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THE CONTRIBUTIONS OF THE U.S. SBIR AND STTR PROGRAMS TO TECHNOLOGY COMMERCIALIZATION

A Report to NEDO – Revised Version

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PREFACE

The study underlying this report was commissioned by the Washington, D.C., office of Japan's New Energy and Industrial Technology Development Organization (NEDO) and was conducted by Technology Policy International, LLC.

The opinions expressed in this report do not necessarily reflect the views of NEDO or of other institutions with which the authors are affiliated.

DISCLOSURE: The authors wish to disclose that Patrick Windham served on two committees of the National Academies of Sciences, Engineering, and Medicine that studied the Small Business Innovation Research Program and the Small Business Technology Transfer Program. However, while this paper to NEDO cites findings from the reports written by those two committees, the views expressed in this paper are solely those of the authors and should not be interpreted as representing the views of the National Academies.

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INTRODUCTION

In 1982, Congress and President Reagan created the Small Business Innovation Research (SBIR) Program. In federal fiscal year (FY) 2013 – the most recent year for which we have data – the program made 4,485 awards to small companies, and the budget that year for new and existing awards totaled $2.1 billion. In 1992, the government created the related, smaller Small Business Technology Transfer (STTR) Program, which gives awards to small firms that partner with research institutions such as universities and federal laboratories. In FY 2013, STTR made 885 awards and had a budget of $254 million.

SBIR and STTR use a three-phase (three-part) approach. Small companies may apply for Phase I awards, which are used for feasibility studies and typically are about $150,000 each. Federal agencies use competitive selection processes to decide which firms win these awards. Companies that successfully complete Phase I projects may apply for Phase II awards, which typically are typically $1 million each – although they be higher. In Phase III, companies are expected to raise additional money from non-SBIR/STTR sources, either private investment or non-SBIR/STTR money from federal agencies.

Most U.S. federal research and development (R&D) programs receive their money through annual Congressional appropriations. However, SBIR and STTR are funded in a different way: federal departments and agencies with large R&D budgets are required to spend a certain percentage of their overall R&D appropriations on SBIR and STTR. Today, 11 federal departments and agencies have SBIR programs, and five have STTR programs.

The 1982 law that established SBIR lists four major goals for the program, one of which is to support the commercialization of innovations that come from federally-funded research.

This paper discusses the history and goals of SBIR and STTR programs; what the programs have and have not accomplished, particularly in terms of innovation and commercialization; their place in the overall U.S. national innovation system; key features of the two programs; and options for improving the programs' performance and evaluation.

The paper reaches five main conclusions:

- First, the SBIR and STTR programs exist because small businesses are politically powerful in the United States and small business owners successfully lobbied the U.S. Congress to create and continue these programs. Members of Congress assume that small high-technology companies contribute to innovation and job creation, but their main objective is to please the small business community. As a result, many members of Congress focus more on whether the agencies are awarding the right amount of money to small companies than on whether the programs are producing major benefits for the nation.

- Second, however, a study by the U.S. National Academies of Sciences, Engineering, and Medicine[1] found that almost half of all SBIR and STTR "Phase II" projects in recent years have succeeded in producing commercial products, services, or processes (defined as items sold either in the commercial marketplace or to the government). While this number is based on what companies told the National Academies and may exaggerate the success rate and while few of the projects have led to large sales and many new jobs, the survey suggests that SBIR and STTR have helped significant numbers of companies to commercialize their technologies. The programs also may have encouraged some entrepreneurs to form their companies. This success exists partly because of the design of the program, partly because the U.S. national innovation system is helpful to small high-technology firms, and mainly because of hard-working entrepreneurs.

- Third, in addition to commercialization the National Academies study found the SBIR and STTR programs also produce other significant but sometimes hard-to-measure benefits. These benefits include new scientific and technical information, new patents, business experience for new entrepreneurs, and a range of benefits for government agencies. Any evaluation of SBIR-type programs may want to consider this full range of possible benefits.

- Fourth, several features of the SBIR and STTR programs contribute to their success: predictable funding; a competitive selection process that encourages high quality projects; a recent emphasis on providing business assistance to new entrepreneurs who win SBIR and STTR awards; publicity that encourages small business owners to apply to the programs; and recent efforts to help companies that win SBIR and STTR awards to obtain additional funding.

- Fifth, it possible that certain changes to the programs would improve their contributions to U.S. innovation and commercialization. For example, larger SBIR/STTR awards might increase a company's chances of commercializing a product.

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[1] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program* (Washington, D.C.: National Academies Press, 2008).

HISTORY, GOALS, AND BUDGETS OF THE SBIR AND STTR PROGRAMS

HISTORY OF THE TWO PROGRAMS

The creation of SBIR. In the 1970s and 1980s, many Americans became concerned about U.S. industrial competitiveness. One particular concern dealt with technology commercialization: while the U.S. did well in research and invention, Japan and Germany often appeared better and faster in commercializing new discoveries and inventions. Because of this concern, policy-makers asked how the U.S. Government could better encourage commercialization, and lobbyists and "policy entrepreneurs" made several important policy proposals that Congress eventually adopted. For example, representatives of Purdue University lobbied Congress to allow universities to retain and license patent rights to federally-funded inventions, and in 1980 Congress enacted the Bayh-Dole Act (part of U.S. Public Law 76-517).

SBIR was another new initiative. In the mid-1970s executives from several small high-technology companies argued that their firms contributed to the U.S. economy but were often unable to get research grants from federal R&D departments and agencies.[2]

Several of these executives met with Senator Edward Kennedy (Democrat of Massachusetts), who at the time played an important role in supervising the National Science Foundation (NSF). Senator Kennedy then added a provision to the NSF Authorization Act for FY 1975 (Public Law 94-86)[3] requiring that 7.5 percent of the budget for an applied research program at NSF be "set aside" (allocated) for small businesses. NSF then assigned one of its program officers, Roland Tibbetts, to design the program. He consulted widely with businesses and government officials and designed the three-phase SBIR model that is still used today. NSF issued its first SBIR "solicitation" (request for proposals) in 1977. Then in 1979 the U.S. Small Business Administration (SBA) suggested that all major federal R&D departments and agencies should have SBIR programs, and the idea also received strong support at a 1980 White House Conference on Small Business. Senator Kennedy and other members of Congress supported this

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[2] The U.S. Government has both "departments" (such as the Department of Energy and the Department of Defense) and "independent agencies" (such as the National Science Foundation and NASA) that are separate from the departments. However, people often refer to both departments and independent agencies as simply "agencies." In this paper, when we say "SBIR or STTR agencies" we mean departments as well as independent agencies.

[3] In the U.S. Congress, authority over government programs is divided between "authorization committees," which write laws that create and modify government programs and recommend funding levels, and the House and Senate "appropriations committees," which decide how much money each agency actually gets each year. Senator Kennedy was a senior member of the Senate authorization committee for NSF and thus an important author of NSF authorization laws.

proposal, and in 1982 – despite opposition from some members of the research community, including leading academic institutions – Congress passed the Small Business Innovation Development Act of 1982 and President Ronald Reagan signed it. It became Public Law 97-219.[4]

One question is why the small business community focused first on NSF, an agency that historically has funded university researchers, not companies. Part of the reason is that in the 1970s President Richard Nixon created a large new applied research program at NSF called "Research Applied to National Needs" (RANN), which funded companies as well as universities. The academic research community did not like RANN, but it existed in the 1970s and provided a convenient home for the first SBIR program. Ironically, the Carter Administration, which was concerned about U.S. industrial competitiveness, abolished RANN in the late 1970s. But that happened after the creation of NSF's initial SBIR program.

The creation of STTR. In 1992, Public Law 102-564 created the similar but smaller STTR program, with the specific goal of encouraging closer cooperation between small companies and research institutions, such as universities and federal laboratories. The government's official SBIR/STTR website explains the difference between the two programs:

> STTR differs from SBIR in three important aspects:
>
> 1. Under STTR, the SBC [small business concern] and its partnering institution are required to establish an intellectual property agreement detailing the allocation of intellectual property rights and rights to carry out follow-on research, development or commercialization activities.
>
> 2. STTR requires that the SBC perform at least 40% of the R&D and the single partnering research institution to perform at least 30% of the R&D.
>
> 3. Unlike the SBIR program, STTR does not require the Principal Investigator to be primarily employed by the SBC.[5]

The politics of SBIR and STTR. While the official reason for creating the SBIR and STTR programs was to advance technology and create jobs, the two programs exist because of lobbying from the small business community and because of strong Republican and Democratic support for small business programs. In the United States programs to help large companies develop new commercial technologies have proven controversial. However, Congress has taken many steps to help small companies, including the creation of the U.S. Small Business

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[4] This history of the SBIR program is drawn from three sources: Elliot C. Kulakowski and Lynne U. Chronister, *Research Administration and Management (*Sudsbury, Massachusetts: Jones and Bartlett Learning, 2006), page 866; "Birth and History of the SBIR Program," https://www.sbir.gov/birth-and-history-of-the-sbir-program; and NSF authorization acts.

[5] https://www.sbir.gov/about

Administration (SBA); Small Business Investment Companies, which are government-supported but privately-run financial assistance firms; other SBA programs; and U.S. Economic Development Administration (EDA) assistance to help small companies in specific regions of the country.

Therefore, Congress created SBIR and STTR primarily to help a politically-popular group. As this paper will show, the two programs have led to some important technical and commercial benefits. But the programs also have many critics, including from universities, who ask whether SBIR and STTR are the most effective use of limited government R&D funds.

The 2011 reauthorization law. In 2011 Congress passed the SBIR/STTR Reauthorization Act of 2011, which "reauthorized" the programs –that is, extended their legal life – through fiscal year 2017. That law increased the "set-asides" for SBIR and STTR – that is, the percentages of their R&D budgets that agencies must devote to these two small programs. In FY 2017 and after, the 11 SBIR agencies must devote at least 3.2 percent of their annual "extramural" R&D money (that is, the R&D money they give to researchers outside the government) to small businesses, and in FY 2016 and thereafter the five STTR agencies must spend at least 0.45 percent of their extramural R&D budgets on STTR. The 2011 law also contained a political compromise regarding a controversial question: whether companies owned mostly by venture capital firms, hedge funds, and private equity firms should be eligible to apply for and receive SBIR and STTR awards.[6]

The 2016 reauthorization law. In the middle of 2016, both the House and Senate Small Business Committees recommended reauthorizing (extending) SBIR and STTR and increasing the percentages. The Senate bill (S. 2812) proposed to increase the SBIR percentage to 6.0 percent by 2028 and STTR to 1.0 percent by 2022. The House bill (H.R. 4783) proposed 4.5 percent and 0.6 percent by 2022.

Both the U.S. university research community and R&D agencies oppose these proposed increases. A recent article from *Science* magazine summarizes the concerns of science organizations:

> Although both sides agree that more academic research needs to be turned into products and services, science lobbyists oppose growing the SBIR and STTR programs at the expense of funding fundamental science. "We recognize that the SBIR and STTR programs are an important component of the innovation pipeline," 77 professional societies and academic organizations wrote in a 13 May letter to key legislators.

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[6] The SBIR/STTR Reauthorization Act of 2011 was one part of a much larger law. It is Division E of the National Defense Authorization Act for Fiscal Year 2012 (Public Law 112-81). U.S. federal fiscal year 2017 will end on September 30, 2017.

> "However, a mandatory increase in the SBIR/STTR allocation as proposed ... will result in fewer research opportunities for [basic research] investigators." It also comes at the wrong time, they write: "The proposed increases ... would be implemented when future funding levels for the federal science agencies are very uncertain."[7]

Obama Administration officials also object to the proposed increases. For example, Dr. Pramod Khargonekar of NSF made the following statement in June 2016:

> The proposed increases would come at the expense of reducing funding in existing highly meritorious fundamental research programs at NSF as well as other non-SBIR/STTR innovation programs.... We believe that any future growth in NSF SBIR and STTR programs should be realized through overall extramural R&D budget increases for NSF. In the current budget environment, increases in these programs mean real cuts to the remainder of the extramural budget. We do not see annual increases in set-asides for these programs as justified, especially at the cost of others, when the overall budget of the agency is flat.[8]

Given this opposition, the two small business committees then proposed only a five-year extension of the two programs – through FY 2022 – and no changes in the percentage set-asides. This reauthorization became law in December 2016. As in 2011, the 2016 SBIR/STTR reauthorization is included in a much larger national defense law.[9]

GOALS OF THE SBIR AND STTR PROGRAMS

The 1982 law gives the SBIR program four main goals, and each participating federal department and agency has the flexibility to choose which goal or goals to emphasize. The STTR program has the same goals. The four are:

- To stimulate technological innovation.
- To use small business to meet federal research and development needs (that is, to meet agencies' own needs for technology).

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[7] Jeffrey Mervis, "U.S. research groups going to war again over small business funding," *Science*, May 18, 2016, http://www.sciencemag.org/news/2016/05/us-research-groups-going-war-again-over-small-business-funding.

[8] Dr. Pramod Khargonekar, Testimony before the Committee on Science, Space, and Technology, Subcommittee on Research and Technology, U.S. House of Representatives, June 16, 2016, https://science.house.gov/sites/republicans.science.house.gov/files/documents/HHRG-114-SY15-WState-PKhargonekar-20160616.pdf.

[9] The SBIR/STTR reauthorization is Section 1834 of the National Defense Authorization Act for Fiscal Year 2017, Public Law 114-328.

- To foster and encourage participation by minority and disadvantaged persons in technological innovation.
- To increase private sector commercialization of innovations derived from federal research and development.

Several points about these four goals are important.

First, today one standard definition of the word "innovation" is a new product, service, or process that has reached the marketplace and that delivers significant value. The 1982 law, however, seems to use the term "innovation" more in the sense of new discoveries and inventions – that is, new knowledge. Today, federal agencies and evaluators usually define this first goal in this second sense. They therefore ask how much the SBIR and STTR programs and their companies generate new knowledge through published scientific and technical papers, new patents, and sometimes licenses of those new patents.

Second, and related, "commercialization" is usually defined as the introduction of new products, services, or processes into the marketplace.[10] Commercialization can be measured, for example, in terms of the number of items sold and revenues earned. In the case of SBIR and STTR, the term "commercialization" has another dimension: it means both sales in the private marketplace and sales to government agencies.

Third, the second goal – to meet federal R&D needs – is particularly important for agencies that develop, buy, and use equipment and services. For example, the Department of Defense (DoD) buys planes, ships, tanks, and other equipment and NASA develops and buys spacecraft. The National Academies committee that studied SBIR and STTR called DoD and NASA "procurement" agencies or "acquisition" agencies because they procure (acquire) equipment and services. Other agencies, though, are "grant-awarding" agencies; they do not develop or buy expensive hardware and software but instead give out research grants to university professors and others. NSF and the National Institutes of Health (NIH) are examples. The Department of Energy (DOE) is both a procurement agency and a grants agency. Its defense nuclear program of course develops and maintains weapons and naval reactors, while its energy and science divisions mainly provide R&D money.[11]

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[10] Whether a new commercial product that has entered the marketplace is also an "innovation" depends on how one defines the term "innovation." Any product, service, or process that is sold in the marketplace has been "commercialized." However, the term "innovation" usually means a product, service, or process that is not just in the marketplace – that is, commercialized – but also that it offers new or special value (that is, it is "innovative").

[11] For a discussion of the distinction between procurement agencies and grant agencies, see Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program,* page 67.

Acquisition agencies and grant agencies have different responsibilities, and they often use SBIR and STTR in different ways. DoD, for example, is less interested in using the program to encourage new private-sector products than it is in funding small firms that will develop specialized technologies or technical services that are useful to defense. NASA often measures success by whether SBIR and STTR help it create a few very specialized instruments needed for space exploration. For NASA, as well as DoD, general commercial success is not the top priority. However, NSF and NIH focus more on encouraging SBIR and STTR firms to develop technologies with broad commercial and public health benefits.

Finally, over the years agencies and Congress have interpreted the "minority and disadvantaged persons" goal to emphasize women-owned companies and companies owned by "disadvantaged minorities," which Americans generally define as African-Americans, Hispanic-Americans, and Native Americans and Pacific Islanders.

SBIR AND STTR BUDGETS AND AWARDS

Appendix 1 of this paper contains detailed statistics about spending levels and the number of awards given by the SBIR and STTR programs. But here we can provide a few numbers:[12]

- For fiscal years 1990 through 2013, federal departments and agencies spent a total of $36.3 billion on SBIR and STTR awards.
- In fiscal year 2013 (which is the most recent year for which we have statistics), agencies "obligated" (agreed to pay) $2.1 billion for SBIR awards and $254 million for STTR awards.
- In FY 2013, agencies received 20,213 Phase I SBIR proposals and made 3,011 Phase I awards. The agencies received 2,706 Phase II SBIR proposals and made 1,474 Phase II awards.
- In FY 2013, agencies received 2,658 Phase I STTR proposals, made 476 Phase I awards, received 349 Phase II STTR proposals, and made 349 Phase II awards.[13]

[12] These statistics come from SBIR-STTR "Dashboard," at: https://www.sbir.gov/awards/annual-reports?program=STTR&view_by=Year.

[13] It appears surprising that every company that applied in FY 2013 for an STTR Phase II award received one. However, this number is what the SBIR website reports.

SMALL BUSINESSES AND THE SBIR AND STTR PROGRAMS IN THE OVERALL U.S. NATIONAL INNOVATION SYSTEM

The United States has a business culture, legal rules, social institutions, and additional government programs that encourage and support small firms, including entrepreneurial start-ups. By understanding how small high-technology firms do and do not succeed in this economic environment, we can better understand how SBIR and STTR help these firms and which improvements in the two programs might further aid these companies.

AMERICA'S ENTREPRENEURIAL CULTURE

American entrepreneurs have long built new technology-based industries. Henry Ford is one example, as are the people who built U.S. aircraft companies, electronics firms, and later biotechnology, software, and Internet companies. And American culture celebrates entrepreneurs such as Ford, Steve Jobs, and Bill Gates.

In addition, since the 1980s America has seen new types of entrepreneurs. For example, before the 1980s it was unusual for professors at most U.S. universities to start companies (Stanford and MIT were exceptions), and many industrial researchers stayed with their companies for their entire careers rather than take the risk of starting new ones. But since 1980, many professors and corporate researchers have helped start new companies. And today many U.S. cities try to attract these entrepreneurs and the highly-skilled "creative" people who work for them.

The U.S. Small Business Administration (SBA) has information about high-technology small firms that have employees (as opposed to one-person companies).

> In 2012, there were 244,243 small employer firms in high-tech industries [out of a U.S. total of 5.8 million small firms with employees].... The majority of these small firms provide services in either computer systems design or architecture and engineering.... Among small firms, the industries with the highest growth from 2007 to 2012 were pharmaceutical and medicine manufacturing, data processing and hosting services, and computer design services....[14]

[14] SBA Office of Advocacy, U.S. Small Business Administration, "Frequently Asked Questions About Small Business," June 2016, page 4, available at: https://www.sba.gov/advocacy/frequently-asked-questions-about-small-business.

Small companies are an important part of the U.S. economy but not the only important part. Of course, many important innovations come from large established companies, and large firms also play a vital role in meeting government needs, such as providing equipment and services for DoD and NASA. In addition, large companies employ millions of Americans. However, small firms do contribute new ideas and new technologies and do contribute to U.S. employment. And some small start-ups eventually become important large companies, such as Microsoft, Apple, Google, or Amazon.

Some analysts worry that the U.S. now creates fewer new companies than it once did and that today, even after the Great Recession, almost as many small firms die each year as are created.[15] But small businesses, including start-ups, remain a vital part of the U.S. economy.

KEY ELEMENTS OF THE U.S. NATIONAL INNOVATION SYSTEM THAT AFFECT THE SUCCESS OF SBIR AND STTR

Along with a culture of entrepreneurship, the U.S. "national innovation system" – the set of institutions and legal rules that affect innovation – also has historically provided great support to high-tech entrepreneurs. This fact means that the SBIR and STTR programs operate in a U.S. business environment in which small high-technology companies have a genuine chance to succeed. But there are also some problems, which SBIR and STTR help address.

R&D investments. The U.S. innovation system begins with the very large investments that government and industry make in R&D and in the education and training of highly-skilled scientists and engineers. The U.S. has many world-class researchers – in companies, universities, and government laboratories. Some of them want to start companies. The U.S. also has experienced business executives who help these companies.

Legal rules. The U.S. national innovation system has legal rules that help high-tech entrepreneurs. The Bayh-Dole Act allows both universities and small companies to own the patent rights to federally-funded inventions, and universities have rules that allow professors to spend part of their time with companies. This set of university rules is so important to U.S. high-technology entrepreneurship that the next section of this paper discusses it in further detail. Other legal rules are also important, including both the patent system and the ability of both companies and individuals to declare bankruptcy and then start new economic lives.

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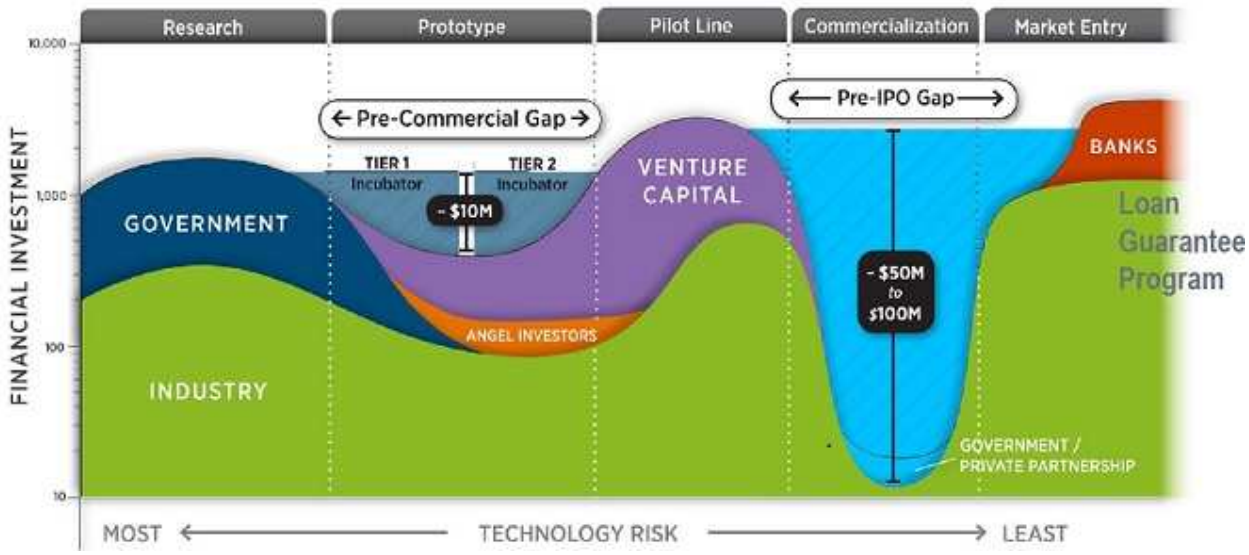
[15] See, for example, J.D. Harrison, "The decline of American entrepreneurship – in five charts," *The Washington Post,* February 12, 2015, https://www.washingtonpost.com/news/on-small-business/wp/2015/02/12/the-decline-of-american-entrepreneurship-in-five-charts/.

Financing. Financing is available for some of the most promising new high-tech start-ups. "Angel investors" sometimes provide crucial early financing, and a few (but not many) venture capital firms also provide so-called "early stage" financing. Once a company develops products and begins to earn money, then regular venture capital firms may provide valuable financing.

There are some important limitations to this system of financing small firms. Many angels and venture capitalists prefer to invest in their own local regions, which is fine in Silicon Valley and other high-tech centers but not necessarily helpful to other parts of the country. These investors also tend to finance companies in only a few technical fields, such as Internet applications or medical devices. And then there is the "valley of death" problem, in which new companies often face difficulty in getting development money to turn a promising invention or discovery into a credible prototype that investors will support. In the energy field and in manufacturing, there is sometimes also a second "valley of death," where companies have promising new products but have difficulty getting money to pay for the large-scale demonstrations and the production facilities needed to successfully enter the commercial market.[16]

The U.S. Department of Energy has produced a chart that illustrates this idea of two funding gaps – the two "valleys of death" – that many high-tech companies face. That chart is below.[17]



[16] "Valley of death" theories are valuable, because many small high-technology companies do face financing problems. However, these theories can also be misleading, because they seem to suggest that money is the one problem that prevents a new company from succeeding. In fact, a new company may face many challenges, such a poor business plan, a lack of markets, strong competition, and management difficulties. So financing may not be the only challenge – and money alone may not guarantee that the company succeeds.

[17] One place where this chart is available is a web page of the Solar Energy Industries Association: http://www.seia.org/policy/finance-tax/loan-guarantee-program.

SBIR and STTR awards can help small firms overcome the first "valley of death" – the one where they need funding for R&D to create prototypes. Of course, these programs are highly competitive, and not every applicant gets SBIR and STTR money. Also, the Phase I and even the Phase II awards are usually relatively small, and it is unclear how often they play a significant role in allowing firms to overcome this valley of death and proceed to commercialization. Still, SBIR and STTR can be very valuable sources of R&D funding for small companies.[18]

It is important to note that other government policies also help small companies. In particular, federal law requires agencies to try to award a significant percentage of government contracts to small firms. An SBA document summarizes these requirements:

> The current, government-wide procurement goal is that at least 23% of all federal government contracting dollars should be awarded to small businesses. In addition, targeted sub-goals are established for women-owned small businesses, small disadvantaged businesses, firms located in HUBZones and service disabled veteran-owned small businesses. These targeted goals are 5%, 5%, 3% and 3%, respectively, and are meant to be subsets of the overall small business goal of 23 percent.[19]

These goals are important because federal agencies have an obligation to reach out to small business and buy from them. In fact, federal acquisitions that have an anticipated dollar value exceeding $3,000, but not over $150,000 are automatically reserved for small businesses. These procurement policies certainly help small companies earn money and may also help companies to raise money from investors.

Other support for entrepreneurs. U.S. "high-tech regions" such as Silicon Valley, Seattle, San Diego, and Austin provide entrepreneurs not only with funding but also with a wide range of other support: specialized legal and accounting services, mentorship organizations, a skilled technical workforce, experienced company managers, university research support, and so forth. These regions have high levels of what is sometimes called "innovation capacity," and the support that institutions in these regions offer to entrepreneurs is invaluable. The success of

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[18] This discussion focuses on the financial needs of small companies. But it is important to note that in the United States and other countries many high-technology innovations come from large, established companies. One reason is that these companies have internal resources that allow them to finance expensive development costs. These large firms overcome the "valley of death" with their own money. Large firms also help innovation is a second, less direct way. Because large companies sometimes buy innovative start-ups or license technologies from these firms, money from these large firms help the start-ups. So large firms and small ones are both parts of the overall U.S. national innovation system.

[19] U.S. Small Business Administration, *Government Contracting 101, Part 1 – Small Business Contracting Programs,* January 2012, page 10, https://www.sba.gov/sites/default/files/files/Work%20book%20gc%20101%20part%201.pdf. HUBZone is a United States Small Business Administration (SBA) program for small companies that operate and employ people in Historically Underutilized Business Zones (HUBZones).

small high-technology companies, including firms that win SBIR and STTR awards, depends on these support services.[20]

Multiple ways to make money. Another important feature of the U.S. innovation system is that high-tech start-ups now have multiple ways to make money for their founders, investors, and employees. These include "initial public offerings" (IPOs) on stock exchanges (which provide money for the investors and founders and also provide money to help the companies grow to larger sizes); acquisitions by larger companies; and royalties from technology licenses. Examples of the IPO route include Microsoft, Google, Facebook, Genentech, and many other companies; they began as start-ups, held IPOs, and grew into large corporations. Acquisitions and licensing are also common. In some industries – particularly information and communications technology and pharmaceuticals – large companies now often want smaller U.S. firms to take the risk of trying to develop new technologies. If the small firms are successful, then large companies will buy the small firms or license their technologies. This practice may prevent a small firm from becoming a big firm, but it does allow the small company and its investors to make money.

The importance of a supportive innovation system. The reason why we have included a discussion of the U.S. national innovation system in this paper is because a supportive innovation system increases the chances that small firms – and the government programs that support them – will be successful. Moreover, the SBIR and STTR programs play an important role in this U.S. innovation system. Whether similar R&D programs in other countries would also be successful depends on the nature of those innovation systems and whether the R&D programs actually help companies within those systems.

THE ROLE OF EMPLOYERS OF INVENTORS IN HELPING SBIR AND STTR WORK

We now want to provide additional details on one particularly important feature of the U.S. national innovation system: the role of employers in helping SBIR and STTR-supported companies succeed.

A substantial proportion of SBIR and STTR awards are made to firms that have been newly established to commercialize a technology that was invented in a different firm or in a

[20] For details about "innovative capacity" in one U.S. region, see Mary L. Walshok, Edward Furtek, Carolyn W.B. Lee, and Patrick H. Windham, "Building regional innovation capacity: The San Diego experience," *Industry & HIgher Education,* February 2002, pages 27-42. Also, today there are many state and regional programs that provide support services to entrepreneurs outside of the high-tech regions, including programs in cities such as Cleveland, Pittsburgh, and many others. The growth in these programs has been a recent trend in U.S. regional economic development.

university, government laboratory, or other non-profit research organization. Frequently, the patent rights to the invention that underlies the technology are owned by the organization in which the invention was made. Furthermore, it is often the case that inventors want to have a lead role in the new firm and in seeking and using SBIR or STTR funding. In addition, the SBIR-supported new firm may wish to have a continuing relationship with the inventing organization, since that organization may have unique expertise that is essential to the success of the new firm and to improving the performance of the initial invention.

The circumstances just described mean that the implementation of SBIR-supported new firms will be heavily influenced by the policies and practices of the employers of the original inventors. When combined with certain rules of participation in SBIR, finding a way to make an SBIR-supported new firm work can be a challenge to the inventor, the inventor's employer, and the new firm.

Let us focus on the most common case: the invention is made at a university by a faculty member and, sometimes, employed research staff members and/or students. What rules apply to this situation?

First, under the Bayh-Dole Act university-based inventions belong to the university.[21] (Many universities have institutional policies that apply Bayh-Dole-like provisions to non-federally funded R&D as well.) If the inventor wishes to commercialize the invention by setting up a company that will seek SBIR funding, the inventor must negotiate a licensing agreement with the employing university. And, while it happens that such licenses are often given to employed inventors, universities must, in fact, offer to negotiate licenses with other parties, so the university even at this juncture retains significant control over the fate of any SBIR potential for the inventor. The inventor cannot participate in negotiations for the license on the university side, since he or she will also be a party to the company side of any deal. Still, in many cases the university will license the patent to the inventor. This step is vital in allowing inventors to start companies.

Second, and also important, many universities allow the inventor who is engaged in a commercialization venture to take a "leave of absence" from the university for a limited time (for example, for one or two years) to participate as an owner, manager, or staff member of a new company, even a company that is based on the inventor's licensed invention. Also, many

[21] Numerous exceptions and complications can arise when the invention is made by multiple faculty members, by students who are not financially supported by the university, by industrial partners, by visitors to the university, or when funds from more than one source are used in making the invention. A discussion of these complications is beyond the scope of this report as they must be addressed on an individual basis and can lead to complex contractual negotiations.

universities allow professors to spend up to one day a week working with outside companies, including their own companies. So sometimes professors do not need to take leaves of absence in order to work with the companies that they helped to create; instead, they can devote up to one day a week to work with these firms.

As is clear from the discussion above, the potential for conflicts of interest arise when employed inventors seek to license technology from their employers for commercialization. Conflicts of interest also arise when the inventor wants to continue to do research related to the technology, even though it has been licensed to a company in which the inventor has an interest.[22]

Some of the conflicts can be ameliorated if the inventor chooses not to be an active participant in the company, but instead serves as a consultant to the company just as he or she might do with any other company. However, even this sort of arrangement contains the possibility of conflicts of interest related to the inventor using his or her position at the university to assist the company's business, and universities develop rules to limit these conflicts. For example, the inventor cannot supervise graduate students who might study the technology that is the subject of the invention because to do so would mean using university resources (in this case, the student) to help the company.

In addition to conflicts of interest, "conflicts of commitment" can also arise. These refer to conflicts on how a professor uses his or her time. They occur when a professor who has not taken a leave of absence spends more than the allowed one day a week working on the company, instead of working on their university job.

So far, we have emphasized problems with conflicts of interest and commitment that can arise from university-employed inventors who seek to commercialize their inventions using SBIR or STTR awards. At the same time, it is important to keep in mind that universities, as a rule, are pleased when their faculty members and students make inventions that have commercial potential. So, universities often offer training sessions for faculty and students on how to set up a new company, on how to apply for an SBIR or STTR award, and how to manage the inevitable conflicts. Some universities even choose to become active investors in faculty-based start-up companies in hopes of benefitting financially from the arrangement as well as to help their faculty start those companies. Needless to say, the latter kind of arrangement can raise additional conflicts of interest that need to be avoided or, if they are unavoidable, to be managed and disclosed.

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[22] For many universities, such continuing research by the inventor at the university is not permitted if the inventor has an ownership or managerial interest in the company.

The key point of this section on the role of the inventor's employer is to recognize that starting a new company based on a university invention, with or without SBIR support, is a complex activity that involves far more than submitting a successful proposal to a federal agency that has an SBIR program or supports STTR activities.

PROGRAM OUTCOMES: WHAT THE SBIR AND STTR PROGRAMS HAVE AND HAVE NOT ACCOMPLISHED

This section of the paper focuses on the accomplishments of the SBIR and STTR programs. Most of the information presented here comes from the National Academies' study mentioned earlier and particularly from the National Academies' 2008 summary report, entitled *An Assessment of the SBIR Program*.[23] This report focuses on the SBIR program, not STTR, but STTR's results are likely to be similar. The 2008 report draws upon data and insights from several sources: information supplied by SBIR Phase II winners, in response to a survey (a set of questions) sent out by the National Academies committee; detailed case studies of individual companies, prepared by the research group that worked with the National Academies committee; a review of academic and government studies of SBIR; information supplied by the agencies; and the expertise of the committee's members.

The 2008 report focuses on how well the SBIR program has met the four goals stated in the 1982 SBIR law. Again, those four goals are: (1) to stimulate technological innovation (which, as mentioned earlier, is usually interpreted today as meaning the stimulation of advancements in scientific and technological knowledge; (2) to use small business to meet federal R&D needs; (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation (usually interpreted today as including women and disadvantaged minorities); and (4) to increase private sector commercialization of innovations (discoveries and inventions) derived from federal R&D.

It is important to mention which questions the National Academies study did ***not*** discuss. The study did not ask whether SBIR and STTR are more effective or less effective than other federal R&D programs in meeting these four goals. It did not ask whether R&D funding spent in small business is more cost-effective in producing major innovation than R&D funds spent in large companies. Also, the study did not ask whether program outcomes would significantly improve if major changes were made in the two programs – changes such as larger award sizes, a greater focus on meeting important technological challenges, or a more explicit focus on creating valuable new commercial products. No one has done a careful study of these important questions.

However, the National Academies study does provide useful information on how well SBIR has met the four goals assigned to it by Congress.

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[23] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program*.

CONTRIBUTIONS TO SCIENTIFIC AND TECHNOLOGICAL KNOWLEDGE

The 2008 summary report reaches several conclusions about how well the SBIR program is contributing to the creation of new scientific and technological knowledge.

> SBIR companies have generated many patents and publications, the traditional measures of activity in this area.... [For example, the survey of SBIR Phase II winners] found that 34 percent of NIH projects surveyed generated at least one patent, and just over half of NIH respondents published at least one peer-reviewed article.[24]

The report also mentions that SBIR projects can produce a wide range of valuable knowledge outputs – a point that is important to consider when deciding on evaluation metrics for this type of program.

> SBIR projects yield a variety of knowledge outputs. These contributions to knowledge are embodied in data, scientific and engineering publications, patents and licenses of patents, presentations, analytical models, algorithms, new research equipment, reference samples, prototype products and processes, spin-off companies, and new "human capital" (enhanced know-how, expertise, and sharing of knowledge).[25]

In addition, the report identifies other valuable benefits. For example, more than two-thirds of the companies responding to the National Academies' survey of Phase II winners had at least one university founder. These findings suggest that SBIR helps link university research and university researchers to companies. The report says that these data "highlight the program's contribution to the transition of university research to the marketplace."[26]

The National Academies study also says, "Projects funded by SBIR often involve high technical risk, implying novel and difficult research rather than incremental change.... This effort to push the technological frontier is a strength of the program and necessarily involves" the failure of some projects but not the failure of the overall program. Furthermore, the knowledge learned in both successful and unsuccessful research projects might prove useful in future research or at other companies. It is hard to measure these so-called "indirect effects," but they do exist.[27]

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[24] Ibid. [that is, from the previously cited report], page 64.
[25] Ibid., page 64.
[26] Ibid., page 65.
[27] Ibid., page 65.

CONTRIBUTIONS TO COMMERCIALIZATION

Overall levels of commercialization. The 2008 National Academies report defines commercialization as either sales of items into the private-sector marketplace or sales to the government. (In case of sales to the government, the two goals of advancing commercialization and meeting the government's needs overlap.)

The 2008 report makes several points about the role of SBIR awards in helping companies to commercialize their technologies. Here are excerpts from that report:

> Although the data vary by agency, responses to the [survey of Phase II winners] indicate that [technologies from] just under half of the projects do reach the marketplace....
>
> SBIR awards result in sale numbers that are highly skewed, with a small number of awards accounting for a very large share of the overall sales generated by the program. This is to be expected in funding early-stage technological innovation and is broadly consistent with the general experience of other sources of early technology financing by angel investors. Most projects, however, do not achieve significant commercial success; a few companies do....
>
> SBIR can be a key input to encourage small business commercialization, but most major commercialization successes require substantial post-SBIR research and funding from a variety of sources....
>
> SBIR funded research projects enable small businesses to develop the technical know-how needed to attract ... interest from a variety of public and private sources, including other federal R&D funds, angel investors, and venture funds. The [survey of Phase II winners] revealed that 56 percent of surveyed projects were successful in attracting additional funds from a variety of sources.[28] [29]

In short, almost half of all SBIR Phase II winners sell something in the marketplace – although only a few SBIR companies have large sales. Second, SBIR is helpful in two main ways, by

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[28] Ibid., pages 55-57.

[29] It is possible that company responses to the National Academies survey of Phase II winners exaggerate the amount of commercialization. The National Academies committee administered the survey in 2001. The committee carefully selected samples of companies that had won Phase II awards between 1992 and 2001 and sent the survey questionnaire to those companies. Forty-six percent of those companies responded. At least two sources of bias are possible: companies that succeeded in commercializing technologies were probably more likely than other companies to respond to the survey, and companies that could not be found and probably failed were not included in the responses. However, the study team made a large effort to contact a wide range of companies. Details about the survey are available in Appendix A of the 2008 report, *An Assessment of the SBIR Program.*

directly funding research and by sending a "signal" to other investors that the government thinks that companies that have won SBIR awards have good commercial potential. Third, while SBIR awards are helpful, in most cases a company needs significant additional research and funding in order to become a major commercial success; it is unrealistic to expect that SBIR awards by themselves provide enough money to produce that success.

One possible criticism of SBIR and STTR is that they have spent over $33 billion since 1990 and yet only a few of the companies they support have generated significant sales or grown into major firms. This possible criticism leads to a question: would an SBIR program with different features lead to more commercialization and therefore to greater economic benefits for the United States? For example, would fewer but larger SBIR/STTR awards increase overall commercial success? The current program implicitly assumes that winning a single $1.5 million Phase II award will often help a company obtain Phase III money, but is that assumption realistic? Is that enough money? Also, would additional business advice and assistance increase commercialization? And are DARPA and ARPA-E better organizational models, with their focus on trying to meet specific technical challenges and with their sometimes significantly larger awards? Or would other approaches, such as expanded R&D tax credits, be more effective in encouraging innovation? Congress did not ask the National Academies to examine most of these questions, but this TPI paper will return to these subjects in a later section that discusses both key features of the two programs and possible options for improving them.

DOE's SBIR program and commercialization. What about DOE's SBIR program? Do DOE's Phase II winners have a high level of commercialization? And does DOE offer useful assistance that helps small companies with commercialization?

In 2008 the National Academies committee published another report that focused just on DOE's SBIR program, and this report said the following about commercialization:

> The DoE SBIR program is focused on commercialization and has seen meaningful achievement. There are, nonetheless, opportunities for improvement in commercialization.... Phase II Survey data [that is, data from a survey of DOE Phase II winners] indicate that 41 percent of SBIR-funded projects reach the marketplace or have commercialization underway.... Phase II Survey data also show a much smaller number (4 percent) of projects generate more than $5 million in revenue.[30]

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[30] C*o*mmittee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program at the Department of Energy* (Washington: National Academies Press, 2008), page 26. After TPI wrote this paper, the National Academies released a second, updated report on DOE's SBIR program: C*o*mmittee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR/STTR at the Department of Energy* (Washington: National Academies Press, 2016),

In short, the National Academies committee found that the DOE program has generated levels of commercialization similar to those in other SBIR programs across the government.

The National Academies' DOE report describes not only how SBIR and STTR help companies commercialize their technologies but also the roles that these awards often play in the speed in which companies develop those technologies and or whether they ever develop these technologies.

> SBIR awards from the Department of Energy fund the development of technologies that otherwise might have developed more slowly, if at all.... More than 80 percent of ... Phase II Survey respondents reported that they would likely or certainly not gone forward with their project in the absence of SBIR funding.... Without exception, [companies interviewed by the National Academies] indicated that SBIR was vital to the development of their technology. Most suggested that the technology would not have been created if there had been no SBIR program. All credited SBIR as having played a significant role in the company's formulation [that is, creation] or development.... [31]

The National Academies committee also found that DOE SBIR funding gives participating companies the ability to do other useful things. Examples include help in creating new partnerships, exploring new technological options, expanding the company's technological capabilities by bringing in additional researchers, enhancing a company's credibility, and helping it to attract other funding from private investors and government agencies.[32]

The National Academies' 2008 DOE report also says that DOE has provided commercialization assistance to its Phase II award winners, but that few data are available on the impact and benefits of these efforts. Also, nearly two-thirds of DOE Phase II winners responding to the National Academies survey say that they had received or made additional investments in the surveyed project. However, none of the companies had received venture capital funding.[33] [34]

This National Academies' report recommends a step to improve the commercialization assistance that the Department provides:

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[31] Ibid., pages 30-31.
[32] Ibid., page 31.
[33] Ibid, page 27.
[34] This lack of funding from venture capital firms reflects an important truth about the U.S. venture capital industry: it only funds companies in a few areas of technology, which are areas where it thinks it can make significant amounts of money in a relatively short period of time. Around 2006-2010 venture firms did fund a few start-ups developing clean energy technologies, such as companies with new solar technologies, but when those investments did not succeed then venture funding for new energy technology companies mostly ended. As discussed earlier in this paper, the process of developing and demonstrating new energy technologies is a very expensive activity, and the lack of venture funding means that businesses often face a "valley of death" and must look for alternative sources of money. Government funds can be very important in this situation.

> [DOE should bring] SBIR participants together with potential corporate customers, perhaps in trade show, technical challenge workshops, or technology demonstration/validation formats. These functions could include large corporations ... including large energy technology corporations that serve as DoE contractors.[35]

Do SBIR and STTR encourage the formation of new small businesses? Encouraging the creation of new small high-technology companies is not one of the official goals of SBIR and STTR. Congress may have assumed that America already creates a healthy number of these firms. However, one important question is whether the two programs do in fact encourage the formation of new companies. A National Academies survey asked firms about this question. Although the results of this survey may be biased because only certain firms responded to the question, the findings are still interesting. According to this survey, "just over 20 percent of companies indicated that they were founded entirely or partly because of an SBIR award."[36] At least in the United States, the government's SBIR and STTR programs do encourage and help the creation of new firms.

CONTRIBUTIONS TO MEETING GOVERNMENT NEEDS

Another important goal of the SBIR and STTR programs is to help federal departments and agencies meet their own R&D and technology needs. In particular, procurement agencies can and do use SBIR and STTR to help develop the equipment, software, and services that the agencies need. These agencies measure SBIR success not by the amount of private-sector commercial sales the winning companies make but instead by whether these companies help the agencies meet their own government needs.

The 2008 National Academies report on the overall SBIR program makes several points about SBIR at the procurement agencies.

> At DoD, considerable progress has been made in aligning SBIR-funded research with the strategic objectives of agency research and acquisition. In some parts of DoD ... significant success has been achieved in improving the insertion of SBIR-funded technologies into the acquisition process. The commitment of upper management to the effective operation of the program and ... additional funding appear to be [key elements] of success....

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[35] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program at the Department of Energy*, page 37.
[36] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program*, page 61.

> At NASA, the primary metric for project success is the deployment of SBIR-funded technologies on space missions, where the agency can point to a number of significant impacts.[37]

Because the 2011 reauthorization law allows agencies, for the first time, to use a small percentage of their SBIR and STTR funds for administrative and management costs, SBIR/STTR staffs at acquisition agencies now have more resources to work with people in other parts of their agencies and therefore will better connect SBIR and STTR to overall agency needs.

The National Academies report also points out that SBIR projects can help even the non-procurement agencies such as NIH, NSF, and the parts of DOE to achieve their missions. For example, NIH sees SBIR "as an important element in the agency's translational strategy – designed to move technologies from the lab into the marketplace." The report adds that DOE can use SBIR to develop specialized equipment for its laboratories, and that NSF can use the program to improve the movement of university research into commercial products.[38]

WOMEN AND MINORITIES

The 2008 National Academies summary report points out that "Women- and minority-owned firms face substantial challenges in obtaining early-stage finance" and that the SBIR agencies "do not have a uniformly positive record in funding research" at these firms.[39]

The U.S. has decided not to impose "quotas" that require agencies to provide a certain percentage of SBIR and STTR funds to these firms, but the National Academies committee believes that the agencies could possibly do a better job of educating potential women and minority applicants about the program, helping them understand how to apply, and helping them to find mentors.

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[37] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program*, pages 59-60.
[38] Ibid., pages 59-60.
[39] Ibid., page 62.

KEY FEATURES OF THE TWO PROGRAMS, WHETHER THOSE FEATURES CONTRIBUTE TO SUCCESSFUL TECHNOLOGY COMMERCIALIZATION, AND POSSIBLE OPTIONS TO IMPROVE THE PROGRAMS' CONTRIBUTIONS TO COMMERCIALIZATION

This section of the paper: (1) describes the main features of the U.S. SBIR and STTR programs; (2) examines how much, and in which ways, these features contribute to the commercialization of technologies developed by SBIR/STTR winners; and (3) discusses policy options that might improve the contributions of SBIR and STTR to commercialization. As part of the discussion of policy changes, this section will discuss the recommendations made by the National Academies SBIR/STTR committee, as well as changes Congress made to the programs in its 2011 reauthorization law.

FUNDING

Program features. The two programs are funded by percentages of federal agencies' annual "extramural" R&D budgets.[40] Sometimes these required percentages are called "set asides," because the SBIR and STTR laws require that federal departments and agencies set aside – that is, allocate – money for the two programs.

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[40] "Extramural" R&D means the R&D money that a department or agency awards to organizations *outside* of the government, such as companies or universities. "Intramural" means R&D monies spent by the agencies' own civil-service laboratories. The budgets of two extramural R&D programs are exempted from this SBIR requirement: DOE's atomic energy programs (nuclear weapons and naval reactors) and the Agency for International Development's funds for international research centers or grants to foreign countries. The SBIR law further defines the term "extramural budget" in terms of what the U.S. Government calls "obligations" – the amount of money an agency actually contracts to spend in a given year. (U.S. budget policy uses three important terms: (1) *appropriations* (also called *budget authority*), which is what Congress and the president provide to agencies each year; (2) *obligations*, which are the amounts in a given year that the agencies commit to spend and which are binding financial agreements; and (3) *outlays,* which are the amounts the agencies actually spend in a given fiscal year. These numbers can differ from each other, particularly in R&D programs, because it takes time to organize and run grant competitions and because R&D awards are frequently for more than one year.) The Small Business Administration is trying to ensure that all SBIR/STTR agencies calculate their extramural R&D budgets in terms of obligations. See: U.S. Small Business Administration, *Small Business Innovation Research, Small Business Technology Transfer Annual Report, Fiscal Year 2013,* pages 10-13, https://www.sbir.gov/.../annual_reports/FY13_SBIR_STTR_AR_Final.pdf.

In the case of SBIR, every federal department and agency with an annual extramural R&D budget of $100 million or greater is required to spend at least a certain percentage of its extramural research budget – currently 3.2 percent –on awards to small businesses.

Currently, 11 federal departments and agencies participate in the SBIR program: the Departments of Agriculture (USDA), Commerce (DOC), Defense (DoD), Education, (ED), Energy (DOE), Health and Human Services (HHS, the parent agency of the National Institutes of Health), Homeland Security (DHS), and Transportation (DOT), plus three independent agencies, the Environmental Protection Agency (EPA), NASA, and NSF.

In the case of STTR, the law now requires that every federal department and agency with an annual extramural R&D budget of $1 billion or more to set aside a percentage of that budget – currently 0.45 percent – for STTR awards. Five departments and agencies participate in STTR: DoD, DOE, HHS, NASA, and NSF.

Using set-asides instead of annual appropriations is very unusual in U.S. R&D programs.

Contributions to commercialization. No one has conducted a study of how using set-asides instead of annual appropriations affects, or might affect, the amount of commercialization that results the SBIR and STTR programs. For example, the National Academies' study did not evaluate the SBIR/STTR funding model. The study assumed that Congress prefers that model, and the study focused on how effective the current programs – including their funding model – are at meeting the programs' four legislative goals.

Using set-asides instead of annual appropriations probably provides budget stability and predictability for the two programs, because the total extramural R&D budget for each federal agency is usually stable from one year to the next. And this predictability may help encourage companies to apply for SBIR/STTR awards, since the companies know that the programs will receive funding each year.

On the other hand, using set-asides instead of annual appropriations may have an indirect negative effect on how well the programs encourage commercialization. Annual budget reviews give Congressional committees the opportunity to examine program effectiveness and consider steps that might improve program performance – such as steps that might improve the amounts and types of commercialization that result from an R&D program. SBIR and STTR do not receive these annual Congressional reviews.

Possible options for improvement. It is possible that changing to annual appropriations might lead Congress to discuss and adopt program changes that would improve commercialization. But a change to annual appropriations, by itself, would not guarantee that Congress makes any changes.

AGENCY FLEXIBILITY

Program features. While the U.S. Small Business Administration (SBA) provides overall policy guidance of the SBIR and STTR programs,[41] each participating department and agency has the flexibility to decide how to use the programs to advance its own mission. Each agency must follow the four goals listed in the 1982 Act, but each agency may also decide which goal or goals to emphasize.

As mentioned earlier in this paper, the National Academies study talked about two different types of agencies and how their SBIR/STTR programs differ.[42] "Procurement agencies," such as DoD and NASA, buy large amounts of equipment, software, and services. Procurement agencies tend to use SBIR and STTR to help create the equipment, software, and services that they need. These agencies select SBIR/STTR "topics" –areas of technology that they want companies to focus on – that fit their particular needs. Related, these agencies are less interested in selecting topics and companies that might lead to large sales in the general U.S. economy.

"Grant agencies" such as NSF and NIH spend most of their money on grants to researchers, and their SBIR and STTR programs tend to emphasize the creation of new technical knowledge (through such activities as published papers and new patents) and private-sector commercialization of that knowledge. DOE's Office of Science, which administers DOE's SBIR and STTR programs, makes grants to universities and thus is also interested in private-sector commercialization. But it also owns several large federal laboratories, which leads it to sometimes use SBIR and STTR to create specialized equipment for those laboratories.

The exact wording of the 1982 SBIR law also affects the type of commercialization that NSF, NIH, and DOE emphasize. The 1982 law says that fourth goal of the SBIR program is "to increase private sector commercialization [of] *innovations derived from Federal research and development"* (emphasis added). This particular statement therefore leads the "grant agencies" to place a special emphasis on funding small firms whose technologies come from federally-funded R&D, such as university research. Some SBIR/STTR money from these agencies does go

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[41] In particular, SBA prepares SBIR and STTR "policy directives" that set general guidelines for agency programs. SBA's current SBIR policy directive is available at: https://www.**sbir**.gov/sites/default/.../**sbir**_pd_with_1-8-14_amendments_2-24-14.pdf. *SBA's current STTR policy directive is available at:* https://www.sbir.gov/.../sttr_pd_with_1-8-14_amendments_2-24-14.pdf.

[42] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program*, page 67.

to small companies that do not have university connections, such as companies started by former employees of large corporations. But these agencies do send a large amount of their program funds to companies that include academic researchers. For example, nearly 60 percent of NSF Phase II winners who responded to a 2011 National Academies survey reported a link to a university (that is, university faculty or graduate students worked on the project or universities were subcontractors). In addition, more than 80 percent of NSF Phase II companies responding to the survey reported at least one academic founder – that is, a university person who helped start the company.[43]

Federal agencies also have a second type of flexibility: the flexibility to decide which types of research "awards" to make to small firms: (1) *grants* (where the recipient is not required to deliver a product or service); (2) *contracts* (where the recipient is required to deliver something); or (3) *cooperative agreements* (in which the government helps oversee the recipient's R&D). In general, the grant agencies provide grants, and the procurement agencies use contracts. In this paper, the terms "R&D awards" and 'SBIR/STTR awards" includes all three categories.

A new requirement: commercialization performance standards. While in general the SBIR/STTR law gives the agencies a great deal of flexibility in choosing which program goals to pursue, the 2011 reauthorization law did add new provisions that require all SBIR/STTR agencies to pay more attention to commercialization.[44]

The 2001 law establishes two new "performance benchmarks" (metrics) that companies with significant numbers of past SBIR/STTR awards must meet in order to be eligible for to receive new Phase I money. The SBIR website summarizes these two new parts of the law and the way in which the agencies are implementing them:

> **Phase I to Phase II Transition Rate**. The Phase I to Phase II Transition Rate requirement applies only to SBIR and STTR Phase I applicants that have received more than 20 (21 or more) Phase I awards over the past 5 fiscal years, excluding the most recent year.... The current Transition Rate requirement, agreed upon and established by all 11 SBIR agencies, is that an awardee must have received an average of one Phase II for every four Phase I awards received during the most recent 5-year time period (which excludes the most recently-completed fiscal year) to be eligible to submit a proposal for a new Phase I (or Direct-to-Phase II) award....

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[43] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR at the National Science Foundation* (Washington, D.C.: National Academies Press, 2015), pages 180-181.

[44] Section 5165 of the SBIR/STTR Reauthorization Act of 2011 (Division E of Public Law 112-81).

> **Commercialization Benchmark**. The Commercialization Benchmark requirement applies only to SBIR and STTR Phase I applicants that have received more than 15 (16 or more) Phase II awards over the past 10 fiscal years, excluding the last two years. These companies must have achieved at least the minimum required levels of commercialization activity, resulting from their past Phase II work, in order to be eligible for a new Phase I award. The current Commercialization Benchmark, agreed upon and established by all 11 SBIR agencies, is that awardee applicant must have received, to date, an average of at least $100,000 of sales and/or investments per Phase II award received, or have a number of patents resulting from the SBIR work equal to or greater than 15% of the number of Phase II awards received during this period....
>
> **Consequences of failure to meet the benchmarks.** SBA will identify, on June 1 of each year, the companies that fail to meet either of these benchmarks. These companies will not be eligible to submit a proposal for a Phase I (or Direct to Phase II) award for a period of one year from that date.[45]

Contributions to commercialization. Sales to the government and sales in the private marketplace are both forms of commercialization. But they are different forms of commercialization, and therefore agency decisions to emphasize one or the other affects how much the U.S. SBIR and STTR programs do and do not contribute to the U.S. civilian economy.

Again, when DoD and NASA focus on their own need for specialized equipment, software, or services, then they pay less attention to companies and projects that might lead to large sales in the private marketplace. In fact, NASA sometimes uses SBIR and STTR to ask a company to create just one or two copies of a particular special piece of equipment, such as an instrument that will fly on one or two spacecraft. This form of commercialization is entirely legitimate under the SBIR/STTR law, but it is not likely to a large number of sales or the creation of a large number of jobs.

With regard to NSF, what are the consequences for U.S. commercialization of NSF's emphasis on academic-related companies? In fact, no good information exists on which of two types of small companies commercializes technologies more often or generates the largest sales and new jobs: (1) university-related small firms or (2) small firms whose founders and technologies come from large companies or other small companies and not from universities.

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[45] "Performance Benchmark Requirements for Phase I," https://www.sbir.gov/performance-benchmarks. The "Direct to Phase II" option is new and will be discussed later in this paper. The patent requirement is difficult to understand, but the website offers an example: if a company has received 18 Phase II awards over the 10-year period, then to be eligible to apply for new Phase I awards it must receive at least 2.7 patents (15 percent of 18) or it must receive sales and investments averaging at least $100,000 per Phase II award.

Finally, what will be the effects of the new commercialization performance standards? Congress wants to encourage companies to work hard to commercialize their technologies. But will this provision actually lead to more commercialization? And, if it does lead to more commercialization, what type of commercialization will occur? Many Phase I winners already win Phase II awards, so it is unclear whether the first of these two new requirements will change SBIR and STTR. The second new requirement – requiring significant sales, investments, or patents before a company can apply again for Phase I awards – may encourage additional short-term commercial products but may deter companies from trying to create significant, more difficult products. It appears that no one has evaluated the effects of these two new requirements.

Possible options for improvement. When examining the effects of agency flexibility on commercialization in the private U.S. economy, three points are particularly important.

First, as mentioned, Congress could require even the procurement agencies to emphasize commercialization in the private economy. However, this requirement would be a big policy change, and the procurement agencies and their supporters in Congress would likely to object to any such proposed change.

The second point is less obvious but also very important: none of the SBIR/STTR agencies has a primary mission to encourage general technological development and U.S. economic growth, and, as a result, none of their SBIR/STTR programs focuses primarily on advancing general U.S. economic growth (although NSF does emphasize the commercialization of university research). Americans have long debated whether the U.S. Government should work with private companies, large or small, to speed the development of new commercial technologies, and unlike other countries the U.S. has only rarely had such programs. If all of SBIR and STTR and their funding were in a separate agency with a mission to help companies with commercialization, then the level of commercialization would probably be higher. But that is not how the U.S. Congress has organized SBIR and STTR.

Third, since Congress created SBIR and STTR primarily to satisfy a popular political constituency – small business –it has never asked if focusing on small firms is the most successful or effective way to get new products, jobs, and growth. If the overall goal were to get the most amount of commercialization for the amount of money spent, then Congress would probably compare the SBIR approach to other R&D options.

THE THREE-PHASE MODEL

Program features. As mentioned earlier, the SBIR and STTR programs each consist of three phases:

- Phase I provides limited funding – usually up to $100,000 prior to the 2011 reauthorization and $150,000 or more thereafter – for feasibility studies. Agencies have some discretion in deciding how much money to provide in their Phase I awards.[46]
- Phase II provides larger funding for further research and development – typically up to $750,000 prior to the 2011 Act and $1 million thereafter. Typically a recipient can use this money for up to 24 months of R&D.
- Phase III is when a company receives non-SBIR/STTR money, either from other government sources (such as DoD acquisition money) or from private investors. Phase III is when a company begins to commercialize its technology.

SBIR and STTR therefore operate in a series of steps. How does this process work?

Agencies begin by issuing "solicitations" (requests for proposals) for Phase I awards. Each department and agency (and in the case of DoD and HHS, individual units within those departments) will identify "topics" (specific areas of technology) that are important to it. The procurement (acquisition) agencies focus on technical topics that are important to their missions. NIH and NSF pick technical topics that they think are related to their government-funded R&D and are potentially valuable in the commercial world. Companies may apply for Phase I awards from more than one federal agency.

Next, Phase I winners are selected through a competitive process; each agency reviews proposals and picks what they are the strongest ones.

Then small companies that have won Phase I awards and completed their feasibility studies are eligible to apply for the larger Phase II awards. Again, this is a competitive process, and not all applicants will win.

The 2011 SBIR/STTR authorization law made two changes in the regular Phase I/Phase II process.

- First, the 2011 reauthorization law allowed NIH to create yet another part of the SBIR program: a "Phase 0" ("Phase Zero") pilot program (experimental program). This

[46] For example, NSF recently increased the size of its Phase I awards from $150,000 to $225,000, and winners may now use these awards for 12 months of research instead of the former six months.

program offers grants, awarded through a competitive process, "to accelerate the creation of small businesses and the commercialization of research innovations."[47]

- Second, the reauthorization law permitted NIH, DoD, and the Department of Education to conduct a "pilot program" from FY 2012 through FY 2017 that allows companies to apply directly for Phase II money, without previous Phase I awards, if the head of one of these agencies determines that the applicant has already done research equal to that in a Phase I project. This policy experiment is called the "Direct to Phase II" pilot program.[48]

Finally, the SBIR/STTR law assumes that after a company wins one or more Phase II awards and completes these R&D projects, then there is a good chance that it will attract Phase III (non-SBIR/STTR funding) to turn the new technology into successful products, services, or processes. The law assumes that the company either will attract private money or it will get additional funding from a government acquisition agency.

However, in recent years both Congress and the agencies have recognized that Phase II winners often face difficulties in raising Phase III money and that these difficulties may prevent or slow commercialization. For example, today venture capital firms usually want to invest in mature start-ups, rather than new ones – that is, they make "late-stage" investments rather than "early-stage" or "seed" investments. And the federal acquisition process is complex and often a barrier to small firms that want to sell to the government.

So, agencies have recently received permission from Congress and the SBA to provide second or even third Phase II awards to an individual company, in order to help that company (1) further develop its technology and/or (2) attract non-SBIR/STTR money. For example, DoD may use some of its SBIR/STTR funds to make so-called "Phase II.5 awards" or "Phase II enhancement awards." NSF and NIH may make "Phase IIB" awards, and NSF also may make what it calls Technology Enhancement for Commercial Partnership (TCEP) Awards. In general, if a Phase II company makes good technical progress and particularly if that company also receives commitments for some non-SBIR funds, then the agency may give the company additional Phase II awards – a step that should help with commercialization. And the possibility of winning additional Phase II money may help the company raise non SBIR/STTR funding.[49]

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[47] Section 5127 of Public Law 112-81.

[48] Section 5106 of Public Law 112-81.

[49] NSF provides this explanation for its Phase IIB and TCEP awards: "The National Science Foundation provides a wide variety of Supplements [supplementary awards] designed to encourage partnerships and commercialization. At the Phase II level, there is a Phase IIB Supplement. At this stage of development NSF will provide a 1:2 match up to $500,000 – meaning that if you secure a $1M investment, NSF will provide an additional $500K. Another Phase II supplement is referred to as the TCEP, which stands for Technology Enhancement for Commercial Partnerships.

Contributions to commercialization. How well does the existing three-phase approach contribute to commercialization?

The advantage of having small Phase I awards is that a large number of firms can study the feasibility of their ideas. Then, if their ideas look promising both technically and commercially, these companies can apply for the much larger Phase II awards. Therefore, Phase I is a way for both companies and agencies to evaluate ideas before moving to more expensive Phase II R&D. And those Phase II awards can provide significant help to small firms.

One big question, though, concerns Phase III. Is the assumption that Phase II winners can often attract Phase III money a reasonable one, and how does this requirement for outside money affect the amount and types of commercialization? There is no clear answer. What is known is that many Phase II winners have difficulty in raising additional money, but no one knows whether this is because their technologies and business plans are not very good or because funding is not available even for good ideas. Phase II.5 and IIB awards probably help increase commercialization by allowing companies to further develop their technologies and by helping them attract outside funding, but the effects of these additional awards are not yet known. The 2008 National Academies report did make this observation:

> While the three-phase approach has often proved successful, there are widely recognized difficulties in obtaining funding for Phase III, and consequently in achieving external commercial success [that is, success in the private marketplace] or agency take-up in agencies with major procurement responsibilities.[50]

Possible options for improvement: Phase I and Phase II. The National Academies committee argued that the three-phase model is a good one and should be kept. One proposal that the National Academies committee rejected is the idea that companies should be allowed to by-pass the Phase I process and apply directly for large Phase II awards. The committee suggests that Phase I awards are valuable, both because they help large numbers of companies explore

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This program provides a $150,000 supplement to SBIR or STTR awardees in order to pave the way for partnerships between strategic corporate partners and investors. The intent of this supplement is to provide funding for additional research that goes beyond the Phase II project's objectives to meet the technical specifications or proof-of-concept requirements of the potential commercialization partner." This quote comes from "Course 2, Tutorial 7, National Science Foundation (NSF)" on the SBIR.gov website: https://www.sbir.gov/tutorials/individual-agency-requirements/NSF.

[50] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program*, page 83.

new technologies and because they help agencies evaluate which companies truly have promising ideas.[51]

However, the National Academies committee did argue that certain reforms could help make the transition between Phase I awards to Phase II awards work better. The 2008 summary report implies that these reforms could therefore improve the performance of the SBIR and STTR programs with respect to all four goals, including commercialization. The most important step would be to reduce the time between when a company completes a Phase I project and when it receives Phase II funding (assuming it submits a successful Phase II application). Today that gap can be many months, because the company must wait for the next Phase II competition, the agency needs time to review proposals and select winners, and the agency's contracts office needs time to actually transfer the money. However, this delay means that a small company with a promising technology may need to abandon its research on that technology because it runs out of money. Possible reforms here include holding more frequent Phase II competitions (not just one or two competitions a year), taking less time to make Phase II award decisions, and encouraging other agencies to use DoD's "Fast Track" process.[52]

Possible options for improvement: Phase II to Phase III. What changes to SBIR and STTR might increase the chances of successfully getting to Phase III -- and thus increase the chances of successfully developing products, services, and processes for both the commercial market and the government's own procurement needs?

If the current experiments with Phase IIB and Phase II.5 money prove to be useful, then one option would be to expand the number of these additional awards. Another option might be to use some SBIR/STTR money to support events where Phase II winners could meet venture capitalists and other funders.

AWARD SIZES

Program features. As mentioned earlier, in general SBIR/STTR Phase I awards are not to exceed $150,000 each, although in some cases agencies can go higher (such as NSF's $225,000 awards). A Congressional Research Service (CRS) report summarizes current Phase II award amounts,

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[51] Ibid., pages 81-82. Note that the 2011 reauthorization does allow three agencies to experiment with "Direct to Phase II" awards.

[52] Under DoD's "Fast Track" process, a Phase I winner who has commitments of non-government funding both for the interim time between the Phase I award and a possible Phase II award and for after Phase II can apply for that Phase II award under a special fast review process. For details, see U.S. Department of Defense, "Process Acceleration: How to Qualify for Fast Track," http://www.acq.osd.mil/osbp/sbir/sb/fasttrackqualification.shtml.

citing the how the Small Business Administration has interpreted Congress' law. The CRS description discusses the rules for SBIR, but the same rules also apply for STTR.

> [SBA's] SBIR Program Policy Directive generally limits SBIR Phase II awards to $1 million (the Phase II award guideline), although the directive provides agencies with the authority to issue an award that exceeds this amount by as much as 50% (for an amount up to $1.5 million). As with Phase I grants, agencies may request a waiver from the SBA to exceed the Phase II award guideline by more than 50% for a specific topic. In general, the period of performance for Phase II awards is not to exceed two years, although agencies may allow a longer performance period for a particular project. Agencies may make a sequential Phase II award [such as Phase IIB or Phase II.5] to continue the work of an initial Phase II award. This sequential Phase II award is also subject to the $1 million Phase II guideline by up to 50%. Thus, agencies may award up to $3 million in Phase II awards for a particular project to a single recipient at the agency's discretion, and potentially more if the agency requests and receives a waiver from the SBA. For sequential Phase II awards, some agencies require third party matching of the SBIR funds.[53]

NIH is one agency that has requested and received an SBA waiver to provide even larger Phase II awards. Between FY 2009 and FY 2012, 23 companies each received between $3.2 million and $5.3 million in total Phase II funding from NIH. The arguments in favor of such large awards are that biomedical research and drug development are expensive, venture funding for early-stage life sciences companies has declined, and (unlike DoD) NIH cannot provide non-SBIR procurement funds to further develop promising ideas.[54]

Contributions to commercialization. Phase I and Phase II awards definitely help small high-technology companies develop and commercialize technologies. Company responses to the National Academies surveys prove that point.

However, no one has asked whether raising or lowering the size of Phase II awards would affect the amount or types of commercialization. Congress did not ask the National Academies to examine this question. (The 2008 National Academies report did recommend that Congress increase the size of Phase I and Phase II awards, but the reason was that inflation had reduced

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[53] John F. Sargent, Jr., "Small Business Innovation Research and Small Business Technology Transfer Programs," Congressional Research Service, CRS Report R43695, August 26, 2014, page 5. The report is available at: http://digital.library.unt.edu/ark:/67531/metadc809752/?q=small%20business%20innovation. This report is an excellent summary of the SBIR and STTR programs.

[54] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR at the National Institutes of Health* (Washington, D.C.: National Academies Press, 2015), pages 96-100.

the true value of awards – not because a change in award size might affect commercialization rates.[55])

NIH's use of a few "extra-large awards" does offer an opportunity to examine whether large awards to small biomedical companies do or do not increase commercialization – specifically, to examine the percentage of Phase II winners who successfully sell products, the amount of sales and revenues related to these products, and the types of products sold. A 2015 National Academies report on the NIH SBIR and STTR programs asked, "So the question is whether NIH received good value for these investments." The report reaches several conclusions:

> Thirty-one companies [responding to the National Academies' survey of Phase II winners] reported receipt of larger awards.... This relatively small number means that caution should be employed in interpreting these outcomes. However, it is notable that three of the four projects reporting at least $50 million in related sales [that is, sales related to the SBIR projects] received larger awards and that this group accounted for four of the nine projects reporting at least $20 million in sales.[56]

This National Academies' NIH report also makes an interesting observation about a politically sensitive question: what would have happened to commercialization and sales if NIH had not made extra-large awards and instead had used its SBIR/STTR money to fund a larger number of Phase II projects.

> In reality, funding additional awards would likely have meant funding weaker applications, as acceptance moved farther down the list of fundable applications. Therefore, it is not likely that additional awards would have generated a return as high as the average return on the existing portfolio of funded projects.[57]

So it appears that in the biomedical field, where research is expensive, larger award sizes can increase the overall amount of commercialization by helping a few companies to succeed. Of course, if award sizes were increased then there would be fewer total awards each year. Therefore, the government must make a trade-off between the size of each award versus the number of awards.

Possible options for improvement. The 2008 National Academies report argued that the Small Business Administration and the agencies should have flexibility when deciding the size of SBIR/STTR awards and should consider "pilot programs" (experiments) regarding award sizes.

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[55] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program,* page 84.
[56] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR at the National Institutes of Health,* page 101.
[57] Ibid., pages 100-101.

> The SBA should continue to provide the maximum flexibility possible with regard to award size and the agencies should continue to exercise their judgment in applying the program standard. Recognizing agencies' need for flexibility to meet new technical or mission challenges expeditiously – such as countermeasures for biological threats or Improvised Explosive Devices – strict limits on the minimum or maximum amount for awards should be avoided. The agencies, as well, should consider whether pilot programs offering larger (or indeed smaller) awards might be useful in some cases, and whether close evaluation of large amounts made in the past could help guide future practice.[58]

ELIGIBILITY

Program features. Which "small businesses" may apply for SBIR and STTR awards? Under the 1982 SBIR law, to be eligible to apply to for SBIR and STTR awards a business must be a for-profit company in the United States, have 500 or fewer employees, and must either be:

- At least 51 percent owned and controlled by U.S. citizens or lawfully admitted permanent resident aliens, or
- At least 51 percent owned and controlled by another business concern that is itself at least 51 percent owned and controlled by U.S. citizens or lawfully admitted permanent resident aliens.[59]

In recent years, three controversies about eligibility have arisen: (1) whether firms that have won significant numbers of awards should meet performance benchmarks (a topic discussed earlier in this paper); (2) whether small firms majority-owned by venture capital firms, hedge funds, or private equity firms (that is, 51 percent or more of the company is owned by one of these financial firms) should be eligible for SBIR and STTR awards, and (3) whether companies should be allowed to receive multiple SBIR/STTR awards. Because an earlier section of this paper discussed performance benchmarks, this section focuses on the second and third issues.

Before Congress passed the 2011 SBIR/STTR law, Senators and Representatives debated whether to allow companies majority-owned by venture firms to apply. The argument in favor of letting them apply was that successful companies are often those with venture funding; this is particularly true, advocates said, for biomedical companies, because the cost of developing new drugs or medical devices is very high and only small companies with significant private

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[58] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program,* page 85.

[59] U.S. Small Business Administration, "Guide to Size Standards," https://www.sba.gov/contracting/getting-started-contractor/make-sure-you-meet-sba-size-standards/guide-size-standards.

money are likely to succeed. The argument against this position said that only companies owned by individuals – the original eligibility requirement – should be allowed to apply.

The 2011 SBIR/STTR law contains a political compromise on this question and one that applies only to SBIR and not to STTR: NIH, DOE, and NSF may award no more than 25 percent of their SBIR funds to such small businesses, and all other SBIR programs are limited to using 15 percent of their SBIR funds for such awards.[60]

Another controversy concerns small companies that apply for and receive multiple SBIR/STTR awards. One argument says that it is unfair and inappropriate for firms to get multiple awards, since that situation prevents other companies from getting awards. The other position argues that agencies sometimes find it useful and appropriate to give multiple awards to companies that provide valuable products or services. In particular, procurement agencies may find a few firms that provide useful goods or services over a number of years. Despite this disagreement, today agencies are allowed to provide multiple awards to companies.

Contributions to commercialization. The SBIR and STTR programs of course focus on giving R&D awards to small companies. Larger firms are not eligible to apply, nor are small firms that are owned by large firms (except for the majority-venture-owned firms mentioned earlier).

The new performance requirements that firms win Phase II awards and have sales, investments, or patents before they are eligible for to apply for new Phase I awards may encourage firms to make greater efforts to commercialize their technologies. But no one has yet evaluated the effectiveness of this new requirement.

Possible options for improvement. Proposals still exist to prohibit venture-owned small companies from applying to SBIR and STTR and to ban multiple awards. However, it is unlikely that these changes, if adopted, would improve the overall amount of commercialization from the programs.

PROGRAM OPERATIONS: PICKING R&D TOPICS AND SELECTING AWARD WINNERS

Program features: topic selection. U.S. agencies differ in how they select "topics" – the R&D areas eligible for SBIR/STTR funding. The 2008 National Academies report identifies three different models used by federal agencies:

[60] John F. Sargent, Jr., "Small Business Innovation Research and Small Business Technology Transfer Programs," page 6.

- *Acquisition-oriented topic selection procedures*. Since DoD and NASA are agencies that buy equipment and services – making them procurement (that is, acquisition) agencies – they select R&D topics that they think will help them with their high priorities. As the National Academies report says, "For these agencies, the goal is to target R&D spending towards projects that will provide technologies that can eventually be acquired by the agency for agency use."

- *Management-oriented topic selection procedures*. At NSF and DOE, the report says, senior managers pick the R&D topics, often based on what their R&D divisions think are important. Neither agency will accept Phase I or Phase II applications outside these topic areas.

- *Guideline-oriented topic selection procedures*. NIH is the only agency that uses the topics it selects as guidelines rather than requirements. Small firms are allowed to propose other topics.[61]

The National Academies report argues that the acquisition and guideline-oriented approaches are appropriate for the agencies that use them. However, it criticizes the NSF and DOE process in which agency managers select topics and do not allow applications outside these areas. This process, the report says, "ensures that excellent science may to wait several years" before NSF decides to allow proposals in those areas.[62]

Other U.S. R&D programs have used different processes for selecting topics. For example, while DARPA officials pick most program topics each DARPA office also has annual "office-wide" solicitations that allow researchers to propose ideas that fall outside of current agency programs.[63]

Another example of an alternative selection process was the one used by the former Advanced Technology Program /Technology Innovation Program at the Department of Commerce. ATP/TIP created "focused programs" (R&D programs in specific technical areas), but industry recommended those topics. In addition, the ATP/TIP had "open competitions" where researchers could propose any topic that they thought would help U.S. industry. The ATP/TIP model, therefore, listened closely to industry – a model that was appropriate to a program that sought to help industry develop valuable commercial technologies.

Program features: competitive selection processes. An important feature of the SBIR and STTR programs – and many other U.S. R&D programs – is that federal agencies select award winners

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[61] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program,* pages 170-171.
[62] Ibid., page 178.
[63] U.S. Defense Advanced Research Projects Agency, "Office-wide Broad Agency Announcements," http://www.darpa.mil/work-with-us/office-wide-broad-agency-announcements.

through competitive processes. However, SBIR and STTR proposals pose special challenges for federal review procedures.

All SBIR and STTR agencies must review not only the technical merits of proposals but also their business potential. DoD and NASA have procurement experts who can help their research colleagues review proposals. However, at NSF, NIH, and DOE this situation can be a challenge, since their staffs are usually scientists and engineers with relatively little business experience.

Some agencies try to include reviewers with business as well as technical experience. For example, here is how NSF's website describes its selection processes:

> In Phase I, technical reviewers with expertise in the field of research being proposed and/or the target market area proposed are asked to confidentially review the proposals. These technical reviewers always possess technical training and expertise in relevant areas of science, engineering, or technology. The Phase I review process relies heavily on input from these technical reviewers, with some reviewers having a mix of commercial and technical expertise. Dedicated commercial reviewers are sometimes asked to participate on Phase I panels; however, SBIR/STTR Program Directors also directly help evaluate the commercialization details of the proposal.
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> In most cases, similar proposals are typically placed into groups of 4 to 18 called a "panel." A group of 3 to 10 reviewers is assigned to a panel, with each proposal being reviewed by at least three of these reviewers. The reviewers read their assigned proposals and provide feedback, and then all of the reviewers meet in person at NSF or via video conference or conference call to discuss all of the proposals in the panel.
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> The Phase II process is similar, but a greater amount of time and effort is dedicated to the evaluation and discussion of each proposal. Additionally, each Phase II proposal generally is assigned to more reviewers. In Phase II, in addition to the technical reviewers, a minimum of two commercial reviewers review each proposal, paying particular attention to the commercialization plan.[64]

Contributions to commercialization. In terms of topic selection, DoD and NASA generally do a good job of picking SBIR/STTR R&D topics that help meet overall agency priorities. But one question is whether NSF and DOE, by focusing on topics agency managers like, are missing an opportunity to select R&D areas that offer particularly high economic potential or that encourage a wide range of new ideas from applicants.

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[64] U.S. National Science Foundation, "Frequently Asked Questions (FAQs) for SBIR-STTR," https://www.nsf.gov/pubs/2017/nsf17029/nsf17029.jsp#q43.

Competitive selection processes help ensure high-quality proposals and awards, which certainly contributes to R&D success and eventual commercialization. One question, though, is whether NSF, DOE, and NIH are as good at judging business potential as they are at judging technical merit.

Possible options for improvement. NSF, DOE, and NIH are in an unusual situation: their primary missions are to fund research and ***not*** to help U.S. industry or to advance commercialization (although DOE and NIH focus generally on energy and public health, respectively). Yet federal law requires them to operate SBIR and STTR programs in which commercialization is one of the four major goals. If they or Congress wish to increase the contributions that their SBIR and STTR programs make to industry and commercialization, then they might add topic selection and applicant selection processes that draw more on industry insights and on evaluations of which new technologies have the greatest commercial potential. A key "success factor" for SBIR-type programs is having government agencies that can effectively judge the business potential as well as the technical potential of topics and applicants.

BUSINESS ASSISTANCE

The people who start small businesses and apply for SBIR and STTR funds are often inexperienced in business matters. This is particularly true for the many university-based entrepreneurs whom NSF and NIH often fund. And many of the business owners who win Phase I awards each year are first-time winners, new to SBIR and STTR.

Besides providing these Phase I and Phase II awards, what else can be done to help winning companies succeed – especially new start-up firms that have good technical ideas but limited business expertise? Two types of additional assistance can help: agency programs to provide business advice to SBIR/STTR winners and possible business or financial assistance from state governments.

Program features: business assistance from SBIR/STTR agencies. In general, before Congress passed the 2011 SBIR/STTR reauthorization law federal agencies had only very small amounts of money to hire business consultants or provide other business assistance to Phase I and Phase II winners. However, recently agencies have experimented with both expanded SBIR/STTR business assistance programs and non-SBIR/STTR programs that can help both award winners and other entrepreneurs.

Agency contracts with business assistance organizations. The SBIR/STTR law has long allowed agencies to give SBIR/STTR winners small amounts of money to purchase "commercialization assistance" from organizations selected by the agencies. Agencies may provide each Phase I

and Phase II recipient up to $5,000 per year to purchase the services of an approved vendor (contractor) that will assist with commercialization efforts.[65]

Several agencies have long contracted with a company named Dawnbreaker. Today, Dawnbreaker works with DOE, DOT, DHS, the Navy, and NSF.[66] In addition, NIH has contracts with another organization, the Larta Institute.[67] NSF contracts with both Dawnbreaker and Larta. These two companies hold workshops on commercialization for SBIR/STTR winners and also sometimes provide consulting to individual SBIR/STTR companies. In some cases, they will help Phase I winners prepare Phase II applications and particularly helping them identify the commercialization potential of the proposed Phase II projects.

Dawnbreaker and DOE. In addition to general business and market research assistance to applicants and winners, Dawnbreaker also has a contract with DOE – through its "Phase 0 Assistance Program" – to provide special assistance to help women- and minority-owned small businesses submit high-quality proposals. It also helps firms in states that historically have low submission rates to DOE's SBIR and STTR programs.[68]

Commercialization Readiness Programs. The Senate and House Armed Services Committees (the committees that oversee DoD) have long wanted DoD's SBIR program to improve its commercialization efforts (with commercialization defined here as creating new products, services, and processes for defense). In the National Defense Authorization Act, FY 2006, Congress directed DoD to create a Commercialization Pilot Program, now known as the Commercialization Readiness Program.[69] The goal was to help accelerate the transition of SBIR-funded technologies to Phase III – meaning to acquisition by non-SBIR parts of the Department. Each of DoD's services (Army, Navy, and Air Force) were to use 1 percent of their SBIR money to create these commercialization programs. Examples of the resulting initiatives included hiring consultants to identify high-potential Phase II projects and companies, hiring Transition Agents to link SBIR officials and companies to DoD technical experts, and expanded small business support.

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[65] The Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) Program Interagency Policy Committee, "Report to Congress: SBIR/STTR Commercialization," September 15, 2014, pages 8-9, https://www.sbir.gov/sites/default/files/4_technet-ipc_report_to_congress.docx.

[66] Dawnbreaker, "What We Do," http://www.dawnbreaker.com/what.php.

[67] See: http://www.larta.org/services/commercialization-assistance-programs.

[68] Dawnbreaker, "Department of Energy SBIR/STTR Phase 0 Assistance Program," http://www.dawnbreaker.com/phase0.php.

[69] Public Law 109-163, Section 252.

According to the National Academies committee, these efforts appear to have created some successes, including SBIR companies that have contributed technologies to a Navy helicopter project and to new Navy submarines.[70]

In the 2011 SBIR/STTR reauthorization law, Congress converted the temporary DoD Commercialization Pilot Program into the permanent Commercialization Readiness Program and created Commercialization Readiness Pilot Programs at the other SBIR/STTR agencies. (The Phase IIB activities are also now part of the Commercialization Readiness Pilot Programs.)[71]

The Federal and State (FAST) Partnership Program. FAST is an SBA-administered program that provides grants to organizations that help small technology firms. Its website describes the program:

> FAST provides about $2 million in funding (typically up to $100,000 per applicant) for outreach and technical assistance to science and technology-driven small businesses. The program places particular emphasis on helping socially and economically disadvantaged firms compete in the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.
>
> Eligible applicants for FAST grants include state and local economic development agencies, Small Business Development Centers, and colleges and universities. Each state, through its governor, may submit one proposal.[72]

FAST remains a small program, focused more on helping companies successfully apply for awards than on mentoring them once the receive awards. It appears to play a small but valuable role.

NSF Innovation Corps. The National Science Foundation Innovation Corps ("I-Corps") program gives grants to universities to help train professors and graduate students to become entrepreneurs, with a particular focus on helping those entrepreneurs to commercialize technology that comes out of NSF-funded research. Created in July 2011, the program is available for all academics, including SBIR/STTR winners and for people who want to apply to SBIR and STTR. In fiscal year 2016, the program had a budget of $30 million, and the Obama Administration requested the same amount for FY 2017. In FY 2015 the program supported 210

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[70] Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR at the Department of Defense* (Washington, D.C.: National Academies Press, 2014), pages 102-133.

[71] Public Law 112-81, Sections 5122 and 5123.

[72] U.S. Small Business Administration, "About Federal and State Technology (FAST) Partnership Program," https://www.sbir.gov/about-fast.

teams of entrepreneurs, at $50,000 each. The program also funds "I-Corps Nodes" and "I-Corps Sites" that provide training and other services to entrepreneurs.[73]

There has been no rigorous evaluation of the I-Corps program, and apparently there are no statistics on how much people trained by I-Corps have commercialized technologies. However, the program appears to be helpful, particularly for professors and graduate students who have no prior business experience. Also, other federal agencies are now establishing similar programs. NIH works closely with NSF and as of February 2016 had funded 19 life sciences teams, sending money through the NSF program. DOE is establishing a Laboratory Innovation Program ("Lab-Corps") to help national laboratory people who want to start companies.[74]

Program features: state and local small business assistance programs. Programs in individual U.S. states, sometimes with federal financial assistance, provide several types of help to small businesses. The FAST Program, mentioned earlier, is one example.

Other small business assistance programs that combine state and federal funding include the Manufacturing Extension Partnership (MEP), which offers technical assistance to small and medium-sized manufacturers; the SBA Cluster Program, which provides funding and consulting to small firms; growth accelerators, which provide physical buildings and mentoring for start-up firms; and Small Business Development Centers, which provide consulting services to small companies.[75]

Several state governments provide "matching funds" to local companies that win SBIR or STTR awards. These funds help the companies conduct additional R&D. In May 2015, nine states provided matching amounts: Delaware, Hawaii, Kentucky, Michigan, Montana, Nebraska, Ohio, Oklahoma, and Wisconsin. Georgia and Minnesota provide technical advice and administrative support to SBIR/STTR winners but no direct funding.[76]

Many state governments offer periodic training programs for inventors or other individuals interested in applying to the SBIR and STTR programs. State governments may also assist inventors in preparing applications and make introductions of inventors to federal officials.

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[73] The home page for the I-Corps program is: https://www.nsf.gov/news/special_reports/i-corps/. More detailed information, including budget information, is available in the I-Corps portion of President Obama's FY 2017 budget request for the program: https://www.nsf.gov/about/budget/fy2017/pdf/38_fy2017.pdf.

[74] For information on Lab-Corps, see U.S. Department of Energy, "Lab-Corps," http://energy.gov/eere/technology-to-market/lab-corps. Note: This DOE program is completely different than the privately-owned medical testing company called LabCorp.

[75] An SBA website provides information on these state business assistance programs: https://www.sbir.gov/state_services?

[76] Angel Capital Association, "Matching Grants: What Does Your State Have?" May 18, 2015, https://www.angelcapitalassociation.org/blog/matching-grants-what-does-your-state-have/.

Contributions to commercialization. These business assistance programs perform important services, particularly for new entrepreneurs. However, further evaluations are necessary before agencies, Congress, and state governments can decide which of these programs are effective.

Possible options for improvement. These business assistance programs are promising. Once the agencies and Congress can see the results and evaluate these programs, then they will be able to decide what additional steps would further improve the amounts and types of SBIR/STTR commercialization.

PROGRAM MANAGEMENT, OUTREACH, AND EVALUATION

Program features: management and outreach. Until Congress passed the 2011 SBIR/STTR reauthorization act, federal departments and agencies could not use any SBIR/STTR funds for the management of their programs. All the money had to go to awards. Agency directors therefore tended to assign only a few staff people to their SBIR/STTR programs, since they had to pay for these staff out of their regular agency budgets. In addition, SBIR/STTR staff did not have money to pay for reviewers (they usually relied on agency volunteers), to pay for "outreach" to educate potential applicants, or to pay for data collection and program evaluation.

The 2011 law created a "pilot program" (a temporary policy experiment) that allows the agencies to spend up to 3 percent of their SBIR funds for several purposes: program administration, outreach and technical assistance, activities relating to oversight and quality control, contract processing costs, and funding for additional personnel and assistance with application reviews.[77]

The agencies have begun to implement this part of the law, but there is not yet any evaluation of how well this new management program is working. Also, while the 2016 reauthorization law extends SBIR and STTR through fiscal year 2022 it does ***not*** extend this management pilot program. Unless Congress enacts another law this year that extends the pilot program, this experiment will expire at the end of fiscal year 2017 (that is, on September 30, 2017).

Program features: evaluation. SBIR and STTR are large programs, spending over $2 billion per year. Yet for many years the agencies conducted almost no program evaluations, because the ban on using program money for management also meant that program money could not be used for data collection and evaluation.

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[77] Public Law 112-81, Section 5141.

Other groups – including the National Academies – performed some evaluations. However, these evaluations, while valuable, focused only on a few specific questions.

*Congressional reviews***.** The Government Accountability Office (GAO) is Congress's agency for audits and evaluation. Over the years, it has conducted several reviews of SBIR and STTR, but it has primarily studied administrative procedures and not program results.

Congressional committees themselves conducted relatively little review of the programs. Each year authorization committees and the House and Senate Appropriations Committees examine most federal R&D programs, but because SBIR and STTR automatically took a percentage of agency R&D monies no one looked closely at the programs. The House and Senate Small Business Committees reauthorized (extended) the programs every few years, but they did not have the time to look closely at programs that existed at 11 different federal departments and agencies.

Evaluations by the National Academies. By 2000 Congressional interest in evaluation had grown, and in the Small Business Reauthorization Act of 2000 Congress directed the heads of each agency with a budget of more than $50 million for SBIR in FY 1999 to contract with the National Research Council – the part of the National Academies of Sciences, Engineering, and Medicine that conduct studies – for the Council to conduct "a comprehensive study of how the SBIR program has stimulated technological innovation and used small businesses to meet Federal research and development needs.... [and] to the extent practicable, an evaluation of the economic benefits achieved by the SBIR program... [and] noneconomic benefits...." [78]

Five departments and agencies had SBIR budgets of $50 million or more: DoD, NIH, NSF, DOE, and NASA. The National Academies study focused on these five agencies. As mentioned earlier in this paper, the National Academies study did not ask whether SBIR and STTR should exist – Congress already had decided that they would exist. Instead, the study followed the 2000 law by focusing on two primary questions: (1) how well did the SBIR programs at the five agencies meet the four program goals set forth in the 1982 SBIR law and (2) what "best practices" – good ways of running SBIR programs – existed that the agencies could teach to each other.[79]

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[78] Section 108 of the Small Business Reauthorization Act of 2000, which was "Appendix I – H.R. 5667" in a much larger law, the Consolidated Appropriations Act, 2001, Public Law 106-554, enacted on December 21, 2000.

[79] This paper focuses on those features of the SBIR and STTR programs that contribute to technology commercialization, and so it does not focus on the details of SBIR/STTR program management, including "best practices." However, for a list of what the National Academies committee thought were "agency best practices," see: Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program,* pages 80-81. That list of "best practices" is also included in Appendix 3 of this paper.

This initial National Academies study lasted from 2002 to 2008 and published several major reports. Appendix 2 of this paper provides web links to these reports. Congress later asked for a second phase of the study, which ended in December 2016. Appendix 2 also provides links to the reports from this second phase of the project.[80]

At the beginning of this work, the National Academies assembled a committee of experts and a group of policy researchers.[81] Dr. Jacques Gansler, a former Under Secretary of Defense, chaired both the Phase I and Phase II National Academies committees. The 2011 SBIR/STTR law requires that the agencies continue every four years to contract with the National Research Council (that is, with the National Academies) for additional evaluations.[82] So the National Academies will continue to study the two programs.

Agency data collection and evaluations. The 2011 SBIR/STTR reauthorization law directs the agencies to collect more data, but it is not yet clear what data they are collecting and how they will use those data in program evaluations. It will be important, however, to collect information on the full range of benefits from SBIR and STTR, including some that are hard to measure. This paper's Appendix 3 provides one list of the wide range of benefits that the programs can provide to small companies and that could be considered in agency evaluations.

The law now requires each SBIR and STTR agency to "develop metrics to evaluate the effectiveness and benefit to the people of the United States of the SBIR program and the STTR program"; to annually evaluate its programs using those metrics; and to submit "an annual report describing in detail the results" of these annual evaluations.[83]

Agencies differ in how much detail they provide in their annual reports. In recent years, for example, DoD has provided only basic statistical data, while NASA has provided more detailed reports.[84] SBA's annual reports on the government's overall SBIR and STTR programs do include summaries of each agency's activities and statistics about applications, awards, and budgets.

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[80] Both the National Academies' Phase II reports and a description of this Phase II work are available at: http://sites.nationalacademies.org/PGA/step/sbir/index.htm.

[81] The first study committee was officially named the Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program. The second, Phase II committee had the same name, except for adding the term "Phase II" at the end of the name. ***DISCLOSURE:*** As mentioned in the Preface to this paper, TPI partner Patrick Windham served on both of these National Academies committees. However, while this TPI paper cites findings from the reports written by those two committees, the views expressed in this paper are solely those of the authors and should not be interpreted as representing the views of the National Academies.

[82] Public Law 112-81, Section 5137.

[83] 15 U.S.C. 638(g) and 638(nn).

[84] For NASA, see: National Aeronautics and Space Administration, *2013 SBIR/STTR Annual Report*, http://sbir.gsfc.nasa.gov/sites/default/files/Annual_report_w_econ_2.2014_web.pdf.

However, the SBA reports, including the most recent one for FY 2013, do not in fact list agency metrics or present evaluations of how well the agency programs are meeting these metrics. Instead, they list major achievements and "success stories" (successful company projects) without any detailed evaluation of how well the agency programs are working. So in fact we see little evidence of detailed program evaluations by the SBIR/STTR agencies themselves.

Contributions to commercialization. As mentioned earlier, the "pilot program" allowing agencies to spend up to 3 percent of their SBIR money on management is still new, and there is no information on how well it is succeeding. But the new funds for management – including outreach, technical assistance, and additional funds for staff and reviewers – should all help to encourage more companies to apply, to help Phase I and Phase II winners succeed, and to help the procurement agencies better connect SBIR winners to procurement officials. If Congress extends the pilot program, it will enable further evaluations.

Possible options for improvement. Congress and the agencies will be able to evaluate possible next steps after they learn more about the impact of these new management and evaluation changes.

CONCLUSION: LESSONS FOR OTHER COUNTRIES

The analysis in this paper suggests four possible lessons for other countries that have SBIR-type programs or may want to create them.

National innovation systems. First, the features of each country's national innovation system are important. The United States has a long tradition of small firms, including start-up firms, developing and successfully marketing new technologies. Certain features of the U.S. innovation system help make this success possible: strong research institutions, legal rules that allow universities to keep the patent rights to federally-funded inventions and allow professors and others to start and participate in companies, a strong venture capital industry, and a wide range of "support institutions" (such as specialized law firms and accounting firms). In this innovation system, SBIR and STTR can significantly contribute to American economic success.

In other countries, innovation may come from small businesses or large firms or government research institutions. If small high-technology businesses are important to a nation's innovation performance and can succeed, then an SBIR-type program may be helpful. Of course, any such program should be designed to fit with the particular strengths and limitations of an individual country's national innovation system.

Features of a successful SBIR-type program. Certain features of the U.S. SBIR and STTR programs contribute to their success. Four features are probably important in any country: (1) a competitive selection process, which contributes to the quality of the awards and the R&D that these awards support; (2) "outreach efforts" to publicize the programs and encourage small business executives to apply to the programs; (3) awards that are large enough to allow companies to develop their technologies; and (4) business assistance programs that help new entrepreneurs learn business skills – skills that will help them succeed. It is less clear that America's set-aside funding mechanism or the three-phase support structure would be important or relevant features for other countries.

The importance of follow-on financing. Government R&D awards help companies develop and demonstrate new technologies. But to succeed in the marketplace, companies, particularly small companies, need additional sources of money – money to turn prototypes into products, money to start production, and money to help them market their products or license their technologies. In the United States, both private funding (such as venture capital) and procurement contracts from the government can provide that money. But if companies in a particular country cannot obtain follow-on financing, then they will not succeed commercially.

Evaluations that measure the full range of potential benefits. When measuring the success of a program such as SBIR, the main metric is commercialization: did the companies supported by government R&D programs successfully develop and sell new products, services, or processes, and were there significant new revenues and jobs? However, the SBIR/STTR experience in the United States shows that these programs also have other significant benefits – and that a good evaluation system will also examine these other benefits. These other benefits include scientific and technical papers and knowledge, new patents, business experience for new entrepreneurs, the ability of government agencies to learn new ideas, and the ability of government agencies to get valuable but low-volume supplies of important equipment. When evaluating the benefits of SBIR-type programs, governments should examine their full range of benefits. Appendix 3 provides one list of these many benefits.

APPENDICES

APPENDIX 1: STATISTICS ABOUT SBIR AND STTR SPENDING AND THE NUMBER OF AWARDS

The following tables and charts provide detailed information about SBIR and STTR spending levels and award numbers from FY 1990 through FY 2013, the most recent year for which we have complete data.[85]

We begin with four tables that summarize spending levels and award numbers. The source of the data for these four tables is: https://www.sbir.gov/awards/annual-reports?program=SBIR&view_by=Year.

[85] The spending levels reported in the first two tables are for "obligations." U.S. budget policy uses three important terms: (1) *appropriations* (also called *budget authority*), which is what Congress and the president provide each year; (2) *obligations*, which are the amounts in a given year that the agencies commit to spend and which are binding financial agreements; and (3) *outlays,* which are the amounts the agencies actually spend in a given fiscal year. These numbers can differ from each other, particularly in R&D programs, because it takes time to organize and run grant competitions and because R&D awards are frequently for more than one year. U.S. budget documents often focus on obligations.

Total Annual SBIR Obligations by All SBIR Agencies
(in thousands of U.S. dollars)

Year	Total Obligated	Phase I Obligated	Phase II Obligated
1990	460,728	118,098	342,531
1991	483,080	127,858	335,856
1992	508,403	127,940	371,150
1994	717,647	220,419	473,600
1995	864,549	232,192	601,938
1996	916,300	228,939	645,786
1997	1,106,997	277,644	789,133
1998	1,129,476	262,284	804,449
2000	1,148,485	302,034	888,177
2001	1,379,000	317,094	977,343
2002	1,413,086	411,468	1,023,364
2003	1,791,806	455,386	1,214,714
2004	1,958,879	498,749	1,368,700
2005	2,029,823	461,187	1,404,713
2006	2,113,981	411,185	1,471,991
2007	2,080,234	447,343	1,197,436
2008	2,134,604	438,192	1,345,547
2009	2,371,203	502,648	1,462,846
2010	2,365,307	538,912	1,472,184
2011	2,214,919	489,959	915,381
2012	2,228,285	534,211	990,107
2013	2,108,109	461,607	930,028
TOTALS	**33,524,901**	**7,865,349**	**21,026,974**

Total Annual STTR Obligations by All STTR Agencies
(in thousands of U.S. dollars)

Year	Total Obligated	Phase I Obligated	Phase II Obligated
2000	69,847	23,935	45,911
2001	75,382	25,454	45,816
2002	95,806	36,387	55,392
2003	96,666	41,135	50,675
2004	198,805	79,728	110,251
2005	233,315	73,934	146,385
2006	241,588	73,982	152,264
2007	247,993	83,465	159,852
2008	230,533	54,924	161,719
2009	273,540	73,000	196,579
2010	276,431	75,410	203,860
2011	247,381	59,583	191,590
2012	263,220	70,714	97,721
2013	254,222	72,351	95,179
TOTALS	**2,804,729**	**844,002**	**1,713,194**

Numbers of SBIR Awards Made by All SBIR Agencies

Year	Total Proposals	Total Awards	Phase I Proposals	Phase I Awards	Phase II Proposals	Phase II Awards
1990	22935	3183	20957	2346	1978	837
1991	22654	3341	20920	2553	1734	788
1992	21890	3475	19579	2559	2311	916
1994	27832	4030	25588	3102	2244	928
1995	23041	4348	20185	3085	2856	1263
1996	21056	4032	18378	2841	2678	1191
1997	22005	4775	19585	3371	2420	1404
1998	21255	4342	18775	3022	2480	1320
2000	20174	4496	17641	3166	2533	1330
2001	19232	4748	16666	3215	2566	1533
2002	25254	5820	22340	4243	2914	1577
2003	31259	6224	27992	4465	3267	1759
2004	34370	6651	30766	4638	3604	2013
2005	30183	6171	26003	4300	4180	1871
2006	27572	5862	24305	3836	3267	2026
2007	25190	5356	22278	3814	2912	1542
2008	25308	5397	22081	3626	3227	1771
2009	25859	5800	22598	4007	3261	1793
2010	28234	5891	24878	4045	3356	1846
2011	28245	5498	24661	3739	3584	1759
2012	24961	5510	21576	3528	3385	1982
2013	22919	4485	20213	3011	2706	1474
TOTALS	**551428**	**109435**	**487965**	**76512**	**63463**	**32923**

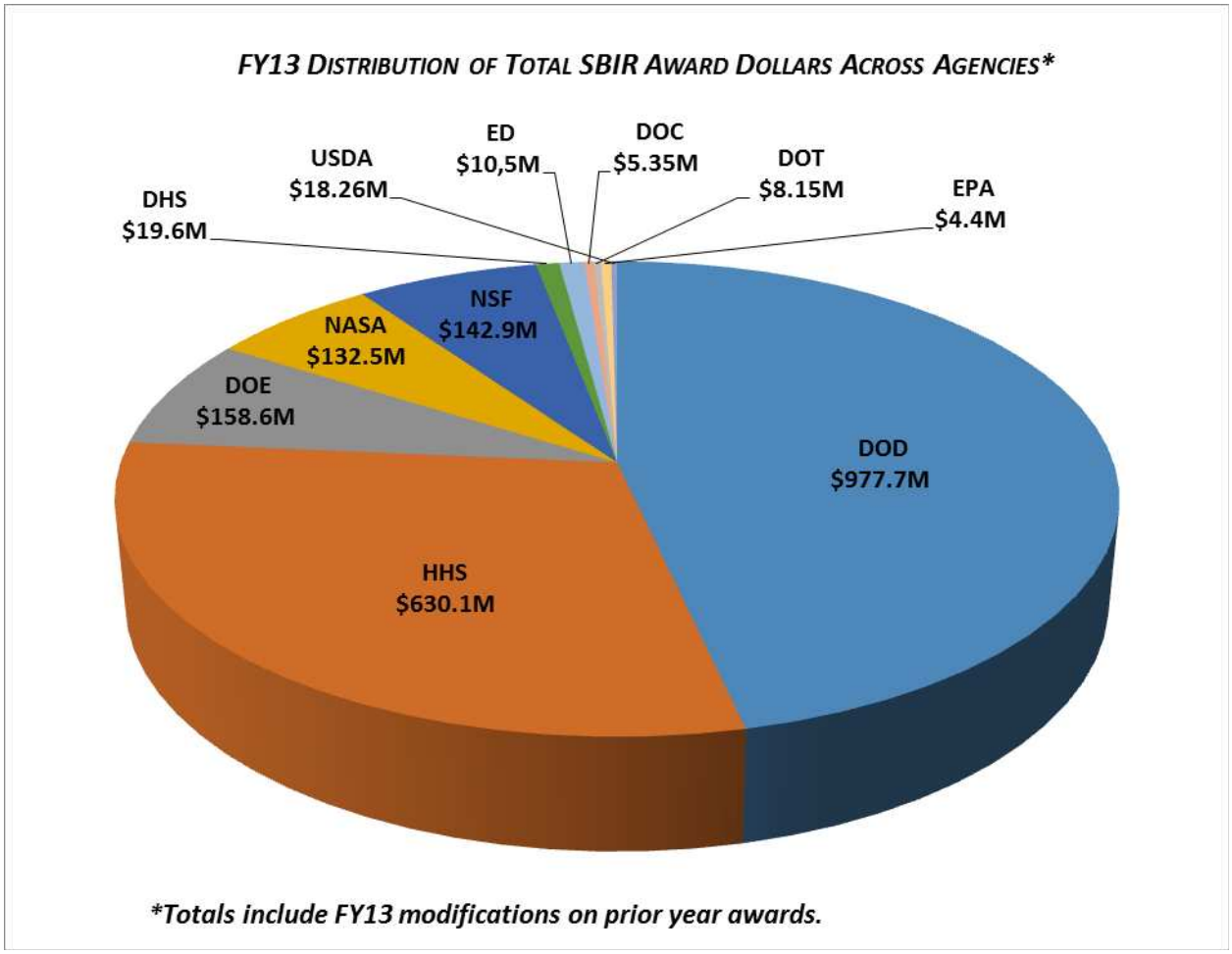
Numbers of STTR Awards Made by All STTR Agencies

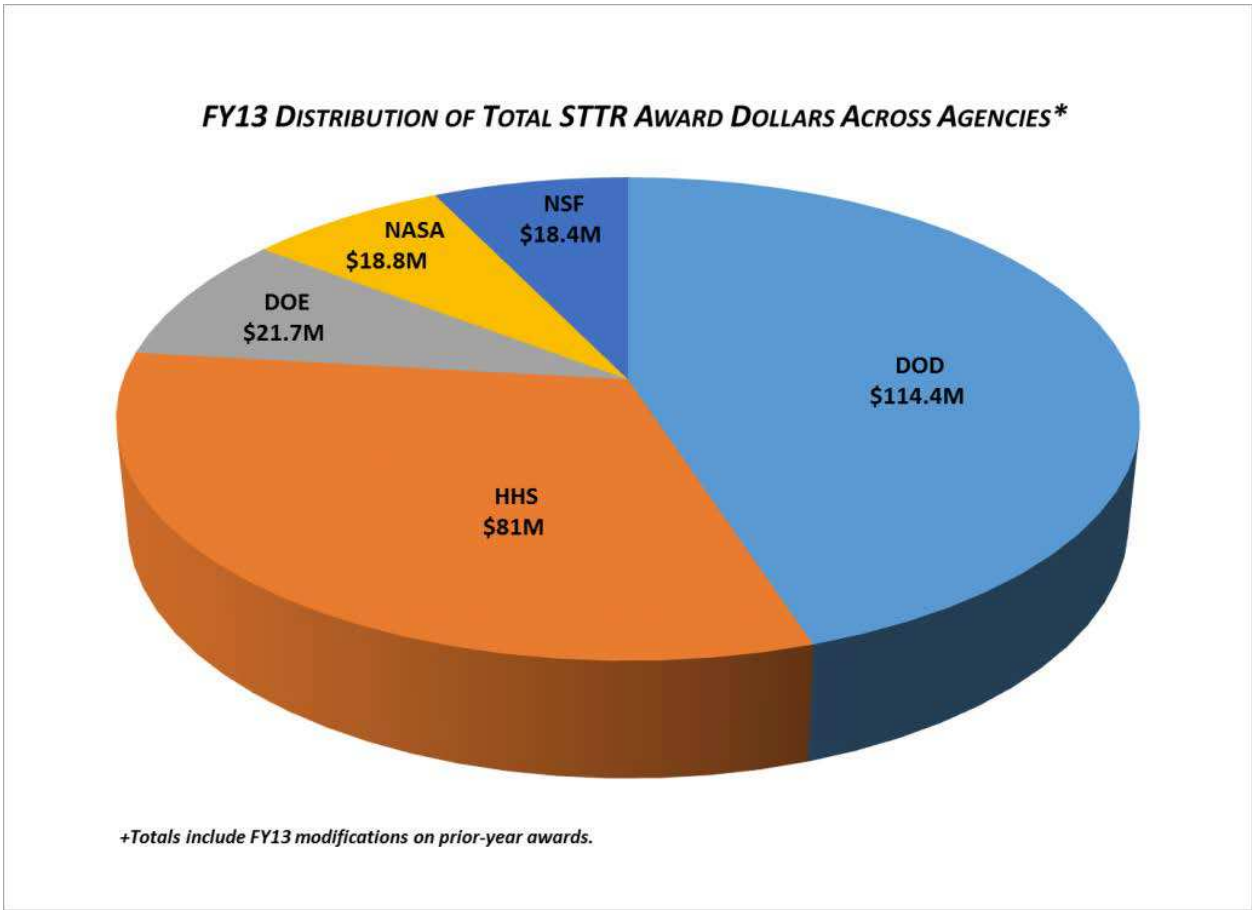
Year	Total Proposals	Total Awards	Phase I Proposals	Phase I Awards	Phase II Proposals	Phase II Awards
2000	1196	328	1026	233	170	95
2001	1111	337	947	244	164	93
2002	1523	470	1289	356	234	114
2003	2040	508	1808	397	232	111
2004	2838	869	2562	674	276	195
2005	3380	832	2931	611	449	221
2006	3776	878	3363	644	413	234
2007	3795	847	3303	634	492	213
2008	3728	734	3264	483	464	251
2009	3271	830	2804	588	467	242
2010	3199	884	2824	625	375	259
2011	2693	720	2155	482	538	238
2012	2743	660	2309	492	434	168
2013	3007	825	2658	476	349	349
TOTALS	**38300**	**9722**	**33243**	**6939**	**5057**	**2783**

Note: It may seem surprising that in FY 2013 all 349 Phase II applicants received awards. But this is the information that the official SBIR website reports.

The following two charts summarize how much each agency spent on SBIR and STTR awards during fiscal year 2013. The "M" in the spending numbers stands for millions.

The source for these two charts is: Small Business Administration, *Small Business Innovation Research, Small Business Technology Transfer, Annual Report, Fiscal Year 2013*, available at: https://www.sbir.gov/sites/default/files/annual_reports/FY13_SBIR_STTR_AR_Final.pdf.




FY13 DISTRIBUTION OF TOTAL STTR AWARD DOLLARS ACROSS AGENCIES*
NSF
$18.4M
NASA
$18.8M
DOE
$21.7M
DOD
$114.4M
HHS
$81M
+Totals include FY13 modifications on prior-year awards.

APPENDIX 2: SOURCES OF ADDITIONAL INFORMATION ABOUT THE SBIR AND STTR PROGRAMS

Information from the U.S. Small Business Administration (SBA)

- The SBA maintains the federal government's official SBIR/STTR website, and that website provides detailed information about the programs: https://www.sbir.gov/. This website also provides Internet links to agency SBIR/STTR websites.
- The SBIR website also includes a set of "on-line tutorials" (information articles) about the SBIR and STTR programs. These tutorials discuss several topics, including basic points about the program, introductions to the SBIR/STTR agencies, the agency solicitations (requests for proposals), and how to prepare a good proposal. The tutorials are available at: https://www.sbir.gov/tutorials.
- The SBA's most recent annual report on the two programs is: Small Business Administration, *Small Business Innovation Research, Small Business Technology Transfer, Annual Report, Fiscal Year 2013*, https://www.sbir.gov/sites/default/files/annual_reports/FY13_SBIR_STTR_AR_Final.pdf.
- SBA's *SBIR Policy Directive* and the similar *STTR Policy Directive* provide overall program instructions to the agencies. The SBIR Policy Directive is available at: https://www.sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf. The STTR Policy Directive is available at: https://www.sbir.gov/sites/default/files/sttr_pd_with_1-8-14_amendments_2-24-14.pdf.

SBIR/STTR Evaluations from the National Academies of Sciences, Engineering, and Medicine

At the request of Congress, the National Academies have conducted a two-phase, 14-year-long evaluation of the SBIR and STTR programs at the five departments and agencies with the largest SBIR programs: the Department of Defense, the National Institutes of Health (part of the Department of Health and Human Services), the Department of Energy, NASA, and the National Science Foundation.

The first phase of the National Academies study took place from 2004 to 2008 and produced several reports. The second phase began in 2009 and will finish at the end of 2016. It also has produced several reports.

In both phases, the National Academies committee: (1) reviewed existing academic and government studies of the SBIR and STTR programs, and (2) gathered new data, through surveys and case studies that asked award winners what commercial outcomes and other benefits resulted from their SBIR-funded R&D.[86]

The Committee then used these existing studies, the new data, its own expertise, and expertise from the SBIR/STTR agencies: (1) to examine how well SBIR and STTR are meeting their Congressionally-defined program goals, including commercialization; and (2) to work with the agencies to identify and share "best practices" to improve program management and outcomes.

A full list of the National Academies' reports, from both phases of its study, is available at: http://sites.nationalacademies.org/PGA/step/PGA_168184. (This website also includes reports from other National Academies studies.)

Additional information is available at the official website for the National Academies' Phase II project: http://sites.nationalacademies.org/PGA/step/sbir/index.htm.

Note: Recently the National Academies changed some of their names. First, the former Institute of Medicine is now called the National Academy of Medicine. Second, for many years the Academies reports said they came from "The National Research Council of the National Academies." The NRC was called the "operating part" of the National Academies, because it was the organization whose committees conducted studies. Today, though, reports simply say "The National Academies of Sciences, Engineering, and Medicine." Third, the Academies sometimes now use the term "NASEM," which means the National Academies of Sciences, Engineering, and Medicine.

Reports from the Congressional Research Service (CRS)

The non-partisan Congressional Research is part of the Library of Congress and produces reports for members of Congress and their staffs. Congress does not allow CRS itself to make these reports available to the public, but some members do give reports to university libraries.

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[86] There is not a large academic literature on SBIR and STTR, but the National Academies committee studied the literature that does exist. For a list of both academic and government studies of SBIR and STTR as well as important studies of the overall U.S. national innovation system, see the bibliography included in the National Academies' 2008 summary report: Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program* (Washington, D.C.: National Academies Press, 2008).

Two CRS reports on SBIR and STTR are particularly useful.

- John F. Sargent, Jr., "Small Business Innovation Research and Small Business Technology Transfer Programs," CRS Report R43695, August 26, 2014, http://digital.library.unt.edu/ark:/67531/metadc809752/?q=SBIR.
- Wendy H. Schacht, "Small Business Innovation Research (SBIR) Program," CRS Report 96-402, November 14, 2012, http://digital.library.unt.edu/ark:/67531/metadc227610/?q=SBIR.

APPENDIX 3: SOME KEY FINDINGS FROM THE NATIONAL ACADEMIES REPORTS

Different Ways in Which DoD's SBIR Awards Have Helped to Transform Small Companies

- Provided first dollars, funding company formation
- Funded product areas where VC and other funders were not interested
- Created connections to acquisition programs
- Opened doors to many potential stakeholders in specific technologies, including agencies, primes, investors, suppliers, subcontractors, and universities
- Helped address niche markets too small for primes and other large companies
- Funded technology development
- Enabled projects with high levels of technical risk
- Supported adaptation of technologies to new uses, markets, and industry sectors
- Provided resources for more diversified expertise, allowed hiring of specialists
- Substituted for private capital funding during economic downturns
- Attracted and developed young researchers
- Redirected company activities to new opportunities
- Developed connections to primes
- Reduced costs
- Helped address needs that require high tech at low volume and relatively low cost
- Moved technology up to Technology Readiness Level (TRL) 7-9 (at which point acquisition funding becomes more likely)
- Provided new companies with greater credibility
- Encouraged researchers to enter business full time
- Helped university researchers manage Intellectual Property (IP) and Information Technology Acquisition Review (ITAR) problems
- Transformed company culture to become more market oriented
- Drove researchers to focus on technology transition
- Supported feasibility testing for high-risk/high-payoff projects (Phase I)

SOURCE: Analysis of company responses to 2011 NRC Survey.

From: Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program – Phase II, *SBIR at the Department of Defense* (Washington, D.C.: National Academies Press, 2014), page 204.

Some Examples of Agency Best Practices

A major strength of the SBIR program is its flexible adaptation to the diverse objectives, operations, and management practices at the different agencies. In some cases, however, there are examples of best practice that should be examined for possible adoption by other agencies. Examples of these best practices include:

DoD: The Pre-Release Period. DoD announces the contents of its upcoming solicitations some time before the official start date of the solicitation. By attaching detailed contact information, prospective applicants can talk directly to the technical officers in charge of specific topics. This helps companies determine whether they should apply and gives the prospective applicant a better understanding of the agency needs and objectives. This informal approach provides an efficient mechanism for information exchange. Federal Acquisition Regulations prevent such discussion after formal release.

DoD: Help Desk and Web Support. DoD maintains an extensive and effective Web presence for the SBIR program, which can be used by companies to resolve questions about their proposals. In addition, DoD staffs a help desk aimed at addressing nontechnical questions. This is appreciated by companies, and is strongly supported by program staff because it reduces the burden of process oriented calls on technical staff.

DoD: Commercialization Tracking. DoD's approach requires companies with previous Phase II awards to enter data into a commercialization tracking database each time these companies apply for SBIR awards at DoD. The database captures outcomes (both financial, such as sales and additional funding by source, and other benefits resulting from SBIR; e.g., public health, cost savings, improved weapon system capability, etc.) from these companies for all their previous SBIR awards, including those at other agencies. It also captures information on firm size and growth since entering the SBIR program, as well as the percent of annual revenue derived from SBIR awards. These historical results of prior awards are then used in proposal evaluation.

Non-DoD agencies should consider adapting both this approach and the DoD technology and contributing to the DoD database. This would provide a unified tracking system. Adaptations could be made to track additional data for specific agencies, but this would provide a cost-effective approach to enhance data collection on award outcomes.

NIH: Resubmission. In many cases, changes in topics between successive solicitations may not allow for resubmission of Phase I proposals. However, agencies should

consider selective use of resubmission of Phase II as a useful way of improving application quality.

NIH: Investigator-driven Topics. While DoD and NASA have focused primarily on topics designed to address specific agency needs, NIH accepts applications that are not directly linked to an explicit topic. Other agencies might consider putting aside some portion of SBIR funds to encourage investigator driven research that does not fall within the "standard" solicitations.

Multiple Agencies: Gap-reduction Strategies. The agencies have, to different degrees, recognized the importance of reducing funding gaps. While details vary, best practice would involve the development of a formal gap-reduction strategy with multiple components covering application, selection, contract negotiation, the Phase I-Phase II gap, and support after Phase II.

NSF: Phase IIB, DoD Phase II Enhancement. The matching fund approach adopted by NSF for Phase IIB and by DoD for Phase II Enhancement might be explored at other agencies. The NSF matching requirement represents an important tool for helping companies to enter Phase III at non-procurement agencies. The DoD funding match by acquisition programs provides a transition link into Phase III contracts with the agency.

DoD-Navy: Technology Assistance Program. The Navy has developed the most comprehensive suite of support mechanisms for companies entering Phase III, and has also developed new tools for tracking Phase III outcomes. These are important initiatives, and other components and agencies should consider them carefully.

NIH: Program Flexibility. NIH is unique in the range of award size, the use of supplementary funding, the competing continuation awards (now called Phase II Competing Renewals Awards) that provide funding for post-Phase II activities, and the use of no cost extensions for awards. While this flexibility may require additional review at NIH, as recommended in the NIH Report, it is also an effective way for agencies to meet the varying needs of small research companies.

DoE: Commercialization Assistance. DoE has the longest running commercial assistance program, and a broad menu of possible services. These have now been widened to include Phase I recipients. This extended range of offerings seems well adapted to improve fits between the varied Departmental needs of small business capabilities.

NASA: Innovative Electronic Interface. NASA has pioneered the development of an innovative electronic interface designed to help applicants navigate the complex process of applying for awards and managers track and assess program activities.

From: Committee for Capitalizing on Science, Technology, and Innovation: An Assessment of the Small Business Innovation Research Program, *An Assessment of the SBIR Program* (Washington, D.C.: National Academies Press, 2008), pages 80-81.