vary—some are good, but others not at all. To be fair, topic managers are spread too thin; improvements in this area would be helpful.

In contrast, topic managers at DoD often have only one topic to manage and they are often the technical point of contact with a deep technical understanding of the topic. This led to a better match between proposals and agency needs. For example, a recent Navy solicitation offered what was for DTI a marginally interesting topic. DTI contacted the TPOC, who said that he was interested in DTI's technical approach. DTI proposed, and was selected. This would not have happened without the contact to the TPOC.

DTI continues to be concerned about unfunded topics and about proposals that are marked fundable but are not funded. Mr. Kempkes observed that DoE SBIR/STTR is selective in the way that Harvard is selective—there are invisible processes and perhaps an invisible lottery behind the scenes. DoE doesn't publicly prioritize its topics, and as a result DTI has written proposals to address a solicitation only to find out later that "DoE didn't care about that anymore." Subtopics all compete with each other, so not all subtopics get funding. DoE prioritizes after the proposals are reviewed. He believed that this has nothing to do with proposal quality—it simply reflects program need. This process could and should have been undertaken before the solicitation was published, not after companies had expended hundreds of hours of effort on topics that were in fact a low priority and were unlikely to be funded in any event.

In fact, some companies—according to Mr. Kempkes—have now ceased to address DoE solicitations because they regard outcomes as unrelated to proposal quality. DTI agrees that this is the case, but keeps applying because their success record is reasonable (in part, because DTI continues to write a lot of proposals).

National Labs and SBIR/STTR

The National Labs vary widely in their capacity to address SBIR, according to Mr. Kempkes. Some people in National Labs have figured out how to use SBIR to help them accomplish their programs, and do what they need to do. Others see SBIR as competition. These differences were often more personal than institutional—it was not possible to say that some Labs were better to deal with than others; it was more a case that some National Labs staff were easier to deal with. For example, one national lab contains both the best partners DTI has found across the system, and the worst. Mr. Kempkes feels that, in general, there

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is fairly widespread feeling at the Labs that the SBC is a potential competitor—that at a minimum it is working on a technology that the lab might wish to work on at some point. Some in the labs also believe that SBIR funding is wasted, because they don't see real products or technologies emerging directly from SBIRs.

As noted earlier, Mr. Kempkes thought that the Labs did a poor job of protecting company IP. The Labs are more academic than commercial, and hence have a different mindset. They see their jobs as in part to collect and disseminate information that they find. They are not set up for, or interested in, keeping track of whose IP is whose: "They live for publication."

Dealing with the Labs is challenging in other ways. The dual nature of the Labs as both customer and reviewer can be a problem. SBIR proposals are considerably stronger when they are bolstered by letters of support from potential users. However, National Labs are not asked for such letters because that could prevent the specific lab (or contact) from reviewing the proposal. More generally, there are difficulties in creating an agreement between an SBC and a national lab. Overall, SBIR/STTR reverses what the National Labs expect in terms of technology transfer. They are comfortable with the notion that the Labs develop technology and provide it to others to commercialize; much less so with the idea of funding SBC's to develop technology for use within the Labs.

STTR

DTI is wary of undertaking STTR projects. It is currently in partnership with MIT Lincoln Laboratory on one SBIR, and has in the past bid on some STTR solicitations in partnership with Arizona State University. Typically, DTI does not bid on STTRs unless there is something that the company really cannot do itself (e.g., ASU grows algae). Usually, there is not enough funding in an STTR to start with, and sharing the funding with a research institution makes this problem even worse.

Technical and Commercial Review

While Mr. Kempkes in general supported the concept of the letter of intent (LOI) at DoE, he noted that it would be more helpful if it provided more concrete feedback, and better signals with regard to possible funding. More recent solicitations had asked for more information at this stage, and he said that it would be helpful to limit the page count of the LOI.

Review quality varies widely, according to Mr. Kempkes. DoE typically provides three reviewers. In his experience, one would typically be thoughtful and one would be cursory. Sometimes reviews are very high quality, but in other cases it is unclear whether a specific reviewer is qualified to address the proposal. In some cases, technical reviews are simply wrong, and DTI is frustrated that the (anonymous) reviewer didn't understand something or had an erroneous view of the technology area. It is possible that a subtopic for a

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rejected proposal will come up again, and DTI will fix or refute the previous review, but there is no assurance that the same reviewer will be assigned, and in general the success rate of re-submittals is very low.

The reality is that at DoE, a proposal needs three positive reviews to have any chance of being funded. There is no appeal mechanism, and no opportunity for rebuttal. Other agencies force reviewers to emerge with a unified view or joint position. That would be a self-check mechanism, but is even more cumbersome and would be difficult within the tight DoE timelines.

Commercial review at DoE is generally poor quality. What the application demands is essentially worthless. If a company is developing a new technology, it is important to have a good general idea of possible uses, but at the P1 stage neither the company nor the reviewer has any idea whether it will be beneficial or adopted. The market is simply too far away. By Phase II it makes sense to have a better understanding of potential transitions, but sometimes even then it is too early for more than a cursory assessment. For a commercialization plan to be useful it should probably be part of the Phase II final report. There is often very little connection between DoE topics and potential commercial applications to begin with, and no clear pathways to getting SBIR technology into DoE projects. Commercialization reviewers also seem to have little experience: sometimes they provide useful feedback, but in other cases do not have an understanding of the market.

Mr. Kempkes said that Navy provides the best example of a successful commercialization support program. The Navy has done an excellent job of linking topics to users and funding, and will not support an SBIR that does not have a transition plan from its sponsors. In contrast, DoE is not an acquisition agency; any acquisition would be for technologies used by the National Labs. He recommended that DoE should require each Lab to develop a plan to integrate SBIR technologies into their programs, as SBIR funding, in effect, makes the Labs acquisition agencies. At minimum, National Labs should be required to report back on the uses of SBIR/STTR technologies that they have sponsored, and how these technologies are being incorporated into their programs. Ideally, having such a plan in advance would be required to get a topic into the SBIR solicitation each year. That would resolve several issues at once, significantly reducing both the number of topics and wasted proposals chasing topics where interest no longer exists.

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LI-COR BIOSCIENCES, INC.[39]

LI-COR Biosciences (LI-COR) is a private company founded in 1971 by William Biggs. The company designs, manufactures, and markets "high quality instruments, software, reagents, and integrated systems for plant biology, biotechnology, drug discovery, and environmental research."[40]

Biggs had recently completed a master's degree in engineering at the University of Nebraska and wanted to commercialize a light meter technology that he had developed. The company's first product, the LI-185 Quantum/Radiometer/Photometer, embedded this technology and enabled the measurement of light as a photon flux.

As the company expanded its product line to include other light sensors, porometers, spectroradiometers, and photosynthesis systems, it expanded its ability to use electromagnetic radiation to measure the characteristics of physical matter. In the 1980s, the company successfully developed fluorescent dye-based instrumentation systems for DNA sequencing and entered the biosciences business. At the same time, with the help of SBIR funding, it developed key technologies for measuring gas exchange in global climate change research.

The company currently operates two product lines, LI-COR Environmental and LI-COR Biotechnology. LI-COR Environmental is a global leader in the design, manufacture, and marketing of high quality, innovative instrument systems for plant biology and environmental research. LI-COR has been in this field for more than 45 years, and its instruments are used worldwide in many environmental applications, including agronomy, ecology, plant physiology, plant pathology, carbon cycle studies, and climate change.

The LI-COR Biotechnology business was built on the use of near-infrared (NIR) fluorescence dyes (currently commercialized under the label IRDye® Infrared Dyes) to perform gene sequencing with higher sensitivity and wider dynamic ranges than its competitors. LI-COR now has a mature business selling automated infrared imaging systems and reagents. The company is also licensing its NIR dye technology to start-ups investigating the application of photoimmunotherapy and image-guided surgery in the treatment of cancer.[41]

LI-COR instrumentation is used in over 100 countries by more than 30,000 customers worldwide in scientific studies ranging from global climate change to cancer research. In addition to its Lincoln, Nebraska headquarters, LI-COR has offices in Germany and the United Kingdom. The company also sells

[39]Primary sources for this case study are the interview with Dr. Dayle McDermitt, Vice President for Environmental Research (November 23, 2015), and a review of the LI-COR Biosciences website (http://www.licor.com) and related company documents.
[40]See http://www.licor.com/bio/news/4.21.10.html/.
[41]Frost & Sullivan, "2013 North American In-Vivo Molecular Imaging Technology Leadership Award," 2013 https://licor.app.boxenterprise.net/s/oslq79yyjyhynj4nccbsecxcg7fw1o1p; IRDye® 700DX Infrared Dye," https://www.licor.com/bio/products/reagents/irdye/700dx/.

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products through a global network of distributors. LI-COR now employs more than 330 people.

LI-COR has received substantial recognition for its work both nationally and locally. In 2015, the SBA awarded LI-COR a Tibbetts Award for its work on low-cost carbon sensors. In 2010, R&D Magazine awarded LI-COR a Top 100 award for its work developing an open path methane detector. LI-COR also received the 2010 Nebraska Governor's Bioscience Award for the development of its automated DNA sequencing technology.[42]

LI-COR scientists and engineers work closely with the scientific community through extensive internal R&D, collaborations with leading scientists, presentations at scientific conferences, and publication in peer-reviewed scientific journals.

Products

LI-COR operates two product lines, LI-COR Environmental and LI-COR Biotechnology. While these product lines are distinct, they are based on the shared need to measure biological parameters based on the interaction between electromagnetic radiation and physical matter.

Environment

LI-COR instruments have become the global standard for measuring gas exchange between the atmosphere and various sources such as landfills, plants and the oceans. In the mid-1980s, LI-COR began designing instruments to measure such processes. Unfortunately, they were not easily transported. An SBIR award in 1998 allowed LI-COR to develop a portable solution based on a technique called eddy covariance. Dr. McDermitt estimates that more than 80 percent of the measurements examining the carbon balance of agricultural and natural ecosystems have been made using LI-COR instruments, noting that "much of what we now know about how climate change might influence ecosystems comes from data provided by these instruments; it's made all this scientific work possible."

With scientists specializing in agriculture, environmental science, and climate change as a market focus, LI-COR has developed a broad range of instrumentation for photosynthesis, gas analysis, and light measurement. In particular, LI-COR sells gas analyzers, photosynthesis systems, area meters

[42]Matt Olberding, "LI-COR's climate change science wins Tibbetts Award from SBA," May 26, 2015, http://journalstar.com/business/local/li-cor-s-climate-change-science-wins-tibbetts-award-from/article_389b0fa2-4371-5a07-b2d5-b523385f5e61.html; "Keeping Tabs on Methane," R&D Magazine, August 11, 2010, http://www.rdmag.com/award-winners/2010/08/keeping-tabs-methane; "LI-COR Collaborators Honored with 2010 Governor's Bioscience Award," April 16, 2010, https://www.licor.com/env/news/04.16.10.html.

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(including canopy meters), light sensors, data loggers, and dew point generators. These products have been used by scientists seeking better estimates of greenhouse gas exchange in locations world-wide, including forests, deserts, cities, and landfills.

Biotechnology

LI-COR also pioneered the development of infrared fluorescence labeling and detection systems for life science domains, such as protein analysis and DNA sequencing. These platforms comprise imaging systems (such as the Pearl® Trilogy and Odyssey®) and related fluorescent reagents (such as IRDye). Using IRDye infrared dyes researchers can label a wide range of entities—antibodies, proteins, peptides, small molecules, lectins, some polymers, and even nanoparticles—and measure their presence using various techniques including Western blotting, protein arrays, cell-based assays, and in vivo molecular imaging. LI-COR products played a significant role in the work of the Human genome Project, according to Dr. McDermitt.

Bio-medical Applications

Based on its success with NIR fluorescent dyes in gene sequencing, LI-COR is now licensing its dye technology to develop therapeutic and surgical methods for cancer treatment. LI-COR has licensed its IRDye to Aspyrian Therapeutics to develop a light activated anti-cancer therapeutic, and the FDA recently gave Aspyrian permission to begin clinical trials testing RM-1929, an antibody conjugate that precisely targets cancer cells and is subsequently light activated to elicit a rapid, targeted anti-cancer response. Aura Biosciences is developing a similar product in which a viral nanoparticle conjugated with the laser-activated IRDye- molecule efficiently and selectively destroys cancerous cells.[43]

LI-COR is also partnering with researchers to investigate the use of IRDye to improve surgical procedures. By causing somatic structures to fluoresce, researchers hope to increase the visual information available to the surgeon. Near-infrared (NIR) fluorescent probes are being developed for several procedures, including angiography, lymph node mapping, and tumor resection.

[43]"Aspyrian Therapeutics Inc. Announces FDA Acceptance of an Investigational New Drug Application for RM-1929, a First-in-Class, Precision-Targeted Therapy for Cancer," May 12, 2015, http://www.prnewswire.com/news-releases/aspyrian-therapeutics-inc-announces-fda-acceptance-of-an-investigational-new-drug-application-for-rm-1929-a-first-in-class-precision-targeted-therapy-for-cancer-300081377.html; "Aura Biosciences Closes $21M Series B Financing Prepares to enter clinical trials for the treatment of rare ocular cancers," March 5, 2015, http://www.aurabiosciences.com/aura-biosciences-closes-21m-series-b-financing/.

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Patents and Other Intellectual Property

LI-COR is the assignee for 89 patents published between 1981 and 2015, according to the U.S. Patents and Trademark Office. Recently, LI-COR's patenting activity has substantially accelerated. As Table E-6 shows, in the period 2012-2015, LI-COR received 37 patents (42 percent of the total patented since the company's creation in 1971) and nearly triple the number of patents in the previous 4-year period.

Business Model

Dr. McDermitt explains that LI-COR has since its inception been a product-oriented for-profit company, where research is designed to meet the need for new products. The company was founded because research scientists sought access to its initial technology, and its products have always been developed at least partly in response to strong market demand. As a result, LI-COR has always managed its own sales and distribution channels, now in part served by subsidiaries located in Germany and the UK.

The company founder is an engineer, and the company was built because scientists and engineers from many countries requested his product; as a result, infrastructure for marketing and customer service was deployed immediately, and LI-COR has grown as a product oriented, customer focused entity since its inception.

The company originally worked with plant physiologists to develop the first practical quantum sensor for measuring photosynthetically active radiation. Following the publication of some seminal papers in the early 1970s, a scientific consensus quickly emerged about the best approaches for measurement in this area, and the first LI-COR product aligned closely with the consensus, which drove a rapid increase in demand for its instruments. Related instruments followed, such as an instrument for measuring leaf area in plants.

TABLE E-6 LI-COR Patenting Activity, 1981 to 2015

Period	Number of Patents Published	Percent of Li-COR Total
2012-2015	37	42
2007-2011	14	16
2002-2006	10	11
1997-2001	12	13
1992-1996	9	10
1987-1991	2	2
1982-1986	4	4
1977-1981	1	1

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Throughout this period of early growth, the company had been marketing to scientists and engineers on a global basis. Dr. McDermitt notes that exports consistently accounted for two-thirds of LI-COR sales, which in turn required a strong international sales and marketing presence. Further, the company is dominated by scientists and engineers, and as a result sought to ensure that the needs of scientists were well served. Dr. McDermitt said that LI-COR had by far the strongest reputation in its niche for providing high quality customer support.

Ongoing business operations are the principal source of funding for R&D activity. The Hoovers/Dun and Bradstreet website reports annual revenue of $100 million by LI-COR Biosciences and an additional $14.8 million from its pair of European subsidiaries.[44] (See Table E-7.)

SBIR/STTR

The company's grant philosophy is to apply for awards only when the topics are consistent with the company's strategic direction and there is a high possibility that the project will result in a commercial product. Dr. McDermitt observes that SBIR funding never covered total out of pocket costs for a project, and certainly did not cover the opportunity cost of devoting company resources to the project. Hence the company could not afford to apply for grants simply to expand the size of its R&D base; grants were instead exclusively sought to subsidize R&D for projects leading to a new product that would be profitable and would make a difference. Grants are especially helpful because the cost of developing advanced instruments is high.

SBIR has been used to support four key projects, of which two have led to commercial products. One was technically successful but was superseded commercially by other approaches, and one is expected to be commercially successful in the future.

TABLE E-7 LI-COR Biosciences, Inc. Revenue Breakout, 2014

	Amount of Revenue (Millions of Dollars)
LI-COR Biosciences, Inc.	100.0
LI-COR Biosciences UK, Ltd.	6.6
LI-COR Bioscience GmbH	8.2

[44] "LI-COR, Inc. Revenue and Financial Data," http://www.hoovers.com/company-information/cs/company-profile.Li-Cor_Inc.b4245b76644713ab.html; "LI-COR BIOSCIENCES UK LTD Revenue and Financial Data," http://www.hoovers.com/company-information/cs/revenue-financial.LI-COR_BIOSCIENCES_UK_LTD.650c82d750559ca4.html; "LI-COR Biosciences GmbH Revenue and Financial Data," http://www.hoovers.com/company-information/cs/revenue-financial.LI-COR_Biosciences_GmbH.69ff7789c35f7144.html. Hoover does not report a year; revenue is assumed for 2014.

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The first SBIR award resulted in the LI 7500 open path water vapor instrument—the most widely used of its type, and by LI-COR's estimate producing more than 50 percent of measurements in this area world-wide. This project was based on a single Phase I award: the project had moved extremely rapidly, and the company had not needed a Phase II award before reaching the market.

The second SBIR Phase I and Phase II awards had led to the LI 7700 open path methane analyzer, now sold as a product primarily for methane emissions from natural ecosystems, from landfills, and natural gas leak detection.

The third SBIR award was used to develop a three-gas analyzer for CO_2, water vapor, and methane. The project had been technically successful, but was superseded by new technology (also produced by LI-COR) before it could reach the market.

The fourth SBIR award has funded development of a low cost high performance gas analyzer, initially focused on CO2 but readily adaptable for use with other gases such as methane and nitrous oxide. A variant of this technology to address national needs for gas leak detection has been funded by ARPE-E.

SBIR at DoE

Like many companies, LI-COR had over time developed a relationship with key agency staff, and particularly with the previous director of environmental research at DoE, who had made a point of visiting conferences such as the annual Ameriflux meeting (a consortium of scientists who are measuring carbon balance in a range of ecosystems). As a result, DoE topics in this area have been closely attuned to the cutting edge of the research community, and DoE was also open to ideas for new topics.

Under a new director, LI-COR has not noticed any significant changes, but relationships always take time to develop. The company has not found any topics of interest during the most recent solicitation, but Dr. McDermitt observed that it was also unlikely to have pursued any given that the R&D staff are fully occupied currently.

Dr. McDermitt notes that as LI-COR has grown, the markets it is interested in serving have grown as well: niche products are of lesser interest; however, LI-COR was not finding any difficulties in identifying markets of appropriate size as targets. At the same time, he observed that SBIR can be an important instrument for agencies in ensuring the development of products that may be uneconomical because a market is too small, but provides important scientific or social benefits.

STTR

LI-COR received one STTR award, which was in the late 1990s in conjunction with the University of Nebraska at Lincoln (UNL), working on a

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precision agriculture system for optimizing nitrogen usage, and the company has a patent on using IR and near-IR reflectance for measuring crop growth. However, it turned out that the product would be too expensive for farmers given the low price of nitrogen-based fertilizer at the time, and the project was shelved.

Dr. McDermitt said that the experience had not been very positive. It had involved a considerable amount of paperwork and issues related to intellectual property that were hard to resolve. As a result of this experience, the company has not applied for STTR awards since that time.

Dr. McDermitt notes that beyond STTR, LI-COR continues to work with universities on a regular basis, including UNL, and in fact had developed a close relationship with the latter—his staff works as adjunct professors there, and the company has had numerous and valuable interactions with the university, and two former employees now worked in the UNL TTO office. LI-COR and UNL faculty had worked together on a DNA sequencer in the 1990s, which had been used on the human genome project; this technology was still in use for protein detection and was now being used by LI-COR for the development of clinical applications.

One of the most complex issues with a research institution (RI) collaboration is how IP gets managed. This was a serious issue for LI-COR, which wanted to own the IP in part because the company usually provided most of the funding. According to Dr. McDermitt, some universities are good to work with and others are not. If they view it strategically as a revenue generation opportunity, that almost always generates significant problems.

Recommendations

Overall, Dr. McDermitt said that the company found the SBIR program at DoE to be managed effectively. The proposal process was clear, the letter of intent process was not too burdensome, and—aside from the enforced no-contact period during the application—project managers were readily available for discussion. The administration of grants and the necessary level of documentation were reasonable and workable. Overall, SBIR was considered a good program to work with.

One frustration was that during the application phase companies were not permitted to contact program managers to get clarifications. While he understood that the no-contact period was necessary in order to ensure that the competition was fair, Dr. McDermitt noted that it did cause some frustration, as there were often technical decisions to be made in designing the proposal that could use program manager input.

Dr. McDermitt said that he strongly supported the idea of providing an "open" category in the solicitation (currently available for most DoE divisions but not EERE). He had for example looked at the current solicitation and had found nothing there for relevance to LI-COR.

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Overall, Dr. McDermitt was positive about the review process as well. The company had a good success rate so had no real complaints. LI-COR had not experienced a review where the reviewer missed the point, which does happen sometimes with peer reviewed papers. Some reviews have offered significant insights to important questions that improved the project. He does not have strong views on the review of commercialization plans, as LI-COR was primarily a for-profit product-oriented company, which had strong business plans for its own purposes and where it owned distribution and marketing channels itself.

MUONS INC.[45]

Muons, Inc. (Muons) is a small private technology company based in Batavia, Illinois, with a wholly-owned subsidiary, Muplus, Inc., that is incorporated in Newport News, Virginia. Muons offers a range of products and services, with a primary focus on particle accelerators for high-energy and nuclear physics discovery science, for secondary beams, and for nuclear power. The company currently typically has between one and two dozen employees, and is owned by its founder, chief scientist, and President Rolland Johnson, who has been involved in particle accelerator research and development for over 40 years.

Dr. Johnson said that he started the company in 2002 to help DoE accomplish its goals through the SBIR program, which was originally created to allow industry to contribute its intellectual and creative energies to national programs in most branches of the government. Having worked in the national labs for many years, he believed that Muons could do things for the labs that needed extra creativity and more funding. Muons hired the most creative people it could find, who were often near national laboratories and who were unable to relocate.

Muons is very different than other SBIR/STTR companies. Dr. Johnson said that most of its work is providing ideas and concepts for national labs, focusing on identifying projects and technologies that will help the labs, but for which there is no available funding, while other companies mostly transfer technology in the other direction. STTR in particular has been used to meet those needs, perhaps acting as a DoE analog to Lockheed's famed Skunk Works as a source of innovative technologies.

Muons has always had close connections to the National Labs. Dr. Johnson spent most of his career at National Labs, initially Lawrence Berkeley National Laboratory (LBNL) and then Fermi National Accelerator Laboratory (Fermilab), where he worked for 17 years before moving to the private sector to

[45]This case study draws primarily on materials published by Muons on the company’s website, an interview with Rolland Johnson, CEO and Founder, August 27, 2015, and other company materials.

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install and commission the CAMD synchrotron light source at LSU and then to the Thomas Jefferson National Accelerator Facility (TJNAF) in Newport News where he also served as a detailee at the Department of Energy in Germantown, MD. After retiring, he built a consulting practice and in 2002 founded Muons. The company's first STTR award was in 2003. Since then, Muons has received 24 Phase II SBIR and STTR awards, and is the largest recipient of STTR awards from DoE.

From its founding in 2002 until 2010, Muons mainly focused on muon collider particle research, and on developing related new technology. It used consulting contracts and SBIR/STTR awards to fund this work. In 2010, the company started exploring Accelerator Driven Subcritical Reactors (ADSR), and this has become a thrust of its commercialization efforts.

Muons workforce varies according to the SBIR/STTR and contracts they are awarded, where fluctuations are mostly accommodated by the number of postdoctoral employees they are able to hire to train in accelerator science who often move on to permanent jobs in National Laboratories. Muons also hires post docs who work within research partner national labs while supported by the company. Muons supports PhD students working on SBIR/STTR grant topics, of whom three women and one man received their degrees in the past 2 years. The company is best viewed as primarily a research organization, developing cutting edge technology, although Muons has recent shifted to become more commercially oriented, as has been required by the most recent SBIR/STTR reauthorization legislation. The most significant commercial application is GEM*STAR.

GEM*STAR: Accelerator-driven Subcritical Reactor for Improved Safety, Waste Management, and Plutonium Disposition

Muons has formed and is leading the GEM*STAR Consortium of four companies (Muons, ADNA Corp., Niowave, Inc. and Newport News Shipbuilding), two national laboratories (ORNL and TJNAF), and two universities (Virginia Tech and George Washington University) and has submitted a proposal to DoE Nuclear Engineering for a $50 million, 5-year funding opportunity titled "Advanced Reactor Industry Competition for Concept Development."

GEM*STAR is a transformative and disruptive technology that has the potential to revitalize the nuclear power industry and lay the groundwork for a path to a viable future for many centuries. It combines proven technologies to provide a new approach to the safety of nuclear reactors, to the management of nuclear waste, and to the disposition of nuclear weapons materials. The primary technologies involved a molten-salt reactor and a high-power proton accelerator, are not new and have already been proven in the Molten Salt Reactor Experiment at ORNL and at many accelerator facilities around the world. It is designed to be commercially profitable and politically adoptable.

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It can burn spent nuclear fuel, natural uranium or thorium, depleted uranium, and surplus weapons material, all without isotopic enrichment or chemical reprocessing. Burning the waste from current reactors can potentially extend their lifetime and turn a huge liability into highly profitable use. Interestingly, with a fleet of accelerator-driven systems like GEM*STAR there is enough uranium out of the ground today to supply the current U.S. electrical power usage for more than 1,000 years. Burning the spent nuclear fuel from the current fleet of nuclear reactors is vastly superior to throwing away its enormous internal energy and just piling it in a hole in the ground for 100,000 years.

Safety: Being subcritical, fission stops when the accelerator is switched off and passive air cooling is sufficient to maintain safe reactor temperature. The system design avoids the major problems associated with all of the historical reactor accidents involving radioactive releases.

Nuclear Waste and Pu Disposition: The accelerator beam generates an enormous neutron flux that induces fission power to generate heat and to transmute fission products and heavy actinides into more tractable waste products. The waste stream from GEM*STAR systems is less of a burden on an ultimate geological store than current reactors, and recycling the waste stream in other GEM*STAR systems could potentially make such a store unnecessary. That same neutron flux burns surplus weapons-grade plutonium more completely than other approaches and satisfies the goals of the year 2000 Plutonium Management and Disposition Agreement between the United States and Russia to each dispose of 34 metric tons of weapons-grade plutonium (enough for 17,000 Hiroshima-sized bombs).

Nuclear Weapons Proliferation is addressed by GEM*STAR operation in that neither isotopic enrichment nor reprocessing is required and by its application to destroy nuclear weapon materials.

The Pilot Plant to be designed will first burn natural uranium as a test and then be upgraded to a mission-capable system for disposing of surplus weapons-grade Pu. The heat generated will be used to drive the Fischer-Tropsch process to provide green diesel fuel to the U.S. military at a profit. This approach mitigates some regulatory issues and avoids the need for initial availability to meet the demands of the electrical grid. This project will carry GEM*STAR through completion of the Conceptual Design Report and the Technical Design Report, including engineering drawings sufficient for the licensing process and to begin pilot plant construction. Experimental studies to improve the design will also be performed.

Muons Technologies

While Muons pivoted in 2010 to focus on ADSRs, it is still developing other technologies including:

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- Numerical Simulation Programs and Graphical User Interfaces to them
- RF technology, both normal and superconducting
- Magnetron power sources
- Superconducting magnets for high fields and high radiation environments

Muons' particle physics simulation programs, G4beamline and MuSim, can be used across the particle accelerator industry. G4beamline is free, open source modelling software based on the GEANT4 program developed by a large collaboration headed by CERN and SLAC that accurately simulates the interactions and decays of subatomic particles. According to Muons' website, G4beamline is downloaded ~15 times weekly, and given the small population of potential users, that accounts for a sizeable percentage of global demand. MuSim is a new particle accelerator simulation program that Muons will license that interfaces to GEANT4 and to MCNP, the workhorse of the nuclear physics community.

Muons also develops technologies that use advanced **Radio Frequency (RF) technology**, including the superconducting resonant cavities that accelerate particles by using microwave electromagnetic fields. These cavities are usually powered by klystrons or Inductive Output Transmitters (IOT). Magnetron power sources, based on the same technology as ordinary kitchen microwave ovens, have the potential to be more efficient and less costly than the klystrons or IOTs if they can be made more frequency and phase stable and controllable. Muons has several magnetron projects underway that are based on new ways to stabilize and control magnetrons that can reduce the cost of RF power sources for accelerators by as much as a factor of five and improve efficiency from 50 to 90 percent compared to klystron sources. This could make Muons products attractive commercially for a number of applications such as production of radioisotopes for medical diagnostics and therapies.

Superconducting magnets. Muon colliders require a high level of muon beam cooling to work effectively. Muon cooling depends on strong and efficient superconducting magnets, which Muons also develops. These magnets are extremely demanding, as some of them need to create extremely strong magnetic fields in complex shapes with forces that require sophisticated engineering.

Electron Recirculating Linear Accelerators. Muons is working on Electron Recirculating Linear Accelerators (RLA) to make radioisotopes for diverse applications such as those used for diagnostics and therapy in nuclear medicine. Muons is developing new techniques for developing commonly used isotopes as well as isotopes for new medical and industrial applications.

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Business Model and Customers

Muons is a small research oriented firm with changing commercial ambitions. Its funding was in large part derived from SBIR/STTR awards, along with some consulting revenues mostly from national labs. However, the company has recently shifted to become more commercially oriented.

Introduction of the new SBIR/STTR commercialization metrics after reauthorization nearly bankrupted Muons, according to Dr. Johnson. In 2011-2012 the company was designated as not commercial and hence SBIR/STTR funding dried up, leading to lay-offs.

However, the company has ramped up its commercial activity with contracts from Fermilab to develop plans to upgrade one of their flagship experiments and Toshiba and Niowave to build magnetrons. The company is close to delivering its first commercial magnetron prototype for Niowave, and expects to provide a testable product that delivers a substantial upgrade in power, from a previous tetrode maximum of 60-70KW to more than 120KW. Besides contracts with its usual research partners, Muons has won non-SBIR/STTR contracts with Los Alamos National Lab and Pacific Northwest National Lab. Non-SBIR/STTR contracts have generated almost $2 million in revenues, mostly in the past 5 years, according to Dr. Johnson.

As a result of these efforts, Muons and MuPlus are now seen by the DoE as commercial companies eligible for SBIR and STTR awards, and have won four in the past year. MuSim, mentioned above, is an important non-STTR project, according to Dr. Johnson. Since it interfaces to many simulation tools including MCNP6, it will be extremely useful to develop the Conceptual and Technical Design Reports that are needed for the GEM*STAR project described above. Muons originally developed a similar tool, G4Beamline, which was provided free and is now in use by many companies and labs. Dr. Johnson said that Muons was able to identify over $18 million in effort generated by the program and he believes that MuSim will have an even larger user community of Nuclear Physicists and Engineers who need a better interface for MCNP6. Muons plans to charge for the MuSim program and is spinning out a new business in software support.

Muons Partnerships

Muon partners with multiple third parties on many of its projects. A proposal for a muon beam cooling experiment for example listed 40 individual collaborators and 5 other institutions. The GEM*STAR proposal has seven partner institutions. Muons has partnered with nine National Laboratories:

- Argonne National Laboratory
- Brookhaven National Laboratory

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- Fermi National Accelerator Laboratory
- Thomas Jefferson National Accelerator Facility
- Los Alamos National Laboratory
- Lawrence Berkeley National Laboratory
- National High Field Magnet Laboratory
- Oak Ridge National Laboratory,
- Pacific Northwest National Laboratory

Muons has an especially close partnership with Fermilab, where ideas for muon cooling for colliders, neutrino factories and stopping beams have been developed and TJNAF, where the newest interest is the development of concepts for electron-ion colliders.

Muons has also partnered with eight universities: Cornell University, University of Chicago, Florida State University, Hampton University, Illinois Institute of Technology, North Carolina State University, Northern Illinois University, and Old Dominion University.

STTR

Muons has received 56 DoE Phase I awards, and 24 Phase II awards. Thirty-six of these awards are SBIR, and 44 are STTR. Total funding (2002-2014) is about $26 million.

Dr. Johnson observed that most companies do not want to deal with STTR grants: "We are masochists, since most companies do not want to deal with National Lab bureaucracies and do not want to share their grant money with the lab. However, most Muons staff members are located near the labs where they used to work, and are often embedded in the labs which give them work space. The Cooperative Research and Development Agreements (CRADAs) that are sometimes required for STTR grants with National Labs often include a section detailing how the labs will make available specific lab and office space."

The company first used STTR grants to develop new ideas for a muon collider, addressing the technical problems of cooling beams of muons so they are dense enough to make such a machine possible. Muons subsequently branched out to related technologies and then some less related areas. The company is now using STTR grants to work on an electron ion collider using polarized electrons and ions at TJNAF. Dr. Johnson believes that this project may have significant commercial potential, although development is still at a very early stage and it takes a considerable time to move from an idea to a product. He noted that this leads to tension inside the DoE SBIR/STTR program, which seems to be seeking commercial outcomes soon after the conclusion of a Phase II award. He noted that a typical time from conception to start of payback in large commercial enterprises is more like 9 years.

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Dr. Johnson said that DoE STTR grants used to require a CRADA, but they are now structured more flexibly, and require only an IP agreement with the Lab (this is part of the CRADA). The STTR grant also requires approval from the DoE Cognizant Officer who is responsible for lab activities, which can also take considerable time. Currently, most labs that use CRADAs require that separate CRADAs be signed for each of the two award phases, which lengthen delays and adds cost. Each CRADA specifies a time period for work to be completed, and amending this requires a change to the CRADA, as does any other significant change to the statement of work (e.g., a shift to a different part of the lab as provider of a device or service).

Dr. Johnson noted that STTR projects can only work well if there is goodwill between the lab and the company. Because Muons has such long and deep connections with national labs, its staff know most of their counterparts at the labs, so the connection is always positive.

Still, lab administrators in general tend to view STTR awards as small projects. From a $150,000 award, the lab will receive maybe $50,000-60,000, and it costs them almost that much just to do the paperwork, according to Dr. Johnson. So STTR agreements can take a long time to receive signoff from the labs, as they are a low priority for lab administrations.

In some cases, these delays mean that the labs and the company are out of sync, and that the lab will struggle to provide its deliverable on schedule. If a lab fails to deliver on time, the company has to step in to fill the gap, which can cause considerable hardship and economic losses for the company. Namely, the company then has to pay for the work directly yet ends up paying the lab anyway as part of the binding STTR agreement.

DoE program managers are quite flexible, but are constrained by STTR legislation which requires that the Research Partner Institution receive a minimum percentage of the award. Program managers will sometimes allow a switch of RI, but in reality this is not practical: the RI has usually been selected because of its specialized expertise. Dr. Johnson said that program managers should be given the flexibility to switch STTR funding back to the company in special circumstances.

Dr. Johnson said that the DoE STTR-SBIR programs run very smoothly. Recent changes, such as the introduction of letters of intent to allow reviewers to be selected in good time and the well-designed timeline on the agency website, are welcome improvements.

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NANOSONIC, INC.[46]

NanoSonic, Inc. is a small nanotech company based in Blacksburg, Virginia. Founded as a spinout from Virginia Tech's College of Science and Engineering in 1998 by Dr. Richard Claus, an electrical engineer, it currently has about 35 employees. The company is managed by President Dr. Jennifer Lalli, CTO Dr. Vince Baranauskas, CFO Melissa Campbell, and CEO and Director of Advanced Development Dr. Richard Claus.

Nanosomic was formed to design and manufacture innovative materials, especially new materials that are unavailable in the commercial market. A major company objective is to create these innovative materials through environmentally benign processes and techniques.

Originally, the company focused on the fabrication of thin films and sensors, but soon expanded its activities to include the scale up of coatings and the use of specialized coatings for a range of applications, according to Dr. Lalli. The company hired several chemists to pursue these new areas, and is now concentrating on materials production rather than electronic products.

SBIR/STTR awards led to a considerable amount of positive press, Dr. Lalli noted, and this led to more awards and then on to three separate Phase III contracts within three years. The first Phase III award was transformative, as it helped NanoSonic scale up manufacturing production very substantially. As the existing facility in Blacksburg was not suitable, this led to a shift to a new facility about 15 miles from Virginia Tech. The new building was not attached to any other buildings, so provided the added benefit that NanoSonic could perform classified work. More recently, NanoSonic has been seeking to take products to the demonstration stage as early as possibly, and then to move forward to cut costs and scale production rapidly.

NanoSonic's innovative materials have attracted considerable interest especially from DoD prime contractors, who have often heard of NanoSonic through the SBIR/STTR program, according to Dr. Lalli. The company is experienced at putting materials through quality testing, and can provide materials as almost or fully qualified products for bulk of sales to defense primes.

Dr. Lalli said that overall, NanoSonic has had more success selling to primes than to DoD itself. She noted that while SBIR and STTR topics and subtopics supported the development of advanced materials, unless DoD had written a specification for them, there was little likelihood that they would be adopted by the agency: without a new specification, existing materials would continue to be used instead. In that respect, the SBIR/STTR topics were often well ahead of agency procedures.

[46]The primary sources for this case study are an interview with Dr. Jennifer Lalli, CEO, August 25, 2015, the NanoSonic Inc. website (http://www.nanosonic.com/), and other materials from NanoSonic.

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These difficulties with DoD has led NanoSonic to take a strategic decision to work more closely with the prime contractors, and to de-emphasize efforts to sell directly to DoD, where NanoSonic in the past has had success (on two projects) in using the sole source designation that comes with SBIR/STTR awards.

NanoSonic has made no effort to raise third party funding, even though NanoSonic's metal rubber products had attracted VC interest, in part because the company is able to bootstrap growth through sales and in part because venture funding entailed potential risks.

The company works with all different sizes and types of companies and organizations, and clients include NASA, DoD, and DOT, providing services that cover all phases of product development; R&D, design and development, and manufacturing. R&D services cover polymer and small molecule synthesis, protective coatings, advanced textiles, antennae, RF testing, and sensors.

Technology and IP

NanoSonic's R&D lab is equipped for the design and synthesis of material precursors (compounds that are formed into other compounds through chemical reactions). The lab also forms synthesized precursors into thin (between 1 nm and 1 µm) and thick film materials, using advanced computers for material design, device modeling, and data analysis. The manufacturing lab is mainly dedicated to HybridSil® and HybridShield® production—it produces 4,000 lbs/day of HybridSil® and HybridShield® nanocomposite formulations.

The company has licensed nine patents from Virginia Tech, covering electrostatic self-assembly processing and use, and is establishing its own intellectual property portfolio in the next step toward commercialization. Currently, NanoSonic has one patent that generally relates to self-formation of a transparent, abrasion-resistant optical coating on solid plastic substrates that protect a solid substrate from wear and/ or provide properties such as magnetism, electrical conductivity, and UV absorption.

Electrostatic self-assembly is a key aspect of this technology. It allows a uniform formation of multiple, nanometer-thick layers of material into functional ultrathin films, and recent improvements allow the formation of much thicker films and bulk materials. NanoSonic has created a library of similar self-assembled materials, many based on electrostatic self-assembly processing, and has demonstrated the synthesis of more than 2000 individual material layers.

Products

Coatings

NanoSonic offers two eco-friendly HybridShield® coatings: Anticorrosion Coating and Icephobic. HybridShield® Anticorrosion Coating is a

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single component protective material designed to protect marine, automotive, aerospace, shelter, and communication structures from harsh corrosive environments. In tests, metallic surfaces protected by HybridShield® endured more than 12 months of continuous beach exposure and 5 months of continuous salt fog exposure without signs of corrosion, and exhibited almost no change in color and gloss. All liquid coatings are sold in gallon and quart sizes, at prices ranging from $100-300 per gallon.

HybridShield® Icephobic coating provides higher durability, lower ice adhesion, and reduced ice accretion than competing passive anti-icing protection technologies, according to the company. This material is a two-part fluidic resin with more environmental and mechanical flexibility than competitors, with tailored cure kinetics to ensure easier application with the varied air sprayers found in the industrial coating environment.

Devices

NanoSonic's EKGear Patch monitors EKG signals without using gels or adhesives. It is made of NanoSonic's metal cloth, an electrically conductive cloth that detects the electrical potential that drives myocardial contraction. EKGear materials must be connected or integrated into projects using conductive epoxy, alligator clips, or rivets of conductive materials.

NanoSonic also sells two unique metal rubber products that combine the high electrical conductivity of metals with the stretching capabilities of elastomers. Self-assembly processing allows the simultaneous modification of both conductivity and modulus (stretchability) during manufacturing.

NanoSonic has developed two related products from metal rubber materials: metal rubber electrodes and sensors. Metal Rubber has been demonstrated in a wide range of applications: large mechanical deformation electrodes, mechanically flexible electrical interconnects, and lightweight, durable, conformal electromagnetic shielding. Both products feature malleable metal rubber electrodes that feature a glass transition temperature (temperature at which an epoxy transforms from hard to rubbery) of -60 °C. They have slightly different shapes, and are designed for different applications. The company sells metal rubber electrodes in packs of five 1.5" x 0.5" strips, for $500. Sensors also come in packs of five strips for $500.

Materials

NanoSonic also sells advanced materials directly. Metal rubber sheets are a highly flexible and electrically conductive elastomer, which can be stretched to 1,000 percent of its original shape while staying conductive. The sheets carry data and electricity, and have multiple applications, including power cables, conductors, fabrics, and carbon nanotubes.

Metal rubber addresses a key weakness of carbon nanotubes: once they are deformed, they can lose physical and chemical properties. Making them

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more flexible—or pairing them with a flexible material like metal rubber—could lead to significant advances in nanotechnology. Metal Rubber sheets are sold in two sizes: 6" x 6" ($1,000) and 12" x 12" ($2,000) sheets.

NanoSonic also sells a fire protection sheet, the HybridShield® Thermal Array. This is a fiberglass sheet that gives extreme fire protection to underlying materials. It is a conformal, highly flexible boundary between firefighters and fire threats that is extremely flame resistant and stable at high temperatures. The company also claims that it provides higher temperature resistance, negligible water absorption, improved impact protection, minimal smoke toxicity, and enhanced flexibility relative to state-of-the-art insulative spacers and energy absorbing materials.

The company anticipates that the HybridShield® Thermal Array will be used for flame/heat protective clothing (firefighting suits in particular), equipment, structures, and vehicles, and has partnered with Shelby Specialty Gloves to create the next generation of firefighting gloves. The new Thermal Array gloves allow for much more precise movement than today's bulky leather gloves. The Thermal Array is sold in single- ($135) and double- ($270) sided arrays.

Current Projects

Beyond the existing products described above, NanoSonic is working on projects which it believes will reach the market in the near term. One such project is a new coating for highway barriers, being developed in collaboration with the Federal Highway Administration. When a car collides with highway barriers, the collision generates friction which can roll the car. NanoSonic is developing a coating to be sprayed onto highway barriers that will lessen friction with the aim of reducing rollovers. Tests have been encouraging, although the project is still in development.

Future Products/ Projects

NanoSonic is also currently working to develop aerosol can versions of its HybridShield® Anticorrosion and Icephobic coatings, which the company expects to be available soon, along with Scorpion Skin: a lightweight, conductive, durable, nonwoven polymer matrix resin.

NanoSonic also continues to work on applications related to fire safety. It is developing a new product called HybridShield® CeaseFire—a flame retardant and blast resistant spray. A recent test conducted with the Blacksburg, VA, fire department was very positive. The right side of a derelict building's attic and roof was treated with about 110 gallons of CeaseFire. The treated side did not ignite despite the introduction of additional fuel. It is worth noting that this product has little-to-no toxic byproducts.

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Finally, NanoSonic has also been working on optical fiber cables. Many local devices—computers, displays, local area networks—can take advantage of the capacity of an already installed optical fiber network, but need to be connected to it through high-speed links. Standard glass optical fiber jumpers can be used for these links, but they are not cheap or easy to install. With support from DoE, NanoSonic, Inc. has been developing low cost, high performance polymer optical cabling that supports high-speed data over the short distances from the optical fiber backbone to local devices and networks. The fibers are manufactured using the company's patented electrostatic self-assembly process.

Awards

NanoSonic has been recognized by the scientific community, and is the recipient of several notable awards. It was named to the Nano 50—NASA's list of the 50 most impactful nanotechnologies, products, and innovators for its metal rubber fabric technology. The company was also named to the R&D 100 in 2007 and 2011, for metal rubber and fire/blast resistant spray, respectively. Other awards include the Top Small Business Award in Virginia, a Top 5 Small Business Award at DARPATech, and a Top 13 Nanostructured Products at NASA.

Business Model

NanoSonic's business model is unusual. While most revenues are still derived either from SBIR/STTR awards or from sales of products and services to businesses or to government agencies, it is also now entering direct to consumer sales, for example its glove for firefighters (developed in partnership with a larger company, Shelby Inc.—see below). And NanoSonic also offers both raw materials (sheets of specialized fabric, or coatings) as well as final products such as the glove.

The company's main customers are government agencies, large aerospace, electronics, and biologics companies, and revenues range from $1 million to $5 million annually. While the company has developed a wide range of technologies with SBIR and STTR funding, and these have constituted a significant amount of revenues to date, NanoSonic is now moving from R&D through product development into manufacturing, and Dr. Lalli anticipates that the balance will tilt further in coming years.

Nanosomic is still focused primarily on R&D—almost all of the current employees are involved in research. However, the company is also reaching out to find new distribution channels, beyond the existing partnership with Shelby. Two additional distribution partnerships are pending as of August 2015, according to Dr. Lalli.

The company is strongly growth oriented. It owns a building with 30,000 square feet of space and with considerable room to expand. It is a "green

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building," certified by LEED and MAS, and featuring a wall of solar wall panels and other earth-friendly technologies. The facility houses a 10,000 square feet process scale-up and manufacturing lab, and a 10,000 square foot R&D lab. Another 100,000 square foot building is on the drawing board for the facility, to be used for manufacturing. Nanosomic has also always had ambitions to become an international company.

SBIR/STTR

NanoSonic has received 281 SBIR/STTR awards, 243 SBIR and 38 STTR. (206 were Phase I and 75 Phase II). 185 awards have come from DoD and 48 from NASA.

STTR

Dr. Lalli observed that 5 years ago, she would have wanted to see STTR folded into the SBIR program, in large part because managing ITAR restrictions in the context of a partnership with a research institution was often extremely challenging.

Moreover NanoSonic had found that the process has moved more smoothly, and while there was a clear tension between academic interests in publishing and company needs for confidentiality, this could be addressed effectively with the right partner.

Today, NanoSonic is a very strong supporter of the STTR program, Dr. Lalli said. The company found a formal agreement to use university equipment to be very helpful, and that the program also helped NanoSonic reach out to cutting edge researchers, and gain access to high quality graduate students.

NanoSonic now has good relationships with at least eight universities. Working with other Virginia schools has been especially fruitful—NanoSonic for a long time avoided partnering with Virginia Tech to avoid conflict of interest issues. Other effective partnerships have been formed with Colorado State University, the Naval Postgrad School, and the University of Arizona, according to Dr. Lalli.

Dr. Lalli said that she did not see STTR as presenting more difficulties than other contracts in terms of partners meeting their deliverables. She observed that in both cases, it would be important to figure out the reason for a failure, and to ask the partner for an alternative solution. Sometimes the problem being addressed was just hard, or there were differences of opinion on what needs to be delivered.

NanoSonic always drives the partnership, according to Dr. Lalli. A typical partnership might involve making the materials at the company, with the university providing technical help in measuring performance. For example, in STTR programs with Colorado State University, the partner there is an expert in

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the measurement of radiation-resistant materials measurement, and also has the necessary equipment in the university lab. He provides evaluations that validate NanoSonic claims, and thus helps the company to improve the material.

Dr. Lalli did however note that the need to deal with ITAR was very challenging. Most SBIR topics from DoD and NASA require this, and NanoSonic is now working to improve its capacity to deal with ITAR-related issues.

Recommendations

Dr. Lalli said that that biggest issue with the program for her company was the lack of clear specifications from DoD for new materials. Simply writing a topic was not enough to ensure that if the material was successful it would have a market within DoD, and she recommended that DoD develop improved procedures for closing the gap between topics and specifications, especially for materials.

PHYSICAL SCIENCES, INC.[47]

Physical Sciences, Inc. (PSI) is a private company founded in 1973 by Robert Weiss, Kurt Wray, Michael Finson, George Caledonia, and other colleagues from the Avco-Everett Research Laboratory. The company is an engineering research and development company, focusing on the application of emerging sciences to the solution of engineering problems for its customers. PSI is headquartered in Andover, Massachusetts, and has approximately 180 employees and annual revenues of more than $40 million.[48] Dr. Green has been employed at PSI for 39 years, starting there as a researcher after completing his PhD in chemistry at MIT.

Initially focused on laser and optics-based sensing applications and computer modeling in the aerospace and defense industries, energy sector, and the environment, PSI has over time applied its core expertise to a wide set of technological applications, and in so doing broadened its technical capabilities to include chemicals, materials, and signal processing. By focusing on technological specialties too small to attract major investment from DoD primes contractors and too mission-driven to excite competition from university laboratories, PSI has a solid reputation helping government agencies and private-sector clients across a broad range of technologies, according to Dr. Green. PSI's principal customer is DoD, and its needs for sensing and

[47]Primary sources for this case study are the interview with Dr. David Green, CEO September 2 2015, and a review of the Physical Sciences, Inc. website (http://www.psicorp.com) and related company documents.

[48]David Woolf, et. al, "High-temperature Selective Emitter for Thermophotovoltaic Energy Conversion," November 12-14, 2014, http://www.psicorp.com/sites/psicorp.com/files/articles/VG14-148-final.pdf, 1.

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monitoring technologies has driven the direction and development of PSI's capabilities.

The company is organized into two R&D divisions, Applied Sciences and Defense Systems, and three subsidiary companies, Research Support Instruments, Inc., Q-Peak, Inc., and Faraday Technology, Inc. SBIR/STTR is an important source of funding, especially in developing new competencies, and starting in 1983, PSI has received a total of $284 million in SBIR/STTR funding, while its subsidiaries received $54 million. However, as Dr. Green points out, PSI has always served an array of markets and SBIR/STTR funding has never been more than 50 percent of annual revenues.

At its headquarters in Andover, Massachusetts, PSI operates over 68,000 square feet of general office, laboratory, and prototyping space. PSI has two satellite offices in Haverhill, Massachusetts, and Pleasanton, California. The 6,000 square feet Haverhill facilities perform composites fabrication and laser machining operations and act as a staging area for various experimental activities. The smaller 2,800 square feet Pleasanton, California, facilities focus on nonlinear optics and laser-based chemical sensing. Subsidiaries operate facilities in Maryland, Massachusetts, New Jersey, and Ohio.

Dr. Green noted that a core of 10 to 20 people has been at PSI for 20 years or more. They understand DoD, NASA, and DoE agency needs. So PSI offers continuity, a deep understanding of the agency mission, and can as a result guide technology development toward meeting agency goals. This is a quite different model than companies seeking to commercialize a single technology, and provides quite different kinds of support to the agencies.

Technology

PSI, since its founding in 1973, has built on its core capacity applying lasers and optics technologies to sensing applications. In the 1980s, with SBIR support, PSI expanded into medical imaging and imaging chemically reacting flows. In the 1990s, PSI extended further into research on materials (especially chemical sensors), batteries, and tunable diode lasers.

Chemistry. PSI works in three broad and interrelated areas of chemistry: energetic materials research (explosives), advanced fuels, and coatings.

Laser-based Sensing. PSI lasers research focuses on three areas: biological structure, physical measurement, and laser spectroscopy. Using optical coherence tomography (OCT), PSI has developed technologies that can capture visually both tissue morphology and function. Based on laser distance and ranging technology (LIDAR), PSI can measure remotely a broad range of the physical and chemical properties of a target and the atmosphere. Finally, with tunable diode laser absorption technology, PSI is developing low-cost,

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high-volume applications such as natural gas leak detection and greenhouse gas monitoring.

Materials. To support research in energy and sensing applications, PSI developed deep competencies in material science. Initially aligned with its work on lasers, PSI expanded into other materials applications in radio sensing such as chaff manufacture to reduce or distort reflected images. PSI has also developed high temperature ceramics for leading edges and combustors in hypersonic flight and high density energy storage for next generation battery technology.

Optics. PSI has worked in optics since its founding, and as a result has developed technical capabilities in a wide range of areas, including integrated optics, photonics, and non-linear optical materials for gas sensing, field sensing, optical communications, interferometry, industrial process control and non-destructive structural evaluation. Current projects include new imagers, spectrometers, and sensors using digital micromirror device (DMD) technology to increase data rates, improve ruggedness, and reduce the overall size and cost. PSI is also developing materials for applications requiring engineered optical properties for absorption, reflection, and emission at any wavelength.

Passive Sensing. Sensing technology is another longtime core competence of PSI. Current areas of research include magnetometry for measurement of local magnetic fields by drones, surface contamination for detecting environmental chemical agents (explosive or industrial waste), hyperspectral imaging for sensing chemical residues on remote surfaces, and low cost acoustic sensors for determining right-of-way encroachment and excavation activity near a pipeline.

Signal Processing. PSI's work on sensors has also led the company into signal processing. For example, PSI has developed the capability to simulate post-intercept radar scenes with thousands of debris objects. Similarly, the company has a strong portfolio of sonar signal processing analysis models and simulations intended to enhance sonar performance against background noise, clutter, and reverberation.

Products

While PSI is not a manufacturing company and has no plans to become one, its technology does transition into products. Typically, if these have larger scale potential they are licensed to bigger companies for market deployment, while PSI itself may manufacture products that are short run or otherwise low volume.

On its website, PSI provides a list of 20 products. Some have been licensed for production to other companies, and some are produced in short runs by PSI.

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Commercialization: Subsidiaries, Spin-Offs, and Licensing

When PSI sees commercial potential in a technology, senior management evaluates the opportunity to determine how to address the opportunity. PSI subsidiaries tend to replicate the R&D culture of the parent company (publication in peer-reviewed journals, use of SBIR funding), to focus on a limited (but stable) commercial opportunity, and to perform prototyping and low volume manufacturing. Spin-outs typically depend on venture backing and incorporate business models targeting larger commercial markets with need for product development, manufacturing, logistics, and sales and marketing.

Subsidiaries

Since 1990, PSI has acquired four wholly owned subsidiary companies. Three continue to operate: Research Support Instruments, Inc. (RSI), Q-Peak, Inc., and Faraday Technology, Inc., while the fourth was sold and now operates as part of a larger company.

Research Support Instruments, Inc.

Founded in 1976, Research Support Instruments, Inc. (RSI) was acquired by PSI in the early 1990s to provide PSI with the capacity to deliver hardware for spacecraft discovery missions as well as on-site engineering support to clients in the DC metropolitan area. The company provides services that enable research and development, systems engineering, instrument test and calibration, and experiment support. It operates offices in Lanham, Maryland; Princeton, New Jersey; and at the Naval Research Laboratories (NRL) in Washington, DC. RSI has had some success generating SBIR/STTR funding. Since its founding, RSI has received 44 SBIR/STTR awards, worth $7.8 million. Twelve percent by value have been STTR awards.[49]

Q-Peak, Inc.

PSI acquired Q-Peak in 2001. From its offices in Bedford, Massachusetts, the company performs contract research and development in the fields of solid state lasers, nonlinear optics and related technologies. Customers include both the U.S. government and private corporations, especially the

[49]"PSI'S CORPORATE HISTORY," http://psicorp.com/our-company/history; "Excellent Technical Support," http://www.rsimd.com/; "Research Support Instruments, Inc." https://www.sbir.gov/sbirsearch/detail/292228.

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aerospace primes. Q-Peak can also produce low volume runs of various devices and systems. Finally, Q-Peak also manufactures a set of products based on diode-pumped, solid state lasers. These standardized, field-proven components can be integrated to provide a broad range of custom functionality. Q-Peak has also had substantial success in acquiring SBIR/STTR funding, having received 110 SBIR/STTR awards, worth $29.4 million. Eight percent by value have been STTR awards.[50]

Faraday Technology, Inc.

Faraday Technology, Inc. provides government and commercial clients with R&D services related to electrochemical engineering development running from bench prototype systems through pilot or pre-production levels. By varying the waveform of the applied voltages and currents, the anode/cathode spacing, the anode design, and degree of mixing within a Faraday cell, company technicians can control the electrochemical deposition rates of various atoms. In addition to engineering services, Faraday also markets rectification equipment and effluent decontamination reactor hardware. Faraday Technology has had success generating SBIR/STTR funding, receiving 90 SBIR/STTR awards, worth $21.0 million. Eleven percent by value have been STTR. Faraday also won an R&D 100 Award in 2011 for its work depositing Mn-Co coating on interconnects in solid oxide fuel cells.[51]

Spin-Outs

In addition to establishing subsidiaries, PSI has also spun out technologies into new companies. Typically, these technologies have presented the opportunity for selling products to mass markets. Although PSI may take an equity stake in the company, most of the funding comes from the venture community. The company's record with spin-outs has been mixed.

Confluent Photonics was founded in 2000 to commercialize components for use in Dense Wavelength Division Multiplexing ("DWDM"). Confluent received $14 million in two rounds of venture funding in 2001 and 2003. In 2006, it was acquired by Auxora.[52] Another medical instrumentation

[50] "Q-PEAK, INCORPORATED." https://www.sbir.gov/sbirsearch/detail/284118; "Research and Development: Overview," http://www.qpeak.com/Research/roverview.shtml, "Products: Overview," http://www.qpeak.com/Products/products.shtml.

[51] "The Company," "The Technology," http://www.faradaytechnology.com/; "FARADAY TECHNOLOGY, INC." https://www.sbir.gov/sbirsearch/detail/164726; "Faraday Wins R&D Magazine's R&D 100 Award," http://www.faradaytechnology.com/PDF%20files/FT%20R&D%20100%20Press%20Release.pdf.

[52] "Confluent Photonics Raises $11 Million Series A Financing," January 10, 2001, http://www.prnewswire.com/news-releases/confluent-photonics-raises-11-million-series-a-financing-from-innocal-venture-capital-rustic-canyon-ventures-cit-venture-capital-and-invesco-private-capital-71002827.html; "Confluent Photonics Raises $3 Million in Second Round Financing," September 11, 2003, http://www.prnewswire.com/news-releases/confluent-photonics-

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firm failed when it could not raise a C round to complete clinical trials to gain FDA approval.

Dr. Green said that IP and staff usually go with the spin-out. None of the spin-outs have been highly successful, and many of the staff have returned to PSI. One spin-out still exists, having been sold three times. Spinouts are however in the end in the hands of the investors who buy control. In some cases, that can be invaluable where they provide good market insight. However, in many cases the technology takes too long to mature, and investors take the new company in the wrong direction. A good recent example would be 3-D cinema—the company's technology was in that case transferred to an outside group which lacked the technical capacity to execute the project effectively.

Licensing

PSI has licensed significant amounts of technology. Perhaps the most successful example is the Remote Methane Leak Detector (RMLD™), a laser sensor used worldwide to detect natural gas leaks. PSI began RMLD™ development in 1999, initially funded by EPA Phase I and Phase II SBIR grants and subsequently with funding from the Department of Energy and industry partners. The eventual product is a hand held device that can detect methane from outside the plume. According to Dr. Green, PSI developed the product all the way through to a pre-production prototype. It worked collaboratively throughout the development with an industrial partner as well as national gas distribution companies.

Four years of work resulted in a prototype. PSI licensed the RMLD™ technology to Heath Consultants, Incorporated on an exclusive basis in 2003, and renewed the license for another ten years in 2013. Heath released RMLD™ commercially in 2005 and has since sold over 3,000 units worldwide at about $17,000 each, generating revenues of approximately $50 million and PSI royalties of $2 million. The detector has spawned its own cluster of jobs through companies using the detector, which Dr. Green estimates at more than 3,000 employees along with commensurate tax revenues. The product team received a 2005 R&D 100 Award. In 2006, PSI received a Tibbetts Award.[53]

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raises-3-million-in-second-round-financing-71066127.html; "Auxora Acquires Confluent Photonics," March 6, 2006, http://www.auxora.com/doce/news-detail-26.html.

[53]"Tibbetts Award Winners," http://www.sbtc.org/tibbettswinners/; "Detecting gas leaks from a distance," August 31, 2005, http://www.rdmag.com/award-winners/2005/08/detecting-gas-leaks-distance.

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According to the PSI website, PSI licensing income recently exceeded $1 million annually following the successful commercialization of its ophthalmic technologies.

Patents and Other Intellectual Property

PSI is the assignee for 70 patents over the period 1987 to 2015. Five patents have multiple assignees reflecting R&D collaboration between PSI and other organizations. They were Faraday, Incorporated; American Air Liquide, the General Hospital Corporation, and Alliant Techsystems. Almost half (32) of PSI patent portfolio has been published in the past 5 years which suggests that PSI's patent strategy has changed.

Partnerships

PSI maintains research relationships with a broad range of university, government, and corporate R&D organizations. For example, PSI has recently successfully licensed technology for ophthalmic instrumentation to both an incumbent and two start-ups. The technology was developed in partnership with scientists, engineers, and clinicians from organizations like the Army Medical Research Branch, the Air Force Research Lab, the Massachusetts Eye and Ear Infirmary, MIT, the University of Texas at Austin, Massachusetts General Hospital, Boston Medical Center, and Brigham and Women's Hospital.[54]

Revenues

PSI generates over $40 million annually in revenues, down slightly from its peak in the late 2000s. The company has received extensive support from SBIR/STTR funding. It also generates revenue from engineering service contracts, product sales from its subsidiaries, technology licensing, and to a lesser extent spin-outs.[55] PSI reports its revenue breakdown for FY 2010 as that listed in Table E-8 (including subsidiaries).[56]

SBIR/STTR

Between 1983 and 2015, SBIR/STTR funded 1,108 projects with PSI: $63 million in SBIR Phase I, $190 million in SBIR Phase II, $8.0 million in

[54]Dan Hammer, et. al. "Biomedical Optics Instrumentation," September 15, 2010, http://www.psicorp.com/pdf/library/VG10-182.pdf, p. 7.
[55]Dan Hammer, "Biomedical Optics Instrumentation,"http://www.psicorp.com/pdf/library/VG10-182.pdf, 1; Woolf, "High-temperature Selective Emitter," http://www.psicorp.com/sites/psicorp.com/files/articles/VG14-148-final.pdf, p. 1.
[56]David Woolf, et. al, "High-temperature Selective Emitter," http://www.psicorp.com/sites/psicorp.com/files/articles/VG14-148-final.pdf, p. 1.

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TABLE E-8 Physical Sciences, Inc.'s Revenue Breakdown, FY 2010

Percent of FY 2010 Revenue	Source of Funding
60	Applied research and development for U.S. government agencies
20	Components, systems, and instrumentation for industry and government sales
15	Product development and commercialization for government and industrial customers
5	Development of pre-production manufacturing processes
2	Licensing fees from strategic partners and spin-outs for high-volume commercial markets

SOURCE: Physical Sciences, Inc.

STTR Phase I, and $23.4 million in STTR Phase II funding. PSI's subsidiaries have also benefited from SBIR/STTR, receiving an additional 244 awards worth $58 million.[57]

Of the 93 SBIR/STTR projects awarded to PSI in 2013 and 2014, 61 percent (57 projects) were funded by DoD, 17 percent by NIH, and 12 percent by DoE. The remaining 10 percent were funded by the Department of Agriculture, the EPA, the Department of Homeland Security, and the National Aeronautics and Space Agency. Over the more than 30 years that PSI has received SBIR/STTR funding, STTR awards account for just under ten percent by value.

Both PSI and the SBIR/STTR programs have evolved over time. Initially, the company was focused on basic and near basic research. Today is it working on applied research and then applications and commercialization. Dr. Green said that the company was already evolving towards a more pronounced focus on commercialization before more recent changes in the SBIR/STTR programs in the same direction.

Today, PSI is a strong supporter of the program's shift away from research-only projects. The company no longer just looks for projects that it can win—managers want to know where the technology will be used, and they want to see effective commercialization, according to Dr. Green. Before staff write a Phase I proposal, the company has to have a commercialization plan—it is part

[57]"Physical Sciences, Inc." https://www.sbir.gov/sbirsearch/detail/273626; National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, 2008, http://www.nap.edu/catalog/11989.html, p. 268.

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of the bid decision for PSI. And while PSI still sees itself as a research house, it is now focused much more closely on applications for that research.

Dr. Green said that successful commercialization of SBIR technologies—especially from DoD and NASA SBIR/STTR projects—required that the company find multiple markets—simply relying on direct agency sales was not sufficient. Thus while PSI's work with NASA had led to a number of commercial successes, these had not been through direct sales to NASA. Diagnostic tools developed for NASA, for example, are now used in the automotive industry. Similarly, PSI is currently building an aviation fuel quality monitor for Navy for aircraft carriers. Orders for these monitors come once every 3 years, so that business alone cannot sustain a company.

STTR

Dr. Green said that he was a strong supporter of the STTR concept. However, while STTR provides funding for the research institution, industry has to be the bridge that transitions technology out of academia. STTR cannot just be pass-through funding to the RI. He believes that STTR encourages each partner to work to their strength: the RI does research and education, and the industry partner does commercialization, and this structure is perfect for technology transition.

Dr. Green observed that PSI had spent more than $9 million on contracts with RIs since 2009. Most of that has been through SBIR/STTR (though there have been some other contracts). In one 6-year period, PSI funded 53 different universities. The company watches the scientific literature to identify possible partners, focusing on faculty who are making cutting edge advances that can meet the needs of PSI's customers. It is rare that a professor says they are not interested in collaboration.

PSI has had a number of successful STTR projects. One focused on imaging of the retina, and stretched over several STTR awards, starting with NIH support. NIH wanted technology to detect macular degeneration earlier, and the technology might also help detect eye diseases in premature infants.

The objective of the project was to resolve to very fine level the vasculature at the back of the eye at the surface and in depth. That allows clinicians to understand the dynamics of the back of the eye using optics only.

PSI had worked on the project with a number of high quality academic partners in the Boston area, including Children's Hospital. Working closely with top researchers, seeing their challenges and identifying tools to resolve them, before working together on clinical trials and further refinement of the tool is highly satisfying for PSI researchers. Publishing academic papers jointly was also important—it allowed new ideas to emerge from the scientific audience, and often stimulated possible new applications for the tool. Dr. Green thus saw the project as creating a powerful virtuous circle: PSI staff are instrument builders, not clinicians, but the company's work helps the clinicians do things they could never have done otherwise. That in turn created more

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publications and more recognition for the project, and ultimately patents that were filed jointly with RIs such as Children's Hospital.

The product of the STTR-funded research has now been licensed to major medical device companies, as it is not realistic for a company the size of PSI to fund clinical trials. Dr. Green said that PSI now receives modest royalties, as the device companies sell the product. Over the past 7 years, 15,000 units have been sold, generating approximately $1 billion in revenues. Perhaps more important, tens of millions of patients have been tested using this technology, improving health for everyone.

While Dr. Green supports STTR, he said that it was not clear that it added substantial value beyond SBIR. PSI works with RIs through both programs, and finds that RIs are brought into projects because they are needed. There is in his view no difference in the company's management of SBIR and STTR programs. All subcontractors need to be managed, which is especially hard to do in the short timeframe of a Phase I award. Universities may even be a little easier to manage than collaborations or subcontracts with large technology companies.

Recommendations

Dr. Green said that overall the review process at the agencies was high quality, particularly at DoE. It often provided many different technical perspectives, which was valuable. Commercial review was probably not as insightful, but no one can perfectly see the path to commercialization. Efforts have been made to improve commercial review, and DoE in particular has tried to raise awareness and improve quality. He suggested that agencies should seek expert advice on commercialization, which was now widely available in the private sector. Reauthorization has resulted in more reporting and a lot more structure. He said that the amount of effort required to submit a proposal has more or less doubled even for a highly experienced company like PSI. This represents a major barrier to entry into the program: Dr. Green noted that the grants.gov SBIR/STTR instructions are 200 pages long, which may in part explain why the number of proposals is falling. Every SBIR/STTR proposal requires that PSI uploads 10 to 30 different sections. One has to be very Internet savvy and very persistent.

Dealing with government has in general become much harder. Now numerous forms and statements are required related to fraud and abuse: all proposals now require that the company has support for every piece of equipment it plans to buy and provide support to show that it is actually paying everyone that it plans to pay.

The agencies need to look again at this, to find ways to simplify the process substantially, to limit the amount of paperwork involved in an application. Everyone should have a fair shot, and that is not really the case

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today. PSI has a fully trained technical publications department to do submissions and it still takes them significant time and effort. It is important that the program remain fully merit-based, to ensure that the best solutions find their way to the market.

VISTA CLARA, INC.[58]

Vista Clara, Inc. is a private company founded in 1997 by Dr. David Walsh, a design engineer with experience developing magnetic resonance imaging systems (MRI) in the healthcare industry. Dr. Walsh said that he had been an entrepreneur even before graduate school, and that he had always wanted to own his own company. After completing graduate school, he had started Vista Clara as a technology consulting company in Tucson, and it had been growing slowly but steadily when he decided to start applying for SBIR funding. The resulting awards allowed the company to develop its core technology (see SBIR/STTR and Vista Clara section below).

Vista Clara develops and manufactures advanced nuclear magnetic resonance (NMR) geophysical instrumentation systems for groundwater, mining, and environmental studies. Vista Clara's NMR instrumentation can operate from the surface, downhole, or in the laboratory, and delivers quantitative imaging of subsurface hydrogeologic structure. The company both sells and rents this equipment, and provides training in its use. Vista Clara also uses its own equipment to perform hydrogeologic field surveys for customers ranging from private land-owners to government agencies and multinational firms.

In 2002, Vista Clara pivoted from its initial focus on healthcare MRI to applications of NMR to hydrogeology. SBIR funding enabled the company to develop its first NMR based system for groundwater surveying. Although initially expecting to focus primarily on the U.S. market, Vista Clara has found greater market acceptance overseas, principally in China and Australia. Exports are the basis of the company's revenue and profit growth.[59]

Vista Clara is receiving recognition for its work. For example, Elliot Gruenwald, the chief geophysicist for Vista Clara, recently won the J. Clarence Karcher award from the Society of Exploration Geologists for his innovative work on surface NMR.[60]

The company's clients include various corporate (Rio Tinto, BHP Billiton), university (Rutgers University, Stanford University), government

[58]Primary sources for this case study are the interview with Dr. David Walsh, CEO, August 18, 2015, and a review of the Vista Clara website (http://www.vista-clara.com) and related company documents.

[59]David Walsh, "Use of Exports to Accelerate Adoption of NMR Geophysical Technology," National Groundwater Association, Theis Conference, November 8-10, 2013, Phoenix, Arizona, https://ngwa.confex.com/ngwa/theis2013/webprogram/Paper9564.html.

[60]Rosemary Knight, "J. Clarence Karcher Award for Elliot Grunewald," *The Leading Edge*, January 2015, 15; http://www.tleonline.org/theleadingedge/january_2015?pg=15#pg15.

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(U.S. Geological Survey, Kansas Geological Survey, Qinghai Geology and Mineral Exploration Bureau, Geoscience Australia) and NGO (Geophysicists without Borders) entities.

Vista Clara currently employs approximately 15 people at its Mulkilteo, Washington headquarters. To serve Asian markets, Vista Clara also maintains a small office in Perth, Australia.

Technology: NMR Hydrogeologic Instrumentation

Water scarcity affects every continent. By 2025, around 1.8 billion people will be living in areas of absolute physical scarcity; two-thirds of the world's population will be living under water stress. For many, underground aquifers are an important source of water. However, in most parts of the world, the data required for principled management of these resources is lacking and groundwater aquifers are being depleted.[61]

Vista Clara is developing NMR products and services to measure groundwater. NMR is a physical phenomenon whereby certain elements absorb and re-emit electromagnetic radiation. The sensing using NMR is a two-step process. First, the magnetic spins in a sample are aligned using a magnetic field, and second a radio pulse perturbs the aligned fields. The exact frequency of the pulse depends on the atom to be detected and the strength of the magnetic field.[62]

Conveniently both hydrogen and carbon show this phenomenon. NMR was first applied in geophysics to oil exploration in the 1960s to help develop understanding of oil flows through hydrocarbon-bearing rock. NMR instruments designed for the oil industry, however, are generally overengineered for hydrological field studies. The hydrogeologic bore holes are substantially narrower, the physically constants of the targets are different, and the operating temperatures and pressures substantially lower.[63] In a hydrogeologic study, NMR allows the measurement of key hydrological soil characteristics. It can

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[61] *Non-renewable Groundwater Resources*, Stephen Foster and Daniel Loucks, eds., Paris: United Nations Educational, 2006), 81; http://unesdoc.unesco.org/images/0014/001469/146997E.pdf; "water & poverty, an issue of life & livelihoods," FAO Water, http://www.fao.org/nr/water/issues/scarcity.html.

[62] Abi Berger, "How Does It Work: Magnetic Resonance Imaging," *British Medical Journal*, January 5, 2002, vol. 324, no. 7328, p. 35, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1121941/; Allan Newman, "Between a Rock and a Magnetic Field: Geologists Exploit NMR," *Analytical Chemistry* 63(8):467, August 1991, http://pubs.acs.org/doi/pdf/10.1021/ac00008a732.

[63] David Walsh, et. al. "A Small-Diameter NMR Logging Tool for Groundwater Investigations," *Groundwater* 51(6):914-915, November-December 2013, http://www.alphageofisica.com.br/vista-clara/papers/groundwater_javelin_www.alphageofisica.com.br.pdf.

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distinguish between bound water that will not flow and unbound water that will. From this, it can also determine the porosity of a soil, a crucial variable in determining flow through that soil.

Initially, Vista Clara developed innovative non-invasive multi-channel (GMR) surface systems designed to enable rapid evaluation of water aquifers without drilling expensive exploratory wells.[64] In the past 8 years Vista Clara emulated the oil industry NMR instrumentation systems for hydrogeologic NMR systems that functioned down bore holes (Javelin) or in laboratories (Corona).

Products and Services

Vista Clara has created a product line that provides different ways of using NMR to evaluate near surface geology (surface-based, small bore holes-based, laboratory-based).

Instrumentation

Vista Clara offers four different instrumentation packages:

GMR. GMR is a surface magnetic resonance sounding system that allows non-invasive detection and measurement of ground water. GMR uses the earth's magnetic field to align the hydrogen atoms in the water molecules and broadcasts an electromagnetic pulse from surface electrodes to generate an NMR response. Sensors detect the return signal enabling groundwater and soil characterization to a depth of 150 meters without the need for drilling bore holes. Applications include groundwater exploration and well site selection.

Javelin. Javelin was designed to profile the hydrological characteristics of the geology surrounding a bore hole. Designed for older well fields in which a network of monitoring wells already exists, Javelin is lowered down each bore hole, developing a vertical profile of the hydrological properties for the soils surrounding the bore.

Discus. Discus is a surface technology that enables rapid characterization of surface soils using NMR without the need for sample extraction, porosity calibration, or radioactive sources. Discus can be rapidly moved across a site to develop a two-dimensional map of surface soil characteristics. Applications include non-invasive studies of agricultural drainage, roadway compaction, and moisture in building concretes.

Corona. Corona is a portable system for evaluating the hydrological characteristics of soil cores. Using the same technology as a MRI scanner,

[64]David Walsh, "Multicoil low-field nuclear magnetic resonance detection and imaging apparatus and method," U.S. Patent 8,451,004, May 28, 2013, http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&u=%2Fnetahtml%2FPTO%2Fsearch-adv.htm&r=1&p=1&f=G&l=50&d=PTXT&S1=8451004.PN.&OS=pn/8451004&RS=PN/8451004.

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Corona exposes a sample to a strong magnetic field and then a series of electromagnetic pulses. This system can be used for engineering, geotechnical, or agricultural studies of soil cores. Vista Clara also uses Corona-enabled core studies to calibrate Javelin and GMR/Discus data sets.

Rental and Training

To enable broader adoption of NMR technology, Vista Clara enables customers to rent NMR products for periods ranging from a few days to a few months. To ensure that data is properly captured and analyzed by both rental and first time customers, Vista Clara personnel will travel to provide on-site training.

Field Surveys

Vista Clara will perform custom field surveys for its clients, although according to Dr. Walsh it prefers to train client staff. It will assist in study design, data acquisition, data review and processing, data interpretation, and report preparation.

Markets

Vista Clara sells small numbers of moderately expensive equipment (GMR systems are approximately $200,000 each), so individual sales have a real impact on the company, according to Dr. Walsh.

In general, Vista Clara sees its markets as global. The company has found that demand for its products fluctuates, but not simultaneously in all markets. In China, the company found an effective distributor for geophysical instruments and had two years of growth, but the recent slowdown of the Chinese economy has limited opportunities in that market. Thus the sale of 3 GMR systems in 2013 has been followed this year by the sale of one system. The company is now seeking to develop systems that can be sold at a lower price, in an effort to build the volume of sales and make revenues less volatile.

Governments are the primary end users of the data generated by Vista Clara systems. Projects involving the systems tend to be large scale—for example, a recent project maps the aquifers of western Nebraska. As a result, systems are typically bought by government agencies or their prime contractors, according to Dr. Walsh, which tends to mean a slow sales cycle. However, the systems are sometimes also used by small geophysical companies who contract to take the actual measurements and then provide the data to the end users. Sales to large entities are usually preceded by a rental evaluation period.

Dr. Walsh noted that while most sales are to large entities, Vista Clara does rent equipment to smaller companies and in some cases has acted as the data collector itself, although it prefers to simply provide the equipment.

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Marketing in this sector is highly specialized. Vista Clara attends 8-12 conferences annually, focused on interacting with the hydrology scientists and their sponsors. The company also attends some conferences for vertical markets—for example, mining conferences in Vancouver and Australia. Vista Clara also publishes papers in peer-reviewed journals, as these articles are read by the customers the company is seeking, especially researchers and academics. Dr. Walsh observed however that publishing remained a challenge as company staff were usually fully committed with company projects.

Dr. Walsh said that the company faced three kinds of competitors:

- Existing established competitors. There is one primary established competitor, which is a state-owned French company with a product that is not cutting edge but which is supported by significant marketing help from the French government.
- Emerging competitors. There is one new company emerging in Australia.
- U.S. and European R&D groups that are trying to develop similar technology but have not yet successfully reached the market. These groups tend to be more focused on academic interests.

Vista Clara retains some key advantages, according to Dr. Walsh. The technology is hard to develop, although once developed it is easy to re-apply in different form factors. Dr. Walsh said that the company had used export services from the Commerce Department, with mixed results. The process had helped the company to acquire some customers in Denmark.

Patents and Other Intellectual Property

Vista Clara is the assignee for the U.S. patents listed in Table E-9.

Operations

Vista Clara generates income from its NMR hydrogeologic instruments, and exports are driving its sales success. Vista Clara reported recently that it has won four of its last five competitively bid proposals in China, the most recent of which resulted in the sale of three GMR surface NMR instrumentation systems.[65]

[65] "Vista Clara secures leading position in China," http://www.vista-clara.com/news/vista-clara-secures-leading-position-in-china/.

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TABLE E-9 Vista Clara Patents

Patent Number	Patent	Year
8,816,684	Noise canceling in-situ NMR detection	2014
8,736,264	NMR logging apparatus	2014
8,581,587	SNMR pulse sequence phase cycling	2013
8,451,004	Multicoil low-field nuclear magnetic resonance detection and imaging apparatus and method	2013
RE43,264	Multicoil NMR data acquisition and processing methods	2012
7,986,143	Multicoil low-field nuclear magnetic resonance detection and imaging apparatus and method	2011
7,466,128	Multicoil NMR data acquisition and processing methods	2008
6,160,398	Adaptive reconstruction of phased array NMR imagery	2000

SOURCE: U.S. Patent and Trademark Office.

SBIR/STTR and Vista Clara

Between 2003 and 2014, SBIR/STTR funded 14 projects with Vista Clara, Inc. amounting to nearly $5.5 million. Of this amount, DoE provided approximately 64 percent, DoD 21 percent, and NSF the remaining 14 percent. The company has received one Phase I and one Phase II STTR award from DoE.

Vista Clara's first SBIR award was a 2003 Phase I NSF award for adapting medical MRI technology for use in groundwater characterization. This was followed by other Phase I awards from DoD and then by a 2005 Phase II NSF award for $500,000 which transformed the company. It now no longer had to rely entirely on other companies for revenues, and could move forward to develop its first product.

By the end of the first Phase II award, the technology was good enough to collect data, and a customer in Germany was prepared to pay for a product in semi-finished format. Dr. Walsh said that he sold his house to raise the money to build the product.

Starting in 2008, Vista Clara received further Phase II SBIR and STTR awards from DoE, which have according to Dr. Walsh allowed it to gain substantial ground on its competitors and develop fully finished products. Funding for the company's second product, the Javelin, came during this period.

Phase IIB funding at DoE was for a project to develop accustom cable for down-hole logging. Vista Clara had sought $300,000 from DoE and had invested $75,000 of the company's capital, and although the DoE program did not require matching funds, Dr. Walsh believed this investment helped the company win the award.

Dr. Walsh said that in his view it was important to ensure that the company had created a finished or close to finished product by the end of Phase

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II, otherwise it would need to find new funding or commit its own resources to fill the gap. The Javelin project fit this model, as a finished product had been completed by the end of the Phase IIB award. The product was now in use in Australia and by the U.S. Geological Service. Companies should also be aware that new technology took time to develop a sustainable market—early adopters could be relied on to purchase a few initial units—but that subsequent sales could take a considerable time.

DoE's interest in Vista Clara technology stems from the agency's need to manage groundwater contamination more effectively. Facilities are currently spending hundreds of millions of dollars on soil and groundwater remediation, and Vista Clara technology offers significant upgrades on existing approaches, according to Dr. Walsh.

However, despite the funding and interest expressed through SBIR awards sponsored by the office of subsurface biology, Vista Clara has as yet made no sales to DoE. Dr. Walsh observed that it appears there is no clear connection between the SBIR program and DoE needs elsewhere in the agency. Thus while there is a topic every year on subsurface characterization and remediation, there are no follow-on contracts for SBIR winners. Vista Clara has won three Phase II awards to develop the NMR technology that the company now sells, but which is not in use at DoE. Contracts for remediation are awarded through a large prime contractor and there appear to be no incentives for the use of small/SBIR companies. This remains the case even though Vista Clara has good contacts at the National Lab near the Hanford remediation site.

Dr. Walsh said that he strongly supported DoE's set aside of part of the STTR budget to pay for articles in peer review publications, which often charged significant amounts. DoE allows labor costs for preparing articles, presenting at conferences, and publication charges for print journals, although these costs do have to be included in the initial proposal budget. He thought that other agencies should follow DoE's lead in this area.

DoE has also recently begun to allow patent application costs up to a set limit. This is a very welcome initiative, according to Dr. Walsh, as the costs otherwise come directly out of the company's profit. At DoE, these can be charged as direct costs.

Dr. Walsh said that he believed DoE reviews in some cases rely too heavily on academic reviewers. He found that proposals could be downgraded if they did not include an academic partner. And while he did not object to partnering with academic institutions on occasion, he said that in most cases Vista Clara could have done a better job without them. In only a few of the seven to eight partnerships formed for SBIR/STTR did the university add real value.

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WOODRUFF SCIENTIFIC INCORPORATED[66]

Woodruff Scientific Inc. (WSI) is a private company located in Seattle, Washington. WSI was founded in 2005 by Dr. Simon Woodruff, with the objective of accelerating the development of commercial fusion energy, after working at Lawrence Livermore National Laboratory as postdoc. He received two SBIR awards in 2005-2006 which were sufficient to make the company a going concern.

Dr. Woodruff noted that these were very ambitious technically. The first award supported development of a set of products and services for the company. Although these awards were not in themselves designed to generate commercial products, they helped the company to develop capabilities that have sustained the company over the past ten years, according to Dr. Woodruff. These awards were followed in 2007-2008 by two follow-on Phase II awards focused on shortening the pathway to fusion power.

WSI owns a subsidiary, Woodruff Scientific Ltd. (WSL), based in Guildford, England. WSL was created to provide the same services and products as WSI, to clients in the European scientific community, but is currently dormant.

Products and Technologies

Capacitors and Pulse Forming Networks

WSI builds, tests, and installs pulsed power capacitor banks used in different applications. Capacitors are essentially batteries; both hold electricity, but capacitors can discharge it instantly (that is why capacitors are used in high intensity devices like defibrillators and particle accelerators). Capacitor banks are groups of capacitors that effectively act as a single capacitor, linked to instantly discharge all of their energy.

Capacitor banks are a type of Pulse Forming Network (PFN), a network of cells (capacitors in this case) that accumulate energy and can discharge it instantly. The time a PFN takes to unload its energy defines its power: One joule of energy stored within a capacitor evenly released over one second delivers peak power of 1 watt. However, if all stored energy were to be released in one microsecond (one millionth of a second), the peak power would be one megawatt (one million times greater). Making PFNs more efficient and hence higher energy could therefore have a substantial effect on particle accelerators and other high energy applications.

[66]Primary sources for this case study are the interview with Dr. Simon Woodruff, CEO, on August 19, 2015, and a review of the Vista Clara website (http://www.vista-clara.com) and related company documents.

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Capacitors and capacitor banks are used in many electrical products, so multiple designs are required. WSI has developed three capacitor bank designs: Modules A, B, and C. They also custom-make banks to client specifications.

Model A is a spark-gap switch bank with 12 kV (kilovolt), 4uF (microfarad) caps in a circular arrangement. Model B is a spark-gap switch bank with 12kV, 120uF caps, and a linear arrangement. Model C is a bank with IGBT switch, 8kV, 4700uF caps, and a linear arrangement. All three models are built to accommodate stand-alone applications.

Plasma

WSI produces custom magnetized plasma sources made to meet specific requirements in fusion energy sciences. These plasma sources require high field strengths, resistance to high currents and high voltages, and often Ultra-High Vacuum compatibility. Most WSI sources have been used for compact torus configurations (doughnut-shaped plasmas).

WSI is also developing Plasma-Material Interfaces: surfaces designed to handle the pressure and heat of a chamber containing plasma-based nuclear fusion. These chambers contain hydrogen atoms heated to high temperatures. Chamber walls have multiple layers: the first wall, several layers of blankets, and a vacuum.

In addition, WSI makes Controls, Data Access, and Communication (CODAC) systems. These are used to control plasma fusion devices. CODACs make physics measurements, control the plasma, and maintain safety during device operation. CODACs have four main components: sensors to measure a control parameter, an analogue to digital converter to convert signal into a form that can be stored or acted on, programming logic to control the variable, and output instrumentation for controlling the parameter. All magnetic fusion chambers use electrical pulses (some from PFNs), but current duration varies. Some fusion chambers use shorter electrical pulses, where a passive stabilization approach can contain the conditions (a well-designed wall, possibly with copper plates, bars, or in some cases a flux-conformal first wall, or flux conserver). For longer electrical pulses, the environment inside the chamber becomes more volatile, so active stabilization is required, and control systems must actively work to contain the conditions to protect Plasma-Material Interfaces. WSI intends to offer custom-made active stabilization for protection of Plasma-Material Interfaces.

Other Devices

WSI custom designs and sells a range of other devices related to fusion and plasma physics. These include:

- Spheromaks, which arrange plasma into a toroidal shape. WSI designed and created the Spheromak in use at Florida A&M University. The

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simple geometry and lack of complex magnets required for spheromaks may allow the construction of much simpler and less expensive fusion reactors.

- Dense Plasma Foci device, which uses a process called “pinching”—electromagnetic acceleration and compression—to produce short-lived plasma hot and dense enough to cause nuclear fusion and the emission of X-rays and neutrons.
- Inertial Electrostatic Confinement devices, usually spherical but sometimes cylindrical or linear. These devices use electricity to heat charged ions to fusion conditions.
- Magnetic field coils custom made for specific pulsed power applications in fusion energy. These coils are used in many products such as magnets that operate in the strongest man-made vacuums, used in settings like the Los Alamos National Laboratory’s Plasma Liner Experiment (PLX).

WSI is developing concepts and seeking further SBIR support for (amongst other areas) compact fusion neutron sources and plasma material interfaces:

- Fusion neutron sources which isolate neutrons, mainly used for nuclear medicine. WSI claims that their patent-pending fusion neutron sources would have a competitive advantage over traditional isotope production because their system is much more compact and independent of any nuclear fission source. Their fusion neutron is also easier to sell: it is illegal to export heavy-enriched uranium outside the United States, and nuclear medicine isotopes are usually developed using a process involving heavy-enriched uranium. WSI’s fusion neutron source is not illegal to export, and it supplants the need for heavy-enriched uranium in developing nuclear medicine isotopes. SBIR proposal was submitted this year.
- Flowing liquid metals could serve as an ideal Plasma-Material Interface (PMI): the surface is continually replenished so the damage sustained by solid PMI concepts will not require periodic maintenance. WSI works in collaboration with national laboratories on this subject, and will be resubmitting a Phase I application this year.

Consulting Services

High Performance Computing

WSI has capabilities in high performance computing which it provides on a consulting basis. Most of their computing is done at the National Energy

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Research Scientific Computing Center on HOPPER, the 67th ranked supercomputer in the world.[67] However, WSI also perform pre-production runs and private contracts in-house on a small computer cluster, and installs and configures operating systems, libraries, and applications for high performance computing applications.

Design and Engineering Services

WSI offers consulting in all stages of the device development process: concept design, engineering design, procurement, fabrication, installation, testing, and operations.

Business Model and Commercialization

Since the initial SBIR awards, WSI has primarily provided consulting services to the fusion research community. Dr. Woodruff is a well know figure in this sector, and his company provides highly specialized services for which there is significant but limited demand.

WSI works primarily to help other organizations deal with pressing physics problems, and to manage legacy code projects in particular where the lead scientist is retiring (e.g., a major project for a company in the UK).

The company focuses its marketing efforts on the fusion community, and attends one to two key conferences annually where sales leads are developed by word of mouth. Company staff also publishes technical papers that sometimes act as lead generators.

The opportunities facing the company can be divided into short term activities related to fusion products, and longer term opportunities related to fusion power itself. While venture firms and other investors are more interested in the scale of the latter, they find that the long timeline to market and the high level of technical and market risk are too formidable to overcome. Conversely, there is limited appetite among investors for shorter term fusion products that service more limited research markets.

Dr. Woodruff said that WSI is currently focusing on diversifying its offerings at the end of the current Phase II award, particularly in the area of 3D printing of metal components and instrumentation.

WSI and SBIR

WSI received a pair of Phase I awards starting in 2006 from DoE, both of which converted to Phase II. Dr. Woodruff noted that WSI has been in business for 10 years, and that all of its commercial offerings had been developed using SBIR funding. The initial awards had been followed more

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[67] See HOPPER description at https://www.nersc.gov/users/computational-systems/hopper/.

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recently by an additional Phase I in 2014, and Dr. Woodruff said that the company had recently been awarded a follow on Phase II for this project. Overall, WSI has to date received $2.3 million in DoE SBIR funding, and has been approved for a further $1 million award in 2015.

Commercialization Support

Dr. Woodruff said that the work of Foresight, a third party commercialization support provider under the DoE commercialization support program had been excellent. Foresight had worked hard to put WSI in contact with the CTO's of energy companies that could be possible partners, and in general had helped substantially with marketing strategy. Given that fusion energy is still so far from the market, Foresight was not able to help develop a business plan related to fusion products.

WSI had also participated in the DoE Dawnbreaker commercialization support program, and Dr. Woodruff said the program has been "world class." WSI had attended monthly during its Phase I award through lectures and teleconferences. The program encouraged him to ask key questions, and provided substantial help in developing the commercialization plan needed for the phase II application. WSI was now seeking non-executive directors to help with commercialization planning for the current Phase II award.

SBIR Issues and Recommendations

Dr. Woodruff noted that even though DoE was quite efficient in limiting the funding gap between Phase I and Phase II, the gap could be a major problem for small companies like WSI, and he urged the agency to close it still further if possible.

Dr. Woodruff said that commercialization had apparently become considerably more important at DoE; the commercialization plan had been of limited importance in 2007, but now seemed to be among the most important elements of the application.

The letter of intent required for all SBIR/STTR applications was primarily used by DoE to help determine which technical reviewers would be needed for the upcoming solicitation, Dr. Woodruff observed. He did not believe it provided particularly useful information to the applicant. Experienced PI's were well aware of the program managers for subtopics and could call for advice about possible applications. This access was however less available to more inexperienced PIs in Dr. Woodruff's opinion.

Dr. Woodruff had a number of concerns about the DoE SBIR review process. He noted that all reviews are anonymous although he sometimes learns of reviewer identities through his own contacts network. Reviewer comments rarely mention the commercialization prospects of the project, even though that

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was a significant part of the application. He did not think overall that reviewers really understood the aims or objectives of the SBIR program, and were often not sufficiently familiar with it overall to differentiate it from the very different and much larger projects typically funded through DoE. And typically, reviewers simply used standard DoE metrics for assessing proposals, which focused heavily on academic inquiry.

While contracting issues at DoE had been a major concern during the first SBIR award, experience with the program now meant that these were minimized, according to Dr. Woodruff. However, he observed that the agency used profit and loss for the previous three years to work out indirect rates; this led to determination of rates in a series of negotiations based on historical and current expenditures. More recently, WSI had used a pre-spending program available at DoE to fund work prior to Phase II initiation. WSI had used this for the 30 days prior to Phase II, but believed that small lines of credit (a practical reality of small businesses) prohibit the use for the full 90 days.

In conclusion, Dr. Woodruff said that the SBIR program is very well tuned to the real needs of the fusion community, although the limited funding available makes it difficult to build any sustainable business around the program that could be focused on DoE's long term needs.

XIA, LLC[68]

XIA, LLC (originally X-Ray Instrumentation Associates) is a private company founded in 1988 by William Warburton. The company invents, develops and markets advanced digital spectrometers for x-ray, gamma-ray, and other radiation detector applications in university research, national laboratories and industry. XIA is headquartered in Hayward, CA, and generates income from the design, development and marketing of spectrometers.

XIA was founded by Dr. Warburton as a sole proprietorship in 1988, following a career as a materials researcher, including a period employed at the Stanford Synchrotron Research Laboratory (SSRL) where he was a beamline scientist. He left when SSRL shut down for a year to make needed repairs, and founded XIA. The company emerged in earnest when Dr. Warburton's first Phase I SBIR award from NIH in 1991 was followed by Phase II and he hired employees to assist with the research.

The company became sustainable after the SBIR-funded development of electronics to control spectrometers, replacing the difficult to tune and expensive to maintain analog controls that had previously been industry standard.

XIA has also responded to DoE SBIR topics that call for tools related primarily to x-ray and nuclear electronics, according to Dr. Warburton. This

[68]Primary sources for this case study are the interview with Dr. William Warburton, CEO and founder, August 24, 2015, and a review of the XIA website (http://www.xia.com) and related company documents.

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approach worked moderately well for a period, providing sufficient revenue to support core company R&D operations. The resultant instruments generated sales to national and international labs, primarily of digital spectrometers for both synchrotron x-ray spectroscopy and for medium sized nuclear experiments. A typical product generated perhaps $200,000 annually in revenues for between 5 and 10 years.

Until recently, the company depended on SBIR or Broad Agency Announcement (BAA) funding to support its advanced R&D activities, using income derived from sales to support new product development. The company currently derives about 75 percent of its income from product sales, with the rest coming from SBIR and BAA grants and from commercial contracts.[69]

The company maintains research relationships with a broad range of academic, government, and corporate entities such as University of California, Davis; University of Texas at Austin; Michigan State University; Pacific Northwest National Laboratory; Los Alamos National Laboratory; Lawrence Livermore National Laboratory; Institute for Nuclear Physics (Germany); Radiation Protection Bureau; Health Canada; Alameda Applied Science Corporation; and IBM, to name only a few.

XIA Technologies

Radiation Data Detector Acquisition Systems

XIA develops digital data acquisition and processing systems for x-ray, gamma-ray, and other radiation detectors. The company's core technology combines digital signal processors (DSP) with field programmable gate arrays (FPGA) and—in various forms—has enabled XIA's portfolio of high speed spectrometers. The FPGA performs and manages data acquisition and storage (i.e., pulse detection, filtering, pileup inspection and coincidence inspection) and the DSP performs higher level post processing analysis (i.e., baseline correction and pulse shape analysis). The FPGA stores input signals to different parts of the system memory based on external interrupts generated by the sensors.

XIA has applied this architecture to a range of problems, in both industry and basic research. For example, XIA x-ray spectrometers have been used in metal sorting facilities: exposed to x-rays, different metals fluoresce in different parts of the spectrum, and XIA tools can identify which metals are fluorescing. DXP systems are then used to analyze the data from x-ray detectors and guide mechanical systems to sort the different types of scrap metal.

A nuclear application example is in low background gamma spectroscopy. In health physics, nuclear waste management, and nuclear materials and weapons security, the ability to detect small amounts of gamma

[69] XIA LLC, https://www.linkedin.com/company/xia-llc.

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radiation against background noise is vital. A XIA PXI-based processor can be used to veto signals that fail pulse shape or coincidence tests and so remove unwanted background events.

Other applications include handheld metal detectors using x-ray fluorescence, high-rate gamma spectroscopy for assaying spent nuclear fuel, discrimination of alpha, beta, gamma, and neutron radioactivity for detectors sensitive to the full range of radiation events, and synchrotron-based spectroscopy for characterizing materials properties in pharmaceutical, engineering, and material science.

Product Architectures

XIA's product line falls into three main digital data acquisition architectures: DXP (Digital X-ray Processor), DGF (Digital Gamma-ray Family), and Ultra-Lo (ultra-low background alpha particle detectors). They allow researchers to store, count, and analyze (height, shape, etc.) the analog signals captured by various different sorts of radiation sensors.

The full line of XIA products includes 13 different products. All can be further customized to particular customer needs. Depending on the system characteristics, XIA's data acquisitions systems range in price from $750 to $60,000.[70]

DXP

The DXP family of products implements XIA's core FPGA—DSP innovation. A field programmable gate array (FPGA) provides the front end shaping of the input signal steps generated by the sensor array and extracts their amplitudes in real time, while a digital signal processor provides corrections to improve energy resolution and stores the resultant values in a spectrum. Because the processing dead time per signal step in DXP processors is essentially zero, extremely high count rate (up to 1 million counts per second) are possible. The DXP architecture is available in products ranging from low cost OEM cards for handheld and bench top applications to PXI-based standalone modules for ultra high rate counting in, for example, synchrotrons or industrial control applications.

DGF

The DGF architecture extends the DXP architecture. With a FIFO memory for digital signal capture and a flexible, two-level triggering system that can span multiple modules, the DGF's digital signal processor—in addition to the pulse height measurement performed by DXP systems—can also perform

[70]XIA, LLC, https://www.linkedin.com/company/xia-llc.

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real time analysis of pulse shape. For example, incoming data can be processed and sorted according to pulse shape characteristics such a risetime or falltime. The DGF product line provides solutions to a wide range of extremely demanding pulse processing applications in the areas of nuclear physics, strip detectors, and very high resolution gamma-ray spectroscopy.

ULTRA-LO 1800

The Ultra-Lo 1800 is based on the DGF architecture and designed to measure the alpha particle emissivity of solid materials. Using dual channel pulse shape analysis, the Ultra-Lo 1800 is able to distinguish between alpha particles emitted by the sample under test and alpha particles generated elsewhere in the instrument. Rejecting the latter, the Ultra Lo 1800 can detect background rates as low as 0.0001 alpha particles/cm^2 per hour. This is a factor of 50 or more time lower than can be achieved using the current state of the art proportional counting systems. The Ultra Lo 1800 was developed to improve quality control processes in the semiconductor manufacturing industry with SBIR funding from NIST and DoE.[71]

Patents and Other Intellectual Property

XIA is not the assignee of any U.S. patents. However, the patents (listed in Table E-10) assigned to William Warburton, the CEO of XIA, are solely licensed to XIA and potentially applicable to any hardware or software developed by XIA.

SBIR/STTR

Between 1990 and 2013, SBIR/STTR funded 53 projects with XIA amounting to nearly $14.3 million. DoE provided approximately 76 percent, NIH 21 percent, and the Department of Transportation the remaining 3 percent. Annual funding was close to $1 million from SBIR/STTR between 2007 and 2012. It has since declined significantly.

In general, Dr. Warburton said that SBIR/STTR had been critical to the foundation and growth of the company. He said that these funds would not have been available from other sources.

However, Dr. Warburton had now come to believe that simply responding to available topics was not always in the company's best long term interest. The company's original business model had led to commercialization at

[71]SBIR Success Story: XIA, LLC, http://www.nist.gov/tpo/sbir/sbir-success-story-xia.cfm.

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TABLE E-10 Patents Assigned to William Warburton, CEO of XIA

Patent Number	Patent	Year
7,966,155	Method and apparatus for improving detection limits in x-ray and nuclear spectroscopy systems	2011
7,342,231	Detection of coincident radiations in a single transducer by pulse shape analysis	2008
7,065,473	Method and apparatus for improving resolution in spectrometers processing output steps from non-ideal signal sources	2006
6,732,059	Ultra-low background gas-filled alpha counter	2004
6,609,075	Method and apparatus for baseline correction in x-ray and nuclear spectroscopy systems	2003
6,590,957	Method and apparatus for producing spectra corrected for deadtime losses in spectroscopy systems operating under variable input rate conditions	2003
6,587,814	Method and apparatus for improving resolution in spectrometers processing output steps from non-ideal signal sources	2003
6,169,287	X-ray detector method and apparatus for obtaining spatial, energy, and/or timing information using signals from neighboring electrodes in an electrode	2001
6,125,165	Technique for attenuating x-rays with very low spectral distortion	2000
5,873,054	Method and apparatus for combinatorial logic signal processor in a digitally based high speed x-ray spectrometer	1999
5,870,051	Method and apparatus for analog signal conditioner for high speed, digital x-ray spectrometer	1999
5,774,522	Method and apparatus for digitally based high speed x-ray spectrometer for direct coupled use with continuous discharge preamplifiers	1998
5,684,850	Method and apparatus for digitally based high speed x-ray spectrometer	1997
5,646,488	Differential pumping stage with line of sight pumping mechanism	1997

SOURCE: U.S. Patent and Trademark Office.

approximately the level of agency SBIR investment, and so produced a steady-state business. But this ignored the opportunity cost to XIA of time spent simply maintaining the company instead of pursuing opportunities for greater growth.

While there are risks involved in taking a different approach, Dr. Warburton believes that the benefits can be considerably greater. He noted that, while a prototype of XIA's Ultra-Lo product emerged successfully following two small SBIR awards (DoE Phase I and NIST Phase I and Phase II), The company then invested approximately $3.5 million in the product over a period of ten years, to develop instruments with a much larger potential market selling for approximately $80,000 each. Market research suggested that XIA would sell 50 instruments a year, and he believes that the company will eventually reach that goal though perhaps not for some years. The company is currently waiting for NIST to produce a standard which will open the door to the marketplace.

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Until then, less sensitive existing instruments can be used and hence to do not need to be replaced.

Metrics. Dr. Warburton also observed that using commercialization as the only metric for assessing the success of SBIR awards was misguided. XIA has sold maybe $10 million to $20 million in instruments for synchrotrons. The latter cost $500 million each to build and perhaps $200 million annually in running costs, but a large percentage of the research undertaken with these systems required instruments such as XIA's. Synchrotron x-ray fluorescence experiments would not run at all without them, and overall productivity (and hence return on investment) would be a fraction of what it was today. Similarly, XIA develops instruments for measuring background radiation that have been used for validating compliance with nuclear testing-ban treaties—another market with minimal sales but large social impacts.

Topics. XIA is seeing fewer topics that are potentially viable under current SBIR evaluation procedures, according to Dr. Warburton. While DoE scientists continue to seek tools and instruments to assist in their research, these generally have extremely limited commercial potential and hence fail DoE's "return on investment" (as measured only by instrument sales) criteria. For example, one recent topic was clearly designed to develop an instrument for use within the four accelerators that exist worldwide. This has almost no commercial potential.

Dr. Warburton said that, in the main, DoE topic managers still appeared to view SBIR/STTR as a tax on their research funding, and so wish to use it to provide tools or technologies that could be used to further their own scientific interests and programs. They have no interest in commercial potential, and he saw no evidence that topics were reviewed for commercial potential before being published. More generally, it did not appear that topics were subject to significant screening or review.

Many DoE topics are highly specific, tuned to the specific technical needs of topic managers. The agency has now started adding broader topics and does occasionally fund them. XIA did win a Phase I for a broader topic, although it did not go to Phase II.

Commercialization review. Dr. Warburton sees a substantial disconnect between the demands of topic managers focused exclusively on science and their technical needs and commercialization review. He found it difficult to pass both reviews. His personal view was that small instrument sales that supported the national laboratories' missions were in the national interest and that this class of SBIR topic should be given evaluation criteria that appropriately reflect their values to those missions. Or, if the DoE only wants responses capable of large commercial returns, it should revamp its calls for proposals to bring them into conformance.

DoE now appears to require projections of sales quite far downstream. These future expected sales have to be large enough to recover the current SBIR

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investment plus provide an annual internal rate of return of 8 percent. This is a substantial hurdle, especially for products which are high risk and where markets are small—it was not clear to Dr. Warburton that any company providing high tech, low volume scientific instruments would ever meet this hurdle rate. He also wondered whether DoE has ever compared actual commercial outcomes in funded Phase II projects to the outcomes projected in the submitted commercialization plans in order to evaluate whether the present methodology actually has any predictive capability or is just an exercise in creative writing.

Review process. More generally, Dr. Warburton said that he had been an NIH SBIR reviewer and saw a number of features of the NIH process that might be beneficially adopted at other agencies. In particular, he believed that the face to face (or phone conference) meeting of the review panel provided a strong boost to the effectiveness of the review overall. In particular, the discussions between the reviewers quickly exposed the strengths and weaknesses of the arguments of both proposers *and* reviewers. At DoE the reviewers never connect, and as result reviewers can misunderstand the proposal—in both positive and negative ways—without having to justify their criticisms to their peers on the panel. In one particularly glaring case, XIA experienced a reviewer who was clearly commenting (negatively) on a non-XIA proposal.

Dr. Warburton also noted that there was no appeal process at DoE, and no possibility for resubmission (as at the NIH). He was therefore a strong proponent of the idea that companies be given an opportunity to respond (briefly—1 to 2 pages maximum) to reviewer comments before final decisions were made.

Operations. Dr. Warburton noted that the DoE payment system is excellent.

STTR

XIA has not had good experiences with the STTR program, Dr. Warburton said. For example, a collaboration with Brookhaven National Laboratory worked out poorly, with no accountability for the project at the lab. The project was developed to help measure carbon levels in the soil, focused on evaluating farming processes that could potentially remove carbon from the atmosphere. The Lab's main role was to develop a vehicle for safely moving the instrument, which included a neutron generator) across a field to be measured, but did not meet project objectives nor produce the vehicle within the time frame of the project.

National Labs have few incentives to cooperate fully with small businesses, Dr. Warburton observed. In the best of cases, the lab scientists involved saw STTR as a means of supporting their own research program, in exchange for providing the company with technical support. In other cases,

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though, lab staff saw the program simply as a means to generate funds and had no interest in commercial outcomes or even their partner's interests.

An ongoing collaboration with Lawrence Livermore National Lab (within the context of an SBIR grant) is proving more successful. It provided a link to a scientist whose life's work is aimed at moving his technology out into the world. He provided access to detectors and sources and lots of feedback. In exchange, XIA supplied him with next generation electronics for his experiments. The collaboration had now lasted 10 years, advanced the state of the art, and should be seen as quite successful.

XIA has not worked collaboratively with the national labs outside the SBIR/STTR program. It does provide customized instruments to lab staff, but on a contract basis. Sometimes this results in joint scientific publications. Dr. Warburton noted that each national lab had its own culture(s); XIA has worked quite successfully, for example, with Pacific Northwest National Lab generally, with a few departments at Lawrence Livermore National Lab, but essentially not at all with Lawrence Berkeley National Lab, even though it is the closest of the three.

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Appendix F

Annex to Chapter 5: Extended 2014 Survey Data

As noted in chapters 1 and 5, Congress mandated four goals for the Small Business Innovation Research (SBIR) program: (1) to stimulate technological innovation; (2) to use small business to meet federal research and development needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation; and (4) to increase private-sector commercialization derived from federal research and development.[1] The goals for the STTR program are to (1) stimulate technological innovation, (2) foster technology transfer through cooperative R&D between small businesses and research institutions, and (3) increase private-sector commercialization of innovations derived from federal R&D.[2] Chapter 5 and the extended data in this appendix provide an analysis of program outcomes related to the goals of stimulating technological innovation, using small business to meet federal research and development needs, increasing private-sector commercialization of federally funded research,[3] and fostering technology transfer through cooperative R&D between small businesses and research institutions. The approach analyzes outcomes as revealed primarily by the performance of Department of Energy (DoE) Phase II SBIR and STTR awards from fiscal year (FY) 2001 to FY 2010 based on data from the 2014 Survey carried out by the National Academies of Sciences, Engineering, and Medicine. This annex reports these data in greater detail and serves as a supplement to Chapter 5.

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[1]Small Business Innovation Development Act of 1982, P.L. 97-219, July 22, 1982.
[2]Small Business Administration, "About STTR," https://www.sbir.gov/about/about-sttr, accessed July 9, 2015. Only the first two objectives are embedded in the authorizing legislation, although there is little controversy about the importance of the third, which appears to have been added by the Small Business Administration (SBA) in drafting its governing Policy Guidance for the program.
[3]The second SBIR goal of using small businesses to meet federal research and development needs was also discussed to some extent in Chapter 2 (Program Management). The third SBIR goal of fostering the participation of women and minorities is the focus of Chapter 6.

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Most response data[4] for the 2014 Survey is reported at the project level. Some survey questions, however, collect company-level information (such as number of employees). In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged. Tables and figures with company-level data are marked as reporting the number and percentage of responding companies.

FOCUS ON COMMERCIALIZATION OUTCOMES

Although there are multiple statutory goals for the SBIR and STTR programs, subsequent legislation passed by Congress, as well as administrative policies pursued by DoE and the other major SBIR/STTR agencies, focus primarily on the commercialization of SBIR/STTR technologies.[5] Moreover, given that commercialization is among the more measurable outcomes of the SBIR/STTR programs, it has become a primary benchmark for program performance. The focus on commercialization, however, should not be allowed to obscure the requirement that the program meet all congressionally mandated objectives. This annex provides additional details of the commercial outcomes of the DoE SBIR/STTR programs, as well as quantitative outcome measures related to stimulating technological innovation.

APPENDIX OUTLINE

The remainder of this annex is broken into two sections: (1) Quantitative Survey Evidence that DoE Increased Commercialization and (2) Quantitative Survey Evidence that DoE Stimulated Technological Innovation.

QUANTITATIVE EVIDENCE THAT DOE INCREASED COMMERCIALIZATION

At DoE, the priority for the SBIR/STTR programs is to support the development and commercialization of technologies that will address the nation's energy needs. In contrast to DoD and NASA, it is not expected that SBIR/STTR technologies will be used by the agency itself, except for some projects used by the National Laboratories. Sales are primarily made into the domestic private sector.

Defining "Commercialization"

Several important conceptual challenges emerge when seeking to define "commercialization" for the purposes of the SBIR/STTR programs. Like

[4]Averaged survey response data is reported to the nearest whole number.
[5]SBA Section 1.(c) SBIR/STTR Policy Directive, October 18, 2012, p. 3.

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many apparently simple concepts, commercialization becomes progressively more difficult and complex as it is subjected to further scrutiny.[6] For example:

- Should commercialization include just sales or other kinds of revenue, such as licensing fees and funding for further development?
- What is the appropriate benchmark for sales? Is it any sales whatsoever, sufficient sales to cover the costs of awards, sales that lead to breaking even on a project, or sales that reflect a commercial level of success and viability? The latter at least would likely be different for each project in each company.
- Should commercialization include license fees and sales by licensees, which may be many multiples of the sales by the licensors?
- Should commercialization metrics focus only on formally recognized Phase III contracts,[7] or should they more widely cover follow-on sales and development activities even when not formally recognized as Phase III?

For the purposes of this study, the committee deployed a broad net to capture a range of data. Once acquired, these data were analyzed in a variety of ways to provide insights into this complex topic.[8] For example, a simple measure of the percentage of funded projects that reach the marketplace is not a conclusive indicator of commercial success.

In the private sector, commercial success over the long term requires profitability. However, in the short term, the path to successful 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.

SBIR/STTR Sales

Perhaps the single most used metric for assessing SBIR/STTR-type programs is sales by the company and/or licensee of products, processes, or services or other sales incorporating the technology developed during the surveyed project. Although we have earlier cautioned against overuse of this metric—and therefore employ a wide range of metrics in the current

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[6]Measurement of commercialization also raises questions about time needed to commercialize new technologies. For a discussion of this "commercialization lag," see Box A-1 in Appendix A. As noted separately in Appendix A, limiting the 2014 Survey to Phase II awards from no later than FY 2010 allowed two years for completion of the Phase II awards and an additional two years for commercialization, and this timeframe was consistent with the 2005 Survey.

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

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

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assessment—sales is still an important consideration.[9] While sales is a legitimate indicator of progress toward commercialization, it is not a reliable measure that commercial success has occurred.

Reaching the Market

The first survey question in this area concerns reaching the market: Did the project generate any sales, and if not, are sales expected (a necessary question given the long cycle time of some projects)? Responses are summarized in Table F-1. Forty-nine percent of all respondents reported some sales, and another 23 percent expected sales in the future. The percentage reporting sales to date was lower than for the 2005 Survey of SBIR award winners carried out by the National Academies, which found 57 percent of respondents reporting sales.[10] Respondents expecting sales in the future increased from 19 percent for the 2005 Survey to 23 percent for the 2014 Survey.

Amount of Sales

Simply identifying the percentage of projects reaching the market is an important metric to signal that commercial activity has begun, but as was noted

TABLE F-1 Status of Sales to Date for DoE SBIR/STTR Projects, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
No sales to date	51	48	67
No sales to date nor are sales expected	28	28	23
No sales to date, but sales are expected	23	20	43
Any sales to date	49	52	33
Sales of product(s)	38	39	30
Sales of process(es)	4	5	
Sales of services(s)	22	23	17
Other sales (e.g., rights to technology, licensing, etc.)	6	6.8	
N (Number of Respondents)	251	221	30

NOTE: Respondents could report multiple types of sales for a single project, so the types of sales do not sum to "Any sales to date."
SOURCE: 2014 Survey, Question 32.

[9]Similar cautions can be found in National Research Council, *An Assessment of the Small Business Innovation Research Program at the National Institutes of Health,* p. 81.
[10]The results of the National Academies' 2005 Survey of SBIR award recipients are reported in National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Washington, DC: The National Academies Press, 2009, p. 143.

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SBIR/STTR at the Department of Energy

previously, it is not sufficient to indicate commercial success. It is also important to understand the volume and distribution of sales and how sales revenue relates to the costs incurred in generating the revenue. The survey asked those respondents who reported some sales of the project-related technology to report the amount of sales. Overall, 32 percent reported sales of at least $1 million (see Table F-2).

Markets by Sector

Because DoE is not itself a significant market, it is not surprising that the largest market reported was for sales made to the domestic private sector. Export markets accounted for an average of 24 percent of sales (see Table F-3). These figures are very similar to those for the 2005 survey.[11] An average of six percent of reported sales were to DoE. Eleven percent were sales to DoD or DoD contractors, a much higher percentage than in the National Academies' 2008 report.[12]

Employment

The 2014 Survey asked respondents both about the number of company employees at the time of the award and at the time of the survey. As shown in Table F-4 and F-5, although 47 percent of responding companies had fewer than 10 employees at the time of award, this figure dropped to 20 percent at the time

TABLE F-2 Distribution of Total Sales Dollars, by Range and Phase, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Total Sales Dollars	Overall	SBIR Awardees	STTR Awardees
None (0)	3	3	0
1-99,999	22	22	20
100,000-499,999	30	29	40
500,000-999,999	14	13	30
1,000,000-4,999,999	23	24	10
5,000,000-9,999,999	3	3	0
10,000,000-19,999,999	4	5	0
20,000,000-49,999,999	2	2	0
50,000,000 or more			
Mean (Thousands of Dollars)	2,314	2,468	655
Median	300	300	300
N (Respondents Reporting Sales)	118	108	10

SOURCE: 2014 Survey, Question 34.

[11]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, p. 145.
[12]Ibid.

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of the survey. The median at the time of award was 10 employees, but the mean size grew significantly from 23 at the time of award to 29 at the time of the survey. Among the 6 percent of firms to report at least 100 employees at the time of the survey, some had grown substantially.

TABLE F-3 Average Percentage of Project Sales by Markets Sector, Reported by 2014 Survey Respondents

	Mean Value (Percent) Reported by Respondents that Reported Sales		
	Overall	SBIR Awardees	STTR Awardees
Domestic private sector	39	39	38
Export markets	24	23	30
Department of Defense (DoD)	6	5	15
NASA	1	1	1
Prime contractors for DoD	5	5	0
Prime contractors for NASA	1	1	0
Department of Energy	6	6	11
Other federal agencies	8	8	3
State or local governments	2	2	0
Other (Specify below, if applicable)	10	11	4
N (Respondents Reporting Sales)	120	110	10

NOTE: For this question, each respondent reported a percentage distribution. The values above are calculated by deriving the mean value for all the responses for each category.
SOURCE: 2014 Survey, Question 36.

TABLE F-4 Number of Employees at Time of Award, Reported by 2014 Survey Responding Companies

	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
1	3	4	0
2	7	7	7
3 or 4	18	17	29
5 to 9	19	19	17
10 to 19	19	18	26
20 to 49	21	22	11
50 to 99	9	8	11
100 or more	4	5	1
Mean	23	24	17
Median	10	10	9
N (Number of Responding Companies)	126	110	15

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged.
SOURCE: 2014 Survey, Question 14.

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TABLE F-5 Number of Employees at Time of Survey, Reported by 2014 Survey Responding Companies

	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
0	3	1	20
1	2	2	0
2	6	6	0
3 or 4	9	9	7
5 to 9	23	22	26
10 to 19	23	23	28
20 to 49	19	21	8
50 to 99	9	9	11
100 or more	6	7	1
Mean	29	30	17
Median	10	10	9
N (Number of Responding Companies)	127	111	15

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the same company were averaged.
SOURCE: 2014 Survey, Question 14.

Further Investment

The ability of SBIR/STTR projects and companies to attract further investment has traditionally been a defining metric for SBIR/STTR outcomes.[13] There has also been interest in the sources of further investment for high-tech innovation.

Overall, as shown in Table F-6, 78 percent of respondents indicated that their company received further investment in the project-related technology. As with prior surveys, there is substantial skew in the amount of additional funding received. Fifty-nine percent of respondents reported receiving some further investment but less than $1 million, and 1 percent reported receiving $5 million or more. Table F-7 shows the sources of further project investments reported by respondents to the 2014 Survey. Of those projects that received additional funding, 39 percent received funding from U.S. private-sector sources, 40 percent from non-SBIR/STTR federal sources, and 20 percent from other external sources. Seventy-five percent received additional funding from internal sources. Overall, 2 percent of those that received additional funding received venture capital funding and 5 percent received funding from angel and other private equity investors. Twenty percent of projects received strategic investments from U.S. partners and 2 percent received strategic investments from strategic foreign partners.

[13]See National Research Council, *An Assessment of the SBIR Program*, Washington, DC: The National Academies Press, 2008.

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TABLE F-6 Additional Funding by Amount to Surveyed Projects, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Amount of Additional Project Funding	Overall	SBIR Awardees	STTR Awardees
None (0)	22	23	15
1-99,999	25	23	37
100,000-499,999	23	24	19
500,000-999,999	11	11	15
1,000,000-4,999,999	18	18	15
5,000,000-9,999,999	1	1	
10,000,000-19,999,999	0	1	
20,000,000-49,999,999			
50,000,000 or more			
Mean (Thousands of Dollars)	814	836	630
Median (Thousands of Dollars)	300	300	50
N (Number of Respondents)	245	218	27

SOURCE: 2014 Survey, Question 30.

Mergers and Acquisitions

SBIR/STTR firms often advance technologies toward commercialization through mergers or other company-level activities. As shown in Table F-8, 53 percent of responding companies indicated that they had not been acquired or merged, had not entered into a strategic partnership with a major industry player, had not implemented or planned an initial public offering (IPO), and had not established a spin-off. Conversely, 30 percent had entered into a strategic partnership with a major industry player, 19 percent had established one or more spin-off companies, and 8 percent had been acquired by or merged with another firm.

Commercialization Assistance

DoE has provided commercialization training for SBIR/STTR awardees for a number of years, through arrangements with third-party providers (see Chapter 3, “Program Initiatives”). Overall, 42 percent of respondents received commercialization assistance in connection with the surveyed SBIR or STTR award: about two-thirds of these from Dawnbreaker and most of the remaining third from Foresight.[14] Of those reporting commercialization assistance, 37 percent rated the assistance as valuable or extremely valuable. Conversely, about one-quarter of participants rated the assistance as not very valuable or not at all valuable. (See Table F-9).

[14] 2014 Survey, Question 49. N (Number of Respondents) = 100.

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TABLE F-7 Sources of Further Project Investment, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Sources of Further Project Investment	Overall	SBIR Awardees	STTR Awardees
Non-SBIR/STTR Federal Funds	40	40	39
Private Investment: U.S. Sources	39	41	23
Venture capital (VC)	2	2	0
U.S. angel funding or other private equity investment (not VC)	5	6	0
Friends and family	3	3	0
Strategic investors/partners	20	20	15
Other sources	15	17	8
Foreign Investment	2	2	0
Financial investors	1	1	0
Strategic investors/partners	2	2	0
Other External Sources	20	17	39
State or local governments	12	11	19
Research institutions (such as colleges, universities or medical centers)	9	8	19
Foundations	0	0	0
Internal Sources	75	75	73
Your own company (Including money you have borrowed)	72	72	73
Personal funds	8	9	4
N (Number of Respondents Reporting Additional Project Investment Funding)	195	169	26

NOTE: Respondents were asked to select applicable categories and subcategories of sources of further investment.
SOURCE: 2014 Survey, Question 31.

The 2014 Survey also asked whether the company has at least one full-time staff person for marketing. In another metric of the extent to which responding companies focus on marketing, less than one-half of responding companies reported employing at least one full-time marketing staff member.[15]

Overview: Commercialization

Data from the 2014 Survey provide useful insight into the commercialization record of SBIR/STTR companies at DoE, on a number of dimensions.

[15]2014 Survey, Question 13. N = 128.

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TABLE F-8 Company-Level Changes, Reported by 2014 Survey Responding Companies

	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
Entered into strategic partnership with major industry player	30	29	33
Established one or more spin-off companies	19	20	7
Acquired by/merged with another firm	8	8	6
Made an initial public offering	2	2	0
Planning to make an initial public offering in the next 2 years	0	0	0
None of the above	53	52	59
N (Number of Responding Companies)	131	114	16

NOTE: Responses do not sum to 100 percent because respondents could select more than one answer.
SOURCE: 2014 Survey, Question 11.

TABLE F-9 Value of Commercialization Assistance, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Extremely valuable	1	12	0
Very valuable	27	30	7
Somewhat valuable	40	35	67
Not very valuable	19	17	27
Not at all valuable	5	6	0
N (Number of Respondents Reporting Receiving Commercialization Assistance in Connection with Surveyed SBIR/STTR Award)	101	86	15

SOURCE: 2014 Survey, Question 51.

The data show that, among survey respondents, *a substantial percentage of projects achieve sales of products or services and/or the receipt of further investment.* Forty-nine percent of respondents reported sales from the awarded project. A further 23 percent expected sales in the future. Given the relatively short time between the award date for some of these awards and the survey date, and the long time-to-market for many products, these expectations are not unreasonable. DoE did not provide independent data against which the validity of the survey responses can be cross-checked.

Overall, *the scale of sales is very limited*. Sixty-nine percent of respondents with project-related revenues reported sales of $1 million or less.

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No respondents reported sales of more than $50 million, and 6 percent of respondents reported sales of $10 million to under $50 million.

Further investment is an important metric for commercialization potential. Many Phase II projects are not yet ready for the marketplace at the end of the award period, but 78 percent of respondents reported additional project-related investment, mostly for amounts of less than $1 million. One percent of respondents reported $5 million or more in further investment and none reported more than $20 million. The sources of this additional funding varied. Forty percent of respondents reported non-SBIR/STTR federal sources, and 39 percent reported U.S. private sector sources (including 2 percent for venture capital and 5 percent for angel investment). U.S.-based strategic investors were also important (20 percent).

The scope of commercialization—that is, the share of firms who either commercialize directly or find additional funding on the path to commercialization—is substantial and meets congressional objectives. However, the small scale of commercialization is less positive. This suggests that the type of projects being funded may not be designed for large-scale commercialization, a point discussed in detail in Chapter 2. Overall, these data support the committee's view that SBIR/STTR funding is associated with outcomes that meet congressional mandates for commercialization. Better outcomes data from the agency would allow for a more definitive conclusion and a more detailed understanding of the links between agency programs and outcomes.

QUANTITATIVE EVIDENCE THAT DOE STIMULATED TECHNOLOGICAL INNOVATION

The committee also considered the question of whether DoE's SBIR and STTR program stimulated technological innovation. The congressionally mandated objective for the SBIR and STTR programs to "stimulate technological innovation" is often equated with 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; some innovative companies prefer to keep their technology secret or to rely on first-mover advantages or other market-based leverage to defend their technologies. Still, standard metrics of knowledge outcomes provide at least a starting point for quantitative analysis. Consequently, the survey addressed different intellectual property (IP)-related metrics.[16] This section of the appendix examines a number

[16]The values of patents, trademarks, copyrights, and peer-reviewed papers as metrics vary. Any unique item, painting, photo, or music score can be copyrighted for a modest fee. Trademarks include more processing, because registered trademarks need to be unique in their field so as to not 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 highly valued outside of academia as inside, although company executives state in interviews that publications help to attract and keep high-quality staff and also provide additional validation for (and publicity about) their technology.

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of measures to examine how the DoE SBIR and STTR programs have stimulated technological innovation—first examining knowledge outcomes such as patents and then returning to the broader topic of fostering innovative companies.

Knowledge Outcomes

Patents

Although patents and peer-reviewed papers are not the only metrics of knowledge development and dissemination by small high-tech companies, they offer a useful starting point. Patents are to some degree the life blood of high-tech firms. Table F-10 shows the overall number of patents that responding companies reported as being related to any SBIR or STTR award they have received (not just DoE SBIR or STTR awards). Overall, 68 percent of responding companies received at least one such patent, and 17 percent reported receiving 10 or more such patents. With regard to patents related to the specific award being surveyed, Table F-11 shows that 39 percent of respondents reported receipt of at least one patent related to the surveyed award, and 2 percent reported receipt of five or more related patents.

Copyrights and Trademarks

Related indicators of the creation of intellectual capital include copyrights and trademarks. Nine percent of respondents reported receiving a

TABLE F-10 Number of Patents per Company Related to All Company SBIR/STTR Awards, Reported by 2014 Survey Responding Companies

	Percentage of Responding Companies		
Number of Patents	Overall	SBIR Awardees	STTR Awardees
0	32	34	14
1	8	9	0
2	12	11	16
3	10	9	18
4	8	7	18
5 to 9	14	13	22
10 or more	17	17	12
1 or more	68	66	86
Mean	6	6	5
Median	2	2	4
N (Number of Responding Companies)	123	109	14

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
SOURCE: 2014 Survey, Question 12.

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TABLE F-11 Patents Awarded Related to Surveyed Project, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Number of Patents	Overall	SBIR Awardees	STTR Awardees
0	61	62	55
1	22	21	36
2	8	9	0
3 or 4	7	7	9
5 to 9	1	1	0
10 or more	1	1	0
1 or more	39	38	46
N (Number of Respondents)	206	184	22

SOURCE: 2014 Survey, Question 38.

trademark related to the surveyed project, and only 4 percent received a copyright related to the surveyed project.[17]

Peer-reviewed Publications

Publications in peer-reviewed journals and conference proceedings are a standard method for disseminating scientific knowledge. As with the first-round assessment by the National Academies, some case study interviewees (e.g. Creare) noted that publication in peer-reviewed journals was an essential part of the firm's work.[18]

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

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

The survey therefore also addressed peer-reviewed publications. As shown in Table F-12, 73 percent of SBIR/STTR respondents overall and 88 percent of STTR respondents indicated that at least one article had been published in a scientific publication for the technology developed as a result of the surveyed project. Thirty-nine percent overall reported publishing three or more such articles.

[17]2014 Survey, Question 38.
[18]National Research Council, *An Assessment of the SBIR Program at the Department of Energy*, Appendix D.

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TABLE F-12 Peer-Reviewed Scientific Publications Related to the Surveyed Project, Reported by 2014 Survey Respondents

Number of articles published in scientific publications for the technology developed as a result of the project.	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
0	27	29	12
1	17	17	19
2	16	16	15
3 or 4	17	18	12
5 to 9	14	13	27
10 or more	8	7	15
1 or more	73	71	88
Mean	7	7	4
Median	2	2	3
N (Number of Respondents)	210	184	26

SOURCE: 2014 Survey, Question 38.

Links to Research Institutions

The survey included a number of questions about the use of research institution staff and facilities on the surveyed project. As shown in Table F-13, nearly one-half of all SBIR/STTR respondents and nearly all STTR respondents reported an RI connection of some kind. Looking at the numbers in more detail, 10 percent of STTR respondents and 1 percent of all respondents reported that the PI was a RI faculty member. STTR respondents were also more likely than than respondents overall to report that the technology was licensed from the RI (13 versus 5 percent) and that the technology was originally developed at the RI by a project team member (30 versus 9 percent). Box F-1 describes a workshop that the committee convened to address a range of issues related to university-SBIR linkages. Linkages to university is an important component in examining evidence that DoE "stimulated technological innovation," a goal of both the SBIR and STTR programs. University connections can also benefit SBCs by giving access to technical expertise.

Respondents were also asked to identify the research institutions with which they worked in various capacities on the surveyed project. Although the type of help varied widely, some universities were mentioned by a number of respondents. Overall, 79 different RIs were identified for 148 projects. RIs mentioned by two or more respondents are listed below in Table F-14 (see Appendix D for the complete list of research institutions that were mentioned). Some of the names on this list are large state universities, a number of which have in recent years focused on technology transition as well as basic research. We believe these data provide a preliminary indication of the connections between specific universities, university systems, national laboratories, and the DoE SBIR/STTR programs.

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BOX F-1
SBIR and the University Connection

When the SBIR was created in the early 1980s, many universities strongly objected to the program, seeing it as a source of competition for federal R&D funds. This perception of program has significantly evolved over the past decades. In the commercialization-sensitive environment created by the Bayh-Dole Act, SBIR and STTR awards are increasingly seen as a source of early-stage financial support for promising ideas arising from university laboratories. Further, SBIR and STTR are seen as effective tools to help universities directly address new missions in technology commercialization and regional development.

To explore this issue, the committee convened a workshop on February 5, 2014, on *Commercializing University Research: The Role of SBIR and STTR*. The committee revisited this issue again in its April 12, 2016 workshop on *SBIR and the Challenge of Commercialization*. These meetings revealed that universities use SBIR and STTR as tools to lower risks and provide incentives to their faculty to create startups and to commercialize their federally funded university research.

Jack Miner of the University of Michigan, speaking at the 2016 meeting, posted data showing that counties in Michigan with public research institutions that receive SBIR/STTR funds create the most technology companies and also create the most technology jobs. For this reason, he noted, the University of Michigan has "embraced" SBIR and STTR as a way of stimulating startups.

Speaking at the 2014 meeting, Barry Rosenbaum of the University of Akron Research Foundation noted that his institution uses SBIR to advance its mission of commercialization and regional development. It encourages and supports faculty to seek SBIR awards and helps them find commercial partners to bring new products to market.

Similarly, Jane Muir of the University of Florida, speaking at the 2014 meeting, noted that the UF Tech Connect program conducts SBIR workshops and other training programs, providing essential technical knowledge for early stage companies, including—particularly—women entrepreneurs.

The value of these partnerships is also reflected in the case studies of the firms profiled in Appendix E of this report. Adelphi Technology Inc., for example, has worked with the University of Florida and other research institutions that are seeking ways to bring their technology to market. In some cases, Adelphi has identified opportunities. In others—for example a recent STTR project—the driver is the university where the researcher is the PI. Another case study company, Calabazas Creek Research, is partnering with North Carolina State University by tapping into university expertise and equipment within a Phase II STTR award.

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These complementarities notwithstanding, some speakers and case study companies acknowledged the challenges involved in managing a successful partnership. These include working through administrative details of the company-university collaboration to assure smooth working relationships, sorting out who pays for what and who owns what, and supporting faculty that are not skilled in the technology commercialization aspects of SBIR/STTR programs.

TABLE F-13 Connections to Research Institutions (RIs), Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
The PI for this project was at the time of the project an RI faculty member	1	0	10
The PI for this project was at the time of the project an RI adjunct faculty member	2	2	3
Faculty member(s) or adjunct faculty member(s) worked on this project in a role other than PI	29	26	47
Graduate students worked on this project	25	21	50
The technology for this project was licensed from an RI	5	4	13
The technology for this project was originally developed at an RI by one of the participants in this project	9	6	30
An RI was a subcontractor on this project	35	29	77
None of the above	50	57	7
N (Number of Respondents)	244	214	30

NOTE: Numbers do not sum to 100 percent because multiple responses were permitted.
SOURCE: 2014 Survey, Question 71.

Finally, as shown in Table F-15 68 percent of companies responding to the survey indicated that at least one founder had an academic background, and 31 percent of responding companies reported that at least one founder was most recently employed by a research institution (see Table F-16).

SBIR/STTR Fostering Innovative Companies

Technological innovation can be stimulated by fostering innovative companies. The SBIR/STTR programs have a range of effects on companies

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which affect their ability to work within the innovation ecology of the agency or more generally. In addition, data about companies can help to define the technological space in which the SBIR/STTR programs operate. In addition, a review of the SBIR/STTR share of overall company activities can provide insights into the degree of dependence on SBIR/STTR for individual companies.

Impact on Company Formation

SBIR/STTR can have a profoundly catalytic impact on company

TABLE F-14 Research Institutions Mentioned by Two or More 2014 Survey Respondents

	Number of Mentions
Lawrence Berkeley National Laboratory	10
Brookhaven National Laboratory	6
Fermi National Accelerator Laboratory	5
Argonne National Laboratory	4
University of California, Los Angeles	4
University of Colorado	4
The Ohio State University	4
University of Colorado	3
Stanford Linear Accelerator Center	3
University of Illinois	3
University of Maine	3
Thomas Jefferson National Accelerator Facility	2
Boston College	2
Case Western Reserve University	2
Montana State University	2
Georgia Institute of Technology	2
University of Texas	2
University of California, Berkeley	2
Florida State University	2
Illinois Institute of Technology	2
University of Massachusetts, Lowell	2
Massachusetts Institute of Technology	2
Arizona State University	2
University of Michigan	2
Pacific Northwest National Laboratory	2
Princeton Plasma Physics Laboratory	2
Old Dominion University	2

SOURCE: 2014 Survey, Question 72.

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formation. Twelve percent of companies responding to the 2014 Survey were founded because of the SBIR/STTR programs, and a further 33 percent were formed in part because of the program (see Table F-17).

SBIR/STTR Share of R&D Effort and Company Revenues

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

TABLE F-15 Number of Academic Founders, Reported by 2014 Survey Responding Companies

Number of Founders with an Academic Background	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
0	32	31	40
1	40	40	42
2	17	17	16
3	5	6	1
4	4	4	0
5 or more	2	3	0
Mean	1	1	1
Median	1	1	1
N (Number of Responding Companies)	125	110	15

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
SOURCE: 2014 Survey, Question 5.

TABLE F-16 Most Recent Previous Employment of Founders, Reported by 2014 Survey Responding Companies

Most recent employment of the company founders prior to founding the company	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
Other private company	68	68	69
Research institution	31	31	35
FFRDCs or National Laboratories	9	8	15
Government	5	6	0
Other	8	9	0
N (Number of Responding Companies)	133	117	16

NOTE (1): In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
NOTE (2): Values do not sum to 100 percent because multiple responses were permitted.
SOURCE: 2014 Survey, Question 6.

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engineers) was devoted to SBIR- or STTR-funded projects. Overall, 40 percent of respondents indicated that 10 percent or less of the company's total R&D effort was devoted to SBIR or STTR activities during the most recent fiscal year (at the time of the survey), and 23 percent indicated greater than one-half (see Table F-18).

These data closely correspond to responses from another survey question, which (again from the perspective of the time of the survey) asked what percentage of company revenues during the most recent fiscal was accounted for by SBIR/STTR funding. As shown in Table F-19, 27 percent of companies reported receiving zero SBIR or STTR funding during the most recent completed fiscal year, and 25 percent reported receiving greater than 50 percent of their revenue from SBIR or STTR. Two percent of companies were entirely dependent on SBIR/STTR funding.

TABLE F-17 SBIR/STTR Impact of SBIR/STTR Programs on Company Formation, Reported by 2014 Survey Responding Companies

Was the company founded because of the SBIR/STTR Program?	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
Yes	12	11	20
In part	33	32	44
No	55	57	36
N (Number of Responding Companies)	133	117	16

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
SOURCE: 2014 Survey, Question 7.

TABLE F-18 Percentage of R&D Effort Funded by SBIR/STTR for Most Recent Fiscal Year, Reported at Time 2014 Survey by Responding Companies

Percentage of man-hours of company scientists and engineers devoted to SBIR/STTR activities	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
0	25	27	13
1-10	15	13	26
11-25	14	14	11
26-50	23	24	16
51-75	11	11	12
76-100	12	11	22
N (Number of Responding Companies)	128	113	15

NOTE: In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
SOURCE: 2014 Survey, Question 10.

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TABLE F-19 Percentage of Company Revenues from SBIR/STTR Funding for Most Recent Fiscal Year, Reported at Time of 2014 Survey by Responding Companies

Percentage of Company Revenues that was SBIR/STTR Funding	Percentage of Responding Companies		
	Overall	SBIR Awardees	STTR Awardees
0	27	29	13
1-10	18	18	20
11-25	14	15	12
26-50	17	17	18
51-75	13	12	19
76-99	10	9	18
100	2	2	0
	100	100	100
N (Number of Responding Companies)	129	114	15

NOTE (1): In cases where company information, as opposed to individual project information, was collected, multiple responses from the the same company were averaged.
NOTE (2): Because survey sample includes inactive awards, some respondents reported zero SBIR/STTR revenues for the most recent fiscal year.
SOURCE: 2014 Survey, Question 9.

Prior Use of SBIR/STTR Awards

Although a more linear interpretation of the process of innovation would imply that ideas are tested in Phase I, prototyped in Phase II, and commercialized in Phase III, many projects require multiple iterations, sometimes restarting with an earlier phase, or multiple efforts are needed to meet specific problems.

The 2014 Survey asked respondents to indicate how many SBIR/STTR awards they had received that were related to the project and technology being surveyed. As shown in Table F-20, 31 percent of respondents reported receiving no other related SBIR/STTR Phase I award related to the surveyed project. Twenty-two percent received at least three other related Phase I awards. Relatedly, Table F-21 shows that slightly less than three-quarters of respondents reported receiving one or more Phase II awards related to the project, and 12 percent of respondents reported receiving at least three. These data support the view that innovative products emerge from clusters of activity, rather than from simple straight line development from Phase I to Phase II to commercialization.

Long-term Impacts on Companies Receiving SBIR/STTR Awards

Although SBIR/STTR awards have direct effects on specific projects, they can also have a longer-term effect on the trajectory of company development, creating capacity and in some cases providing a critical input that

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TABLE F-20 Additional SBIR or STTR Phase I Awards Related to the Surveyed Project, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Number of Awards	Overall	SBIR Awardees	STTR Awardees
0	31	32	23
1 or more	69	68	77
1	32	32	37
2	15	14	23
3 or 4	14	15	10
5 to 9	6	6	3
10 or more	2	2	3
Mean	2	2	2
Median	1	1	1
N (Number of Respondents)	236	206	30

SOURCE: 2014 Survey, Question 39.

TABLE F-21 Additional SBIR or STTR Phase II Awards Related to the Surveyed Project, Reported by 2014 Survey Respondents

	Percentage of Respondents		
Number of Awards	Overall	SBIR Awardees	STTR Awardees
0	37	39	25
1 or more	63	61	75
1	35	33	50
2	16	17	14
3 or 4	9	9	7
5 to 9	2	2	0
10 or more	1	1	4
Mean	1	1	1
Median	1	1	1
N (Number of Respondents)	228	200	28

SOURCE: 2014 Survey, Question 39.

transforms long-term outcomes. The survey asked respondents about these impacts directly and results are summarized in Table F-22. Respondents reported an overwhelmingly positive impact. Overall, 96 percent of respondents reported a positive effect, and 61 percent reported a highly positive or transformative impact. Of the 192 companies responding to the survey question, two reported negative effects.

Additional Company-Level Information: Industry Sector

The 2014 Survey asked about other potentially significant aspects of the company. Previous analyses of SBIR/STTR did not address a potentially

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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 for software than for materials or medical devices. Interestingly, only 53 percent of SBIR/STTR awarded at DoE reported that they worked in the energy sector. Table F-23 shows the distribution of responses by sector.

This question was designed to provide an approximate map of activities by sector. There is considerable overlap between some categories, and respondents would have substantial leeway to define sectors differently, so these findings should be viewed as highly preliminary. A few key points emerge:

- Just over half of companies responding are primarily working in energy technology.
- Almost as many (48 percent) report working in engineering, with the majority of these in scientific instruments
- About a quarter are working in aerospace and defense
- Within the energy sector, a quarter are in other unspecified areas, 20 percent are in energy efficiency, 18 percent are in renewable energy, and 11 percent in energy storage and distribution.

PI Demographics

The committee observed that the age profile of PIs within the program may need to shift with the aging of the baby boomers. Accordingly, the 2014 Survey asked the respondents to report their age at the time of the award. The age distribution is presented in Table F-24. Eight percent of respondents reported being younger than 35 at the time of the award, and the median age at the time of award reported by respondents was 47. Twelve percent of respondents were age 60 or older at the time of award.

TABLE F-22 Long-term Impacts on Recipient Companies, Reported by 2014 Survey Respondents

	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Had a highly positive or transformative effect	61	60	67
Had a positive effect	35	35	30
Had no effect	4	5	0
Had a negative effect	0	0	3
Had a highly negative or disastrous effect	0	0	0
Number of Respondents	248	218	30

SOURCE: 2014 Survey, Question 57.

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TABLE F-23 Distribution of Responses by Sector Phase, Reported by 2014 Survey Respondents

	Percentage of Responses		
	Overall	SBIR Awardees	STTR Awardees
Aerospace and Defense	23	23	23
Aerospace	12	12	10
Defense-specific products and services	17	17	16
Energy and the Environment	53	54	48
Renewable energy production (solar, wind, geothermal, bio-energy, wave)	18	17	19
Energy storage and distribution	11	11	13
Energy efficiency	19.6	20	16
Other energy or environmental products and services	25	25	23
Engineering	48	46	55
Engineering services	9	10	7
Scientific instruments and measuring equipment	29	27	42
Robotics	1	0	3
Sensors	13	14	10
Other engineering	10	10	10
Information Technology	8	6	16
Computers and peripheral equipment	1		10
Telecommunications equipment and services	2	1	10
Business and productivity software	1	1	0
Data processing and database software and services	1	1	0
Media products (including web-, print- and wireless-delivered content)	0	0	0
Other IT	2	2	3
Materials (including nanotechnology for materials)	19	19	19
Medical Technologies	14	15	10
Pharmaceuticals	1	0	3
Medical devices	7	7	7
Biotechnology (including therapeutic, diagnostic, combination)	3	3	0
Health IT (including mobile, big data, training modules)	0	0	0
Research tools	8	8	3
Education materials	0	0	0
Other medical products and services	3	3	3
Other (please specify)	15	13	23
N (Number of Respondents)	255	224	31

NOTE: Values do not sum to 100 percent because multiple responses were permitted.
SOURCE: 2014 Survey, Question 21.

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TABLE F-24 Age of Principal Investigator at Time of Award, Reported by 2014 Survey Respondents

Age of Principal Investigator at Time of Award	Percentage of Respondents		
	Overall	SBIR Awardees	STTR Awardees
Under age 25	0	0	0
25 to 29	1	0	3
30 to 34	7	6	10
35 to 39	14	15	3
40 to 44	16	17	10
45 to 49	16	17	13
50 to 54	17	16	23
55 to 59	18	18	20
60 to 64	6	5	10
65 or older	6	5	7
Mean	48	48	50
Median	47	47	52
N (Number of Respondents)	256	226	30

SOURCE: 2014 Survey, Question 17.

The limited number of PIs at both ends of the age spectrum suggests a challenge for SBIR programs. Given that there is evidence that breakthrough technologies may be predominantly developed by younger scientists and engineers, do the limited number of awards for younger applicants indicate an over-reliance on track record during the selection process? Do changing demographics in the United States indicate that successful research programs will need to engage older scientists and engineers as they become a larger percentage of the total science and engineering workforce?

Overview: Stimulating Technological Innovation

What emerges from these data is a picture of companies that are dynamic centers of technological innovation, a considerable amount of which is protected through the patent system. Sixty-eight percent of companies reported receipt of at least one patent related to their work under SBIR/STTR contracts, while 39 percent reported receipt of at least one patent related to the surveyed project.

SBIR/STTR companies participate at a high level in the standard form of technical knowledge dissemination: publishing in peer-reviewed journals. Seventy-three percent of respondents indicated that at least one scientific paper had been published for the technology developed as a result of the surveyed project, and 22 percent reported publication of at least 5 such articles.

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Finally, some SBIR/STTR companies are closely connected to the universities. Nearly one-half of respondents reported a university connection on the surveyed project, across a number of different modalities, and 11 universities were specifically mentioned as playing a role in at least three reported projects. These findings suggest that SBIR and STTR may in some cases play a potentially important role in supporting the practical implementation of university research.

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Appendix G

Glossary

ARRA—American Recovery and Reinvestment Act

ASCR—Advanced Scientific Computing Research

BER—Biological and Environmental Research

BES—Basic Energy Sciences

COTR—Contracting Officer's Technical Representative

CRADA—Cooperative Research and Development Agreement

DNP—Office of Defense Nuclear Nonprolifieration

DoD—Department of Defense

DoE—Department of Energy

EERE—Office of Energy Efficiency and Renewable Energy

EIN—Employer Identification Number

EM—Office of Environmental Management

FAR—Federal Acquisition Regulation

FE—Office of Fossil Energy

FES—Fusion Energy Sciences

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FOA—Funding Opportunity Announcement

FY—Fiscal Year

GAO—Government Accountability Office

HEP—High Energy Physics

IP—Intellectual Property

ITAR—International Traffic in Arms Regulations

LOI—Letter of Intent

MOSB—Minority-owned Small Business

NASA—National Aeronautics and Space Administration

NE—Nuclear Energy

NIH—National Institutes of Health

NP—Nuclear Physics

NRC—National Research Council

NREL—National Renewable Energy Laboratory

NSF—National Science Foundation

PAMS—Portfolio Analysis and Management System

PI—Principal Investigator

PNNL—Pacific Northwest National Laboratory

R&D—Research and Development

RI—Research Institution

SBA—Small Business Administration

SBC—Small Business Concern

SBIR—Small Business Innovation Research Program

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SC—Office of Science

STTR—Small Business Technology Transfer Program

TM—Topic Manager

TTM—Technical Topic Monitor

TPM—Technical Project Manager

TPOC—Technical Point of Contact

TRL—Technology Readiness Level

WOSB—Woman-owned Small Business

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Appendix H

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