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Becoming America's Seed Fund: Why NSF's SBIR Program Should Be a Model for the Rest of Government

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The National Science Foundation's Small Business Innovation Research (SBIR) program focuses on high-growth startups and commercializing federally funded research and development (R&D). Other federal agencies should consider emulating this model.

KEY TAKEAWAYS

- SBIR is a federal program coordinated by the Small Business Administration that funds small business R&D. The program has helped seed companies such as Apple, 23andMe and Qualcomm, and has been copied by 17 countries around the world.
- Over the past two decades, the National Science Foundation (NSF) reinvented its SBIR program to specifically target growth-focused startups and to emphasize commercializing innovations derived from federal R&D.
- Other agencies should follow NSF's model and do more to target growth-focused companies, centralize program management, hire dedicated program directors, and coordinate SBIR awards with other agency programs that provide support for commercialization.
- Congress should reform SBIR funding to grant agencies more autonomy, require agencies prioritize commercialization potential in funding decisions, allow awardees to use funds for commercialization activities, and increase federal funding for R&D.

If the United States is to solve its most pressing challenges, including sustaining prosperity, improving public health, ensuring national security, and combating climate change, it must expand, diversify, and accelerate innovation. Small businesses with big ambitions to develop and commercialize new technologies have the potential to play these critical roles in America's innovation ecosystem. But many are not able to realize this potential due to a lack of early-stage capital.

The federal government's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are designed to help fill this gap, but they do so imperfectly. The authorizing legislation for SBIR and STTR—which are typically considered one program and will be referred to here as SBIR, for simplicity—lays out several goals: stimulating technological innovation, addressing federal research and development (R&D) needs, supporting social and economic diversity among small businesses, and, finally, commercializing new technologies. The agencies implementing the program have substantial discretion to prioritize these goals.

NSF reinvented its SBIR program over the past two decades to focus more sharply on one of the program's objectives: commercializing innovations derived from federal R&D.

The National Science Foundation (NSF) has an effective program that is worthy of examination—and perhaps emulation—across much of the federal enterprise. NSF reinvented its SBIR program over the past two decades to focus more sharply on one of the program's objectives: commercializing innovations derived from federal R&D. And over the past five years alone, NSF's SBIR awardees have received $6.5 billion in private investment and had 87 exits.[1] We draw on original interviews with program stakeholders, quantitative data, and prior research to further illustrate NSF's progress toward promoting commercial success among small businesses.

The report concludes by setting forth a model, drawn from the NSF experience, SBIR programs in other agencies should consider. The approach would more effectively stimulate private-sector commercialization of SBIR-funded R&D, thereby enhancing the impact of this federal investment to benefit society. It involves:

- Targeting growth-focused companies;
- Centralizing program management;
- Hiring dedicated program directors; and
- Coordinating SBIR awards with other agency programs that provide support for commercialization.

We also describe steps Congress should take to support agencies seeking to implement the model, notably:

- Reforming SBIR funding to allow agencies more autonomy;
- Requiring agencies to increase the weight of projects' commercialization potential in funding decisions;

- Allowing small businesses to use a portion of SBIR awards for commercialization activities; and
- Increasing overall federal funding for R&D.

THE ISSUE FACING INNOVATIVE SMALL BUSINESSES: A CAPITAL GAP

Solving the nation's most pressing challenges requires bold technological innovations to be brought from conception to commercialization. Improving health outcomes depends in part on the development of new therapies and medical devices. Eliminating carbon emissions requires innovations in energy supply, management, and use. Creating whole new industries, which is central to the U.S. economic model, requires a robust innovation ecosystem.[2]

New growth-oriented, technology-driven businesses play a key part in this innovation ecosystem, whether they ultimately grow large themselves or their assets are eventually acquired by a large firm. Such innovative start-ups often pursue ideas more established firms fail to spot or won't invest in. They may also pursue ideas very similar to those of larger competitors, but do so more nimbly or creatively. Each wave of information technology (IT) over the past few decades, to take the most prominent example, has been characterized by the emergence of start-ups that grew to be major employers and household names—from Intel in the 1960s and 1970s to Apple, Microsoft, and Qualcomm in the 1980s and 1990s to Google, Facebook, and Amazon in the 2000s and 2010s.[3]

However, a substantial body of research suggests that ambitious new businesses often face daunting barriers when they seek investment. To be sure, these ventures are risky and ought to pay a premium relative to more established and diversified companies to cover that risk. But even when analysts adjust for risk, "severe financial frictions," as New York University economist Sabrina Howell put it, that disadvantage such firms remain.[4]

Borrowing from banks is rarely an option for innovative new businesses because they typically lack collateral and revenue. Venture capital fills the capital gap in some sectors, particularly IT, where upfront investments are modest, and returns can be extremely large and relatively quick. However, in many other economic sectors, as well as in many regions of the country outside of technology hubs, venture capital is not available. For instance, as a recent working paper from the MIT Energy Initiative puts it, venture capital is "the wrong model" for clean energy hardware start-ups, because the upfront investment is large, and the returns may take a decade or more to materialize.[5]

Some indicators suggest that the capital gap may be growing, particularly for the earliest-stage start-ups. Venture capital has been flowing toward deals that are larger and later stage, often after the viability of a product has already been demonstrated. The number of seed-stage deals declined approximately 46 percent over the past three years, while overall venture funding has increased.[6] Moreover, only 20 percent of such funds have gone to ventures outside the IT sector.[7]

Many states have established seed-stage investment funds to aid local entrepreneurs who want to start and grow innovative companies. These funds tend to be modest in scale and constrained in scope; they have barely made a dent in the problem. The federal government's SBIR program,

which the U.S. Small Business Administration (SBA) has labeled "America's Seed Fund," deploys more than $3 billion annually, and has the potential to fill a much larger portion of this early-stage capital gap.

THE SBIR PROGRAM

NSF program officer Roland Tibbets developed SBIR for NSF in 1977, after which Senator Edward Kennedy (D-MA), with SBA's backing, spearheaded a push to expand it across the federal government. Partly in response to concerns about growing foreign economic competition, President Reagan signed the resulting Small Business Innovation Development Act into law in 1982.[8] A decade later, Congress enacted the STTR program, which differs from SBIR only in that it requires small business awardees to partner with research institutions.[9] The current authorizing language for both programs lies in the Small Business Act.[10]

SBIR has four statutory objectives:

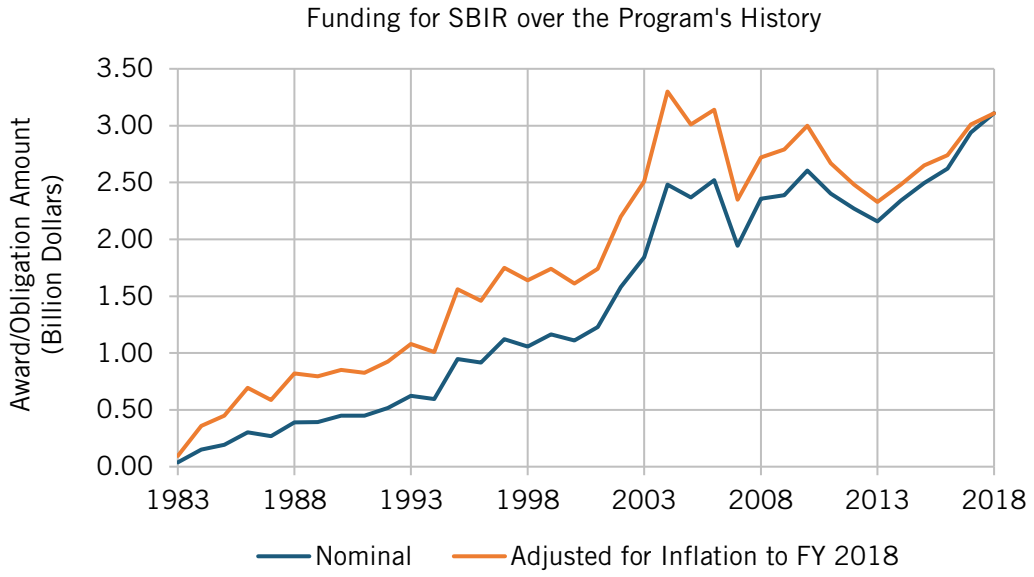
1. Stimulate technological innovation;
2. Use small business to meet federal R&D needs;
3. Foster and encourage participation by socially and economically disadvantaged small business concerns (SBCs) and women-owned SBCs in technological innovation; and
4. Increase private-sector commercialization of innovations derived from federal R&D.[11]

Program Structure and Funding

Federal agencies that support over $100 million per year in extramural research (i.e., research conducted outside of the agency) are required to commit at least 3.2 percent of these funds to SBIR, while agencies with extramural research budgets over $1 billion are required to devote an additional 0.45 percent of these funds to STTR.[12] Five federal agencies with large extramural research budgets provide both SBIR and STTR awards and collectively fund 97.5 percent of the program: the Department of Defense (DOD), Department of Energy (DOE), Department of Health and Human Services (HHS), National Aeronautics and Space Administration (NASA), and NSF. Six other agencies fund the remaining 2.5 percent of the program, providing SBIR awards but no STTR awards: the Department of Agriculture, Department of Commerce, Department of Education, Department of Homeland Security, Department of Transportation, and Environmental Protection Agency.

Figure 1 shows total funding provided by SBIR since its founding. The program obligated over $3.1 billion in fiscal year (FY) 2018.

Figure 1: Total funding for the SBIR program across all agencies has increased to $3.1 billion as of FY 2018. The awarded amount is shown for 2014 and beforehand, and the obligated amount is shown for 2015 and thereafter[13]



SBA serves as the coordinating agency for the SBIR program, although it does not fund R&D. It reviews the implementing agencies' progress, and reports on the program to Congress. Most important, SBA is responsible for issuing a policy directive that outlines implementation guidance for agencies, which was updated most recently in May 2019. The policy directive provides specific instructions on a range of topics, such as the timelines on which solicitations must be issued and reviewed; how to minimize regulatory burdens; reporting requirements; and procedures to ensure awardees are more likely to receive additional agency funding beyond the scope of the SBIR program.[14]

To be eligible for SBIR, an applicant must qualify as an SBC.[15] An SBC is a for-profit entity with a place of business in the United States, over 50 percent U.S. ownership, and no more than 500 employees. In 2018, federal agencies awarded nearly 6,000 SBIR awards to over 3,000 SBCs.

As stated in the program objectives, the SBIR program endeavors to increase participation by women, socially or economically disadvantaged individuals, and businesses in underrepresented areas. The SBA's Federal and State Technology (FAST) Partnership Program funds state and regional efforts to increase the number of applications from these groups to the SBIR program.[16]

A key feature of the SBIR program—and one that is common across awards from all participating agencies—is its three-phase model. Table 1 shows the objectives, eligible applicants, maximum award amounts, and award durations for each SBIR phase. In brief, Phase I awards help agencies determine the feasibility of a project, and Phase II awards enable companies to further carry out their projects, complete the R&D requested of them by the agency, and develop a technology that may be commercialized. These awards each require separate applications to an agency's SBIR program, and typically only Phase I awardees are eligible for Phase II awards. Phase III refers to an agency's continued support for former SBIR awardees' commercialization efforts without using SBIR funds, typically through government procurement contracts. For

phases I and II, agencies also have some flexibility in instituting award amounts and durations above and below the values shown in Table 1.[17]

Table 1: The SBIR program funds businesses using a three-phase model[18]

	Phase I	Phase II	Phase III
Objective	Establish technical merit, feasibility, and commercial potential of proposed effort and assess a small business's performance	Continue R&D from Phase I, with funding based on the results achieved during that time	Allow small businesses to pursue future commercialization objectives through alternative agency funding mechanisms (i.e., not the SBIR set-aside)
Eligible Applicants	Small Business Concerns	SBIR Phase I Awardees	SBIR Phase I/II Awardees
Typical Maximum Award Amount	$150,000	$1,000,000	N/A
Typical Award Duration	6 months	2 years	N/A

Table 2 shows the total number of awards and budgets associated with each of the major SBIR agencies for FY 2018.

Table 2: Five agencies fund the vast majority of all SBIR awards as of FY 2018[19]

Agency	Awards	Firms	Avg. Awards per Firm	Total SBIR Budget (in Millions USD)	Percent of Total
DOD	2,226	1,006	2.2	1,314	42.3%
HHS	1,575	1,187	1.3	1,061	34.1%
DOE	602	397	1.5	278	9.0%
NSF	400	400	1.0	197	6.3%
NASA	515	333	1.5	183	5.9%
Other	292	261		77	2.5%
Total	5,610	3,584		3,110	100%

DOD and HHS provide the majority (76.4 percent) of funding across the federal government; DOE, NSF, and NASA provide most of the remainder (21.2 percent); and the other six agencies funding the program collectively provide a relatively small amount (2.5 percent).

It is worth noting that for many SBIR agencies, SBIR set-asides are not treated as a single pot of money. Agencies such as DOD and the National Institutes of Health (NIH) at HHS essentially operate a number of autonomous programs across different branches, institutes, and centers. And for certain agencies, such as DOE, congressional language dictates specifically how much SBIR funding should be allotted to specific programs and offices.[20] This restriction can limit an individual program to only funding one to a few awards per year, which could impede its ability to support new and existing projects effectively. Subdivisions of agencies can also be protective of their SBIR budgets. When the set-aside is perceived as being drawn directly from their full research budgets, the program is often seen as a tax.

At NSF, appropriations are allocated as a lump sum, there are no congressional restrictions on how they must be spent, and the program is not seen as a tax on its directorates because they play no role in the program; rather, the whole SBIR program's management is centralized in one office.

Within the framework provided by Congress and SBA, agencies have significant flexibility in how they administer the program. Their choices reflect their missions, resources, and priorities among the program's four goals. They may structure the program to meet these goals through the designation of R&D topics, issuing of solicitations, review and selection of grant proposals, and assessment of companies' performance.

The average number of SBIR awards won per firm is an indicator that offers insight into how agencies manage their programs. For instance, NSF provided a single award to each company it funded in 2018, whereas DOD provided on average over two awards to each company. These numbers reflect NSF's model of funding start-ups, and DOD's frequent use of the program for contract research to deliver specific technologies for its use.

Commercializing Innovation Through SBIR

SBIR funding has helped enable awardees to generate 70,000 patents, found nearly 700 publicly traded companies, and garner approximately $41 billion in venture capital investments in its 35-year history.[21] SBIR alumni include success stories such as 23andMe, Apple, and Qualcomm. An ITIF review of award-winning innovations from 1970 to 2006 highlighted by *R&D Magazine* found that about one-quarter were developed by companies that had been supported by SBIR.[22] The program has been copied by 17 countries around the world.[23]

Individual agency programs have also been shown to have significant economic impacts. A 2018 study of the National Cancer Institute's SBIR program related $26 billion in economic output, $9.1 billion in sales, and over 100,000 new jobs to companies that were awarded Phase II grants between 1998 and 2010.[24]

Still, there is room for improvement, especially in improving the commercialization of innovations funded by the program. Some agencies administer the program with a greater emphasis on the technologies funded than the businesses supported—often to address specific R&D needs that

have been identified by agency subject-matter experts or to build technologies that the agency itself may need to use.

This strategy is certainly a legitimate use of the SBIR program. But a consequence of prioritizing technologies over businesses is agencies may concentrate a share of SBIR funding among a subset of the applicant pool: companies that have previously received many awards, use contract research as their business model, and have relatively little incentive to grow and commercialize their work.

Prior research suggests that favoring repeat awardees detracts from the program's objective of promoting the commercialization of federally funded innovation and economic growth. A study measuring outcomes across SBIR programs found that companies that continually sought SBIR contracts were less likely to commercialize the outputs of their research.[25] Another study, which examined SBIR awards from DOE's Office of Energy Efficiency and Renewable Energy, found that firms tend to produce 20 percent fewer patents with each additional previous SBIR award, and firms with previous SBIR awards have half the probability of acquiring subsequent venture capital investment compared with firms with no prior awards.[26]

NSF's SBIR program concentrates on seeding new companies that can develop transformative technologies, and distributing its funding widely among companies with high potential for growth. However, the program has not always been managed this way.

SBIR AT NSF

NSF is one of the five largest agency funders of the SBIR program. As shown in table 2, in FY 2018, with a budget of $197 million, NSF funded 400 SBIR awards that amounted to 6 percent of SBIR funding across the federal government. The program is housed within NSF's Division of Industrial Innovation and Partnerships within the Directorate of Engineering.

NSF has reinvented its program over the past two decades in ways that distinguish it from those of many other agencies, and bring to life the government-wide slogan, "America's Seed Fund." Perhaps most important, the agency has chosen to strengthen the program's role in promoting the commercialization of SBIR-funded innovations and company growth in line with the statutory objectives for SBIR. A 2015 study of the NSF SBIR program by the National Academies of the Sciences, Engineering, and Medicine (NASEM) finds that the program does meet all of the statutory objectives for SBIR, with the exception of sufficiently encouraging participation by women and minorities.[27] (This failure is not limited to NSF, which performs about as well on this objective as the other major SBIR agencies.)[28]

To this end, the program has aimed most of its funding at start-ups, as opposed to well-established small businesses. NSF has also shifted away from a decentralized management structure in which program directors across the agency dedicate a small part of their time to the SBIR program; dedicated SBIR program directors are based in a single office and support the program full-time, engaging with companies before and after they are awarded grants. NSF has also instituted additional programs within and outside SBIR to further support the ability of awardees to commercialize the outputs of their R&D.[29]

A Focus on Commercializing Innovation

According to Benaiah Schrag, who serves as NSF's senior program director for SBIR and has been with the program since 2009, these changes to the program happened relatively organically. They were driven by a changing vision among program administrators of what NSF's SBIR program should focus on—driving commercialization and economic growth—and a recognition of the types of awardees and program structures that would enable NSF to meet its objectives.[30] Three elements of NSF's program demonstrate its goal to maximize commercial output: its focus on start-ups, the topical flexibility of its solicitation, and the emphasis on commercialization in its Phase I and Phase II solicitations.

NSF focuses on funding start-up companies, as opposed to more well-established small businesses. Schrag said that NSF's emphasis on start-ups was not the "result of a top-down mandate," but rather of "working with a lot of different types of companies and seeing over time that the start-up companies tend to outperform other companies in terms of the commercial outcomes."[31] This approach is in contrast to some other SBIR agencies, such as NASA and DOE, that tend to give greater consideration to the capacity of firms to fulfill a specific R&D need, with less regard to size or the number of prior SBIR awards.[32]

To target start-ups, NSF values applications from companies that have not previously received SBIR awards, and limits the number of awards given to the same company. One program director interviewed as part of the 2015 NASEM study on NSF's SBIR program stated he intentionally avoids offering multiple Phase II awards to the same company.[33] NSF has institutionalized this approach by limiting the number of applications a company can submit: currently one application per each of the two annual calls for proposals.[34] This strategy has increased the number of new applicants to the SBIR program, reduced the number of applications it receives, and dissuaded companies from using NSF as a "second shot on goal" for proposals that had been rejected from other agencies.[35] The award data in table 2 shows that each of the 400 companies awarded by NSF in FY 2018 received precisely one award.

While NSF is not the only federal agency committed to supporting basic research, its mission is unique in that it seeks to advance all fields of science and engineering (with exceptions in the medical sciences) and does not aim to use the outputs of the research it funds. Consequently, NSF's SBIR program uses its wide latitude to promote the most promising businesses and ideas across all fields, wherever there are opportunities for commercial and societal impact.[36] This flexibility is reflected in NSF's SBIR solicitation. The agency requests projects that fall within a wide range of scientific topics, and does not automatically exclude proposals that fall outside of these areas (for which there is an all-encompassing "Other Topics" category).[37] The full set of topic areas, shown in table 3, is reflective of the areas of research the entire agency supports. In the words of one program director, it is "unlikely that a good project would not find a topic."

Agencies such as NASA, DOE, and DOD only support technologies that align with their narrower missions. In many cases, they are also looking to serve as downstream buyers of the technologies they fund. They therefore typically request that SBIR applicants address narrower, predefined R&D needs. As an example, an FY 2016 DOE solicitation issued a call for a "single bounce monolithic axis symmetric x-ray mirror optics with parabolic surface profile."[38] At NSF, a similar project might be submitted to the broader call for advanced optical components and systems under the Photonics topic area.

Finally, NSF has integrated its focus on commercialization into its solicitation. One driver of this effort was Errol Arkilic, who served as a program director from 2003 to 2011 and was among the team that was charged with improving the SBIR program to increase commercial output. Arkilic described working with a team of investors and industry partners to reform the commercialization work plan, an element of the Phase II application. The new commercialization work plan better reflects what private investors look for, such as market potential, subsequent finance plan, and the company's track record of commercialization. A similar line of questioning evaluating companies' commercial potential was added to the Phase I application, where previously there had been no discussion of commercialization.[39]

These changes, especially the limitation on applications per company and inclusion of a commercialization history, initially caused "an enormous amount of friction" among some SBIR applicants, according to Arkilic. He described a community of small companies, referred to by some as "SBIR mills," that had been using the SBIR program for 20 years as a means of conducting contract research, with relatively few attempts to commercialize their work. These companies would often use NSF as a backup application for SBIR proposals submitted and rejected elsewhere, given NSF's all-encompassing solicitation. Eventually, he said, the new measures instituted by the agency caused these companies to stop applying for NSF's SBIR support.[40]

Table 3: The Technology Topic Areas offered by NSF's SBIR program cover a wide range of disciplines and applications. NSF will also consider applications outside of these areas[41]

NSF SBIR Program Technology Topic Areas	
Advanced Manufacturing	Advanced Materials
Artificial Intelligence	Biological Technologies
Biomedical Technologies	Chemical Technologies
Digital Health	Distributed Ledger
Educational Technologies and Applications	Energy and Power Systems
Environmental Technologies	Information Technologies
Instrumentation and Hardware Systems	Internet of Things
Medical Devices	Nanotechnology
Other Topics	Photonics
Quantum Information Technologies	Robotics
Semiconductors	Sensors
Space	Wireless Technologies

Centralization of Program Management and Hiring of Dedicated Program Directors

Beginning in the mid-to-late 1990s, NSF reorganized the management of its SBIR program to better meet its focus on commercialization. The agency centralized the program in one office and began hiring full-time SBIR program directors. These program directors are "effectively in charge of the entire grant stream" from seeking out companies that would be strong SBIR candidates,

reviewing applications and making recommendations, and supporting their awardees throughout the duration of their SBIR awards.[42] At NSF, there are currently 11 program directors, each of whom handles a section of NSF's science and technology portfolio.

NSF values entrepreneurial expertise in SBIR program management. NASEM's review noted that, as of 2015, "all [program directors] have strong backgrounds in the commercialization of technology," in addition to "deep knowledge of specific fields," with seven of the nine program directors holding Ph.D.'s.[43] For instance, Benaiah Schrag joined the program from an SBIR-funded start-up developing high-performance magnetic microsensor products.[44] Errol Arkilic joined the program after serving as the president and CEO of a venture-backed start-up in Silicon Valley.[45] Nearly all of NSF's program directors today have strong backgrounds in entrepreneurship.[46]

Most of the other SBIR agencies have decentralized management structures (although the National Cancer Institute at NIH is an exception).[47] For instance, at DOE, the duties of managing the SBIR program are spread among roughly 100 people; SBIR accounts for a relatively small portion of these officials' portfolios; and individuals may only be responsible for one stage of the grant process, such as proposing solicitation topics or serving as a technical point of contact.[48] The technical points of contact at DOE and other agencies with decentralized management structures are typically subject-matter experts, but are not necessarily experienced in entrepreneurship.

Additional Institutional Support for Commercialization of Innovations

NSF has also added institutional support to help bolster companies' commercial prospects. Two key examples are the Innovation Corps program (I-Corps) and Phase IIB funding—both of which have been adopted by other agencies. The I-Corps program, which was developed by NSF with entrepreneur Steve Blank, is a seven-week boot camp in which companies learn how to commercialize their innovations through "training in customer discovery and guidance from established entrepreneurs."[49] While I-Corps and SBIR are separate programs, they are linked: The SBIR program is pitched to graduates of the I-Corps program, and all SBIR awardees are strongly encouraged to participate in a condensed version of the I-Corps program.[50] The development of I-Corps was also motivated by an issue observed in the SBIR program, that many companies were failing "due to insufficient engagement with, or understanding of, their customers and market."[51]

NSF pioneered the Phase IIB program in 1998 to bridge the "valley of death" companies face between the end of government funding and commercial revenue or private investment.[52] The Phase IIB program provides supplemental funding to Phase II awardees that can leverage funding from an external third party (typically a venture capital fund). Arkilic described Phase IIB as "one of the most significant elements of the change [to NSF's program]" and a "real pure measure" of a company and project's commercial viability.[53] The director of the NSF Division of Industrial Innovation & Partnerships, Kesh Narayanan, testified in 2009 to Congress that awardees who "[qualified] for Phase IIB have had better success in commercializing their innovations. After 5 years, about 69 percent of companies that received Phase IIB funding were successful, whereas only 30 percent of those not having a IIB supplement were successful."[54]

IMPACTS OF NSF'S SBIR PROGRAM

In the process of conducting this study, two current and former NSF program directors; four agency officials involved in the SBIR programs at other agencies; a pair of SBIR consultants; and eight founders of small businesses who had received awards from multiple agencies, including NSF, were interviewed. (See appendix A). These conversations, data from SBIR.gov, and the NASEM study and others yielded several findings about the impact of NSF's reinvention of its SBIR program:

- NSF has increased the share of companies in its portfolio receiving only one Phase II award, which is indicative of the agency's shift toward targeting innovative, growth-focused start-ups. In this respect, NSF's portfolio is starkly different from those of other SBIR agencies.
- Small businesses have a high level of satisfaction in NSF's SBIR program, although they also indicate ways the program can improve.
- Companies awarded SBIR grants by NSF have demonstrated substantial commercial success.

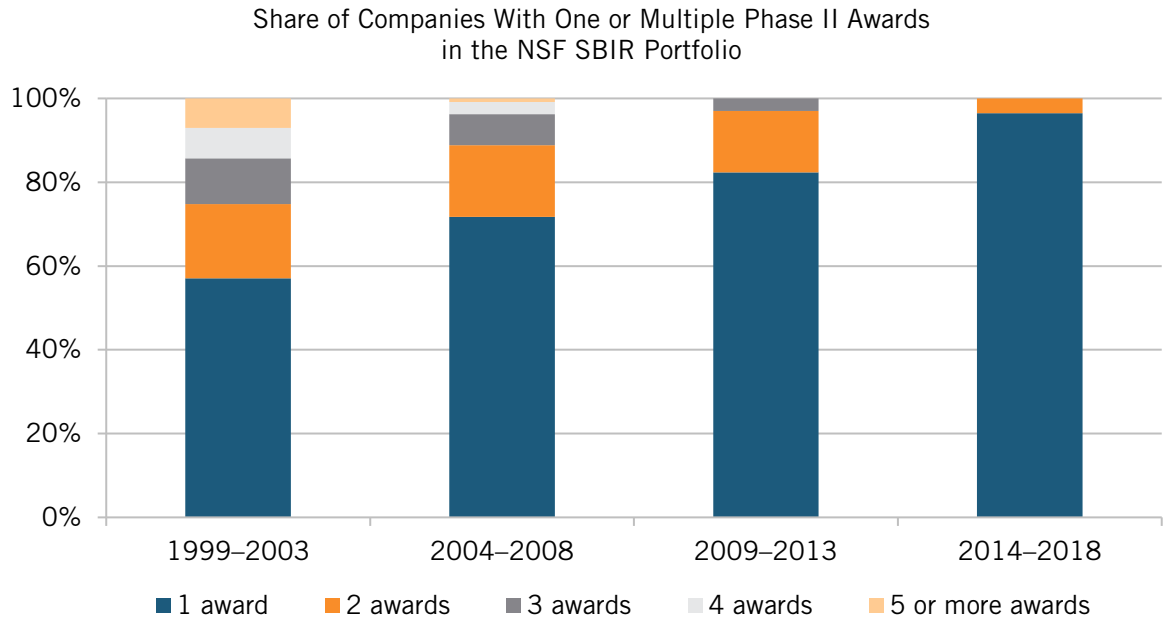
Funding for Start-Ups

NSF has sought to increase the number of start-ups it funds, and to provide these companies with a stream of investment (Phase I, Phase II, and potentially Phase IIB) intended to enable them to access follow-on private investment. Its portfolio is start-up-heavy: As of 2019, 56 percent of the firms it funds have been in existence for less than 24 months, 74 percent of these firms have 0 to 3 employees, 96 percent have received no prior Phase II SBIR/STTR award, and 47 percent of firms are submitting for the first time to NSF.[55]

To build this portfolio, NSF aims to limit the number of companies it funds that might receive high numbers of SBIR grants without effectively commercializing their R&D. One metric to measure this is the share of companies in NSF's Phase II portfolio that have received only one Phase II SBIR award, most of which are likely first-time awardees (Phase II awards are analyzed here because they represent a more significant investment on the part of the agency than Phase I awards).

Figure 2 shows the share of companies with one or more Phase II SBIR awards from NSF and all other SBIR agencies in four five-year periods, starting in 1999. The growth of first-time awardees in the portfolio is clear, rising from 57 percent to over 96 percent over 20 years. NSF's focus on promoting start-ups has clearly taken hold.

Figure 2: The share of first-time Phase II awardees in NSF's portfolio has increased over the past two decades, which is indicative of NSF's effort to target start-ups[56]



NSF's performance in this indicator is unique. Figure 3 shows the share of companies holding one or multiple Phase II awards within the portfolios of each of the major SBIR agencies from 2014 to 2018. While NSF funds nearly entirely first-time awardees, NIH provides only about half of its Phase II awards to companies with no prior awards; and DOE, DOD, and NASA only provide about one-quarter of their Phase II awards to companies with no prior awards. Figure 4 shows DOD's approach in further depth. Nearly as many awards were received by companies with over 20 awards as were received by companies with a single award.

Figure 3: NSF is unique among major SBIR agencies in that the vast majority of companies in its portfolio have only received one Phase II SBIR award[57]

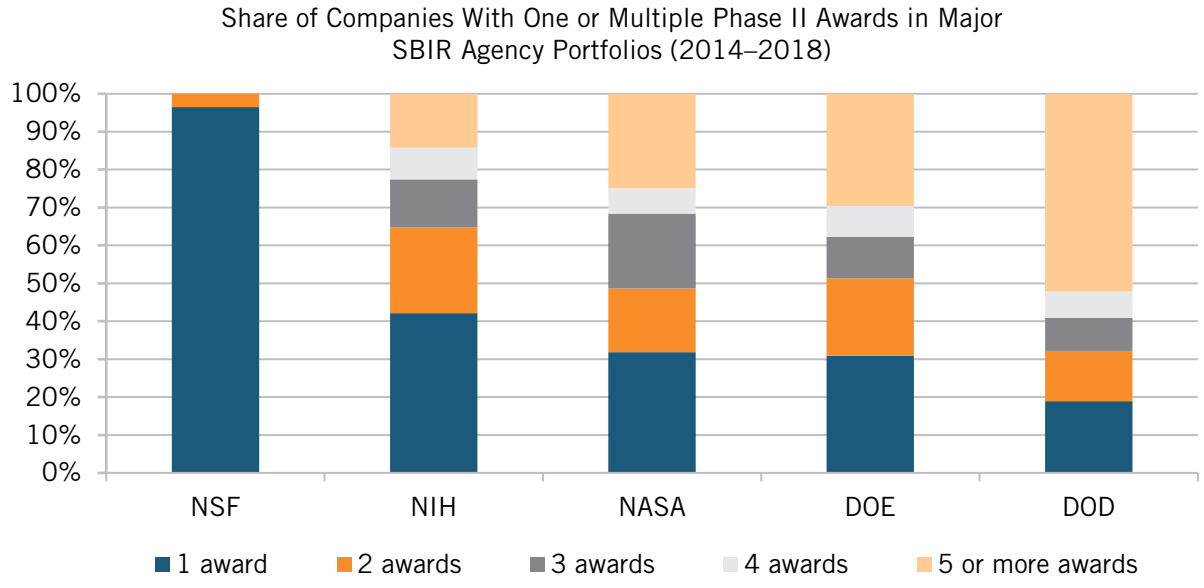
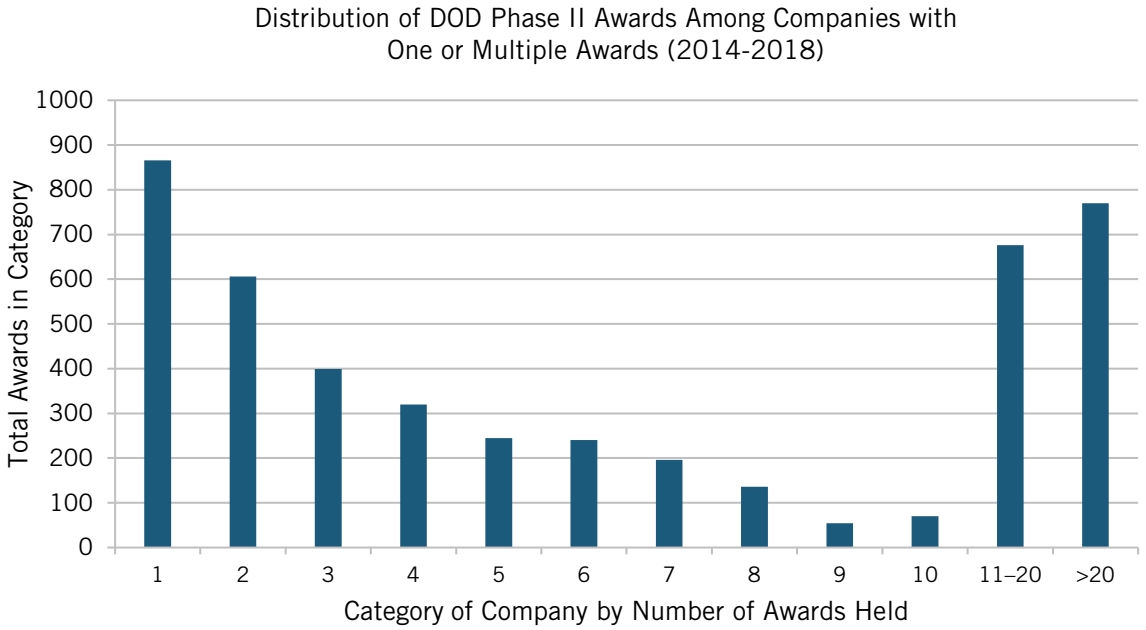


Figure 4: In contrast to NSF, a large number of DOD's awards are held by companies that are recipients of multiple awards[58]



Data from SBIR.gov shows that across all SBIR agencies, the number of small businesses that procure many awards is not insignificant. In fact, 47 percent of all SBIR Phase II awards in the program's history have gone to companies that have received more than 10 Phase II awards. This includes the 18 percent of all Phase II awards that have gone to companies receiving over 50 Phase II awards. And 25 individual companies have received over 100 Phase II awards, collectively obtaining 10 percent of all Phase II awards in the program's history.[59]

A Supportive Environment for Small Businesses

Interviews with recipients of NSF's SBIR awards suggest the program is providing strong support to small businesses. Awardees have praised the relationship the program directors have with the companies, and the topical flexibility of NSF's program, both in the solicitation phase and during Phase I, as applications of R&D can evolve. One interviewee described NSF's program as a meritocratic system, as opposed to a bureaucratic one.[60]

NSF AWARDEE STORIES

These stories of NSF SBIR awardees illustrate the kinds of innovative businesses the program supports, as well as its impacts.

Opus 12

Etosha Cave is the founder and chief science officer of Opus 12, a start-up that is developing a process to convert carbon dioxide into higher-value products such as diesel fuel or plastics. The research underpinning the company—which she founded with a lab mate and another MBA student at Stanford University—was borne out of her graduate work there. As the company progressed through the Cyclotron Road program (an entrepreneurial fellowship with Lawrence Berkeley National Laboratory (LBNL) that provides funding, Berkeley Lab space, and other support), SBIR funding became the best option to sustain and grow it. In fact, few other options were available. Opus 12 has received SBIR awards from NASA, DOE, DOD, and NSF. Of the NSF program, Cave said, "[T]hey've brought in program [directors] who want to see America be innovative again," and are fulfilling the role of "true early stage investors." She also stated that program directors have been supportive, providing helpful feedback when she was an applicant and, as an awardee, making an effort to ask her what they could do better to help companies such as hers. She added that she's been really impressed by what they've done and feels proud to be a part of it.[61]

CinderBio

Jill Fuss is the cofounder and chief technology officer of CinderBio. This start-up uses heat- and acid-stable enzymes derived from microbes that live in hot volcanic waters, such as those in Yellowstone National Park, to enhance the efficiency of industrial processes. Fuss, a scientist who has been working at LBNL for 17 years, cofounded CinderBio in 2012 with a colleague and CinderBio's CEO, Steve Yannone, based on work from his laboratory. They applied to SBIR after their business had raised enough funds to rent an independent lab space. Their first successful proposal won an NSF award to develop products that would improve cleaning processes in the dairy industry. Fuss said that what they liked about NSF was that it was more "risk tolerant" and that it "like[s] to be the first money in." She added, "[T]he philosophy seemed to be a good fit for us." Fuss's experience with the program was positive overall, and she praised the program director for being knowledgeable and understanding about the needs of new start-ups and for being accessible, in part by holding remote "office hours on Fridays." Since winning the NSF award, CinderBio has gone on to win an SBIR award from NIH and a Cyclotron Road fellowship. CinderBio, along with its corporate partners, is currently field testing products for cleaning and sanitation in the food and beverage industry, as well as products for use as laboratory reagents, with expected sales to begin next year.[62]

Some interviewees attributed their experiences with different agencies to the individual who was their program director or technical point of contact, and simply saw NSF's program as one of several that gave them money to do their work. Interviewees also highlighted a few areas in which the program could improve, such as streamlining the application process and improving the quality of proposal reviews.

A NASEM survey in 2011 of Phase II awardees from FY 1998 to FY 2007 funded by all SBIR agencies confirmed that "the 'NSF' Model revolves around the role of the [program director]," and that overall respondents reviews of NSF's SBIR program directors were "highly positive." The following survey results are indicative of the level of support companies feel program directors provide:

- Nearly 90 percent of respondents said it was easy to contact their program director.
- Over 40 percent of respondents said their program directors were highly useful, and 30 percent found their program directors were moderately useful.
- 97 percent of respondents thought their program directors were somewhat to extremely knowledgeable about the SBIR program.
- 19 percent of respondents said their program directors provided substantial support in making connections with private firms, and 15 percent said the same of connections with universities.[63]

In summarizing its description of the NSF model, NASEM wrote, "Overall, the NSF model is intelligently designed and executed by dedicated and highly credentialed staff that appears to be capable of making the judgments demanded by the system."[64]

Commercial Success

The NASEM survey also found evidence showing NSF's SBIR program's support for commercialization:

- About 70 percent of Phase II respondents reported sales, and an additional 19 percent anticipate future sales.
- Respondents grew on average from 6 employees at the time of the award to 10 employees at the time of the survey, a period of 4 to 13 years.
- 80 percent of respondents said Phase II accelerated commercialization of their product or services, and nearly one-quarter of Phase IIB projects had project-based revenues of $3 million or more.
- About 70 percent of respondents said the project likely would not have continued without SBIR funding.[65]

NSF has funded 3,000 awards since 2012. Since 2014, its awardees have received $6.5 billion in private investment, and had 87 exits (i.e., had private investors sell their stakes in order to realize their returns on investment).[66] A more complete picture of how NSF's portfolio of companies has fared could be compiled by tracking publicly available data such as follow-on investment, exits, mergers, acquisitions, and initial public offerings. NSF has been conducting such an analysis and may publish these results in the future.[67]

IMPLICATIONS OF THE NSF MODEL FOR OTHER AGENCIES

SBA proclaims that SBIR is "America's Seed Fund." NSF's SBIR program is arguably playing that role more effectively than its counterparts. NSF has a well-designed system to select innovative businesses and enable them to create and commercialize new technologies, consequently fulfilling key objectives of the program's statutory mission. It is true that no other agency has as broad a mandate as NSF—or the flexibility that comes with it. However, some other SBIR-awarding agencies, or parts thereof, could and should strengthen their programs to better embody "America's Seed Fund."

SBIR Beyond NSF: Agency Highlights

To evaluate the applicability and potential benefits of the NSF model to other agencies, it is useful to understand how other agencies operate their SBIR programs. Three of the civilian programs are highlighted as examples here: that of DOE, NASA, and the National Cancer Institute (NCI) at NIH.

DOE

DOE has a decentralized program, with approximately 100 agency officials spread across the agency fulfilling different aspects of the role played by NSF program directors. SBIR is typically only a small portion of these officials' portfolios.[68] Congressional language dictates how SBIR funding is to be distributed among DOE's programs and offices.[69] Funding for program administration is limited. A government-wide administrative funding pilot program for SBIR, while useful, only allows for 3 percent of SBIR funds to be spent on the administrative improvements, and because the pilot program is temporary, DOE primarily uses it to fund contractors as opposed to federal employees. DOE releases solicitations for specific subtopics that change with every solicitation cycle, which are developed by subject-matter experts from within the agency, often in collaboration with its national laboratories, universities, and private industry. Each office in DOE uses the SBIR program independently to advance its individual mission; in this respect, SBIR is just one component of each research program.

The DOE Office of Science, which typically focuses on longer-term, "hard science" opportunities, is the largest contributor to the SBIR program. The applied offices of DOE, such as the Office of Energy Efficiency and Renewable Energy and the Office of Fossil Energy, typically focus on research that can address larger commercial markets. The SBIR program of the Advanced Research Projects Agency-Energy is funded and managed distinctly from the rest of the agency.

To improve the program in recent years, DOE has undertaken initiatives such as adding a "Letter of Intent" step to the application process through which companies can get early feedback on their proposals before applying (a similar project pitch has been adopted by NSF); taking steps to significantly reduce decision timelines; instituting a program to provide application assistance to new and under-represented applicants; issuing collaborative awards where multiple businesses can combine relevant capabilities; implementing Phase I principal investigator meetings (adopted from NSF); and implementing second and third Phase II awards. The third Phase II award is based on the NSF Phase IIB program.[70]

NASA

NASA also has a decentralized program, in which the agency's four directorates provide technical content for solicitations, a small program office manages the business aspects of the program, and many officials acting as technical points of contact interact with businesses throughout the duration of their awards. Appropriations are allocated to the program in a lump sum without specifications as to where those funds must be spent. A key distinction between NASA and NSF is NASA is often—but not always—the customer of its own innovations (e.g., technologies that can aid space missions). For this reason, the agency more often evaluates the innovation as opposed to the innovator, and provides funding through contracts rather than grants, thereby allowing the agency more control over the deliverables it seeks.[71]

Beginning in 2016, NASA sought to transform its SBIR program to be more business friendly. This has included providing internal and external assessments of the program's support for businesses. It now offers businesses annual opportunities to provide feedback to the program on barriers and potential solicitation topics through a request for information and an Industry Day to encourage networking among small businesses, research institutions, industry, and the program. It has also redeveloped the online portal through which agencies conduct many activities for the SBIR program (e.g., submitting applications).[72] NASA and NSF have also collaborated on administering a call for space-related SBIR proposals, and, like NSF, NASA administers the I-Corps program.[73]

NCI

Each of the various institutes and centers at NIH administers its own SBIR program. Most of the programs are relatively decentralized, but NCI's program is an exception. In the mid-to-late-2000s, NCI sought to reinvent its program and drew on the NSF model for inspiration. The institute established an NCI SBIR Development Center, which functions as a central point of management for the SBIR program and, like NSF, is staffed by full-time program directors. One reason this transformation was possible was the scale of the institute; with a budget of $173 million in FY 2019 to manage the SBIR program, it is the largest program at NIH.

NIH has adopted a series of funding options beyond the basic SBA model, including fast-track grants that allow businesses to apply to Phase I and Phase II at the same time, an option for eligible businesses to apply directly to Phase II, and a version of NSF's Phase IIB program. Furthermore, the award sizes at NIH are typically larger than those of other agencies because of the expensive nature of the funded R&D in life sciences. To support commercialization, NCI has also instituted an Investor Initiatives Program that allows select companies to meet investors at events around the country.[74]

According to a February 2019 external evaluation of NCI's SBIR program, NCI has created a program with "strong centralized management" and "good flexibility" that targets the "early-stage startup ecosystem" and has demonstrated a "significant and substantial rate of commercialization.[75]

Criteria for Adopting the NSF Model

To evaluate whether an agency or office is well suited to focus on supporting commercialization of SBIR-funded R&D, it is useful to consider two questions:

1. Does the agency or office intend to buy or use the outputs of the SBIR R&D?
2. Does the agency or office only support areas of research with limited commercial potential?

If the answer to both questions is "no," the agency or office is a good candidate for sharpening its focus on commercialization because the R&D that its SBIR program could fund has the potential to address promising markets. DOE, NASA, and NIH, as well as DOD to a lesser extent, all could benefit from adopting elements of the NSF model. The DOE Office of Energy Efficiency and Renewable Energy, for example, is ripe for such an approach because it seldom, if ever, is a technology buyer; and as an applied research office, it is already focused on commercialization.

If the answer to both questions is "yes," there is less scope for NSF's model. If, for example, NASA contracts a small business to develop a sensor for a space mission, the agency may be the only market for that technology. Further attempts at commercialization would therefore be pointless.

It is also reasonable for these agencies to fund companies that have received many SBIR awards to fulfill such specialized needs if they are the best ones to do the job. Furthermore, some research projects in more technically difficult or cost-intensive fields may require multiple awards to complete. Manny Oliver, the director of DOE's SBIR program, said that some of the research in DOE's science portfolio requires this level of dedication, citing an example of how one company needed ten to fifteen years to develop a handheld sensor that could visually map and identify radioactive material in real time.[76] But while companies with many awards can be useful, they may not be the most productive candidates for the SBIR program, given its mission to promote economic growth and societal impact.

It is doubtful that a small business set-aside is the best way to meet agency needs for specialized technologies. Whether the technology performs well at a reasonable cost is far more important than what size company produces it. Congress might consider focusing SBIR on commercialization and growth, and finding another mechanism that enables agencies to identify when small businesses are best suited to fulfill their missions, if they are procuring technology or pursuing niche areas of R&D with limited commercial potential. As Atkinson and Lind argued in *Big Is Beautiful: Debunking the Myth of Small Business*, a preference for small businesses, simply because they are small, can result in undue favoritism that is ultimately be detrimental to societal welfare.[77]

RECOMMENDATIONS

To improve SBIR's commercialization potential, agencies should consider adopting the following principles:

- Fund more small businesses focused on growth and commercialization, and spread awards across more companies. Start-ups are especially strong candidates for SBIR awards.
- Offer greater topical flexibility in SBIR solicitations.
- Centralize management of SBIR among dedicated program directors.
- Hire program directors with experience in entrepreneurship and commercialization.
- Implement additional programs, such as I-Corps, that support companies' transition from federal to private funding.

It is worth noting, as discussed in the descriptions of other agency programs, that some agencies have already taken significant steps in this direction. NCI has developed a model much like that of NSF, and DOE and NASA have recently instituted changes to better support businesses and commercialization.

Congress can also enhance agencies' ability to adopt the principles by taking a series of actions—some of which have been proposed in the Senate version of the SBA Reauthorization and Improvement Act of 2019 and the Research Advancing to Market Production for Innovators Act.[78] These actions include:

- Appropriating funds for SBIR to agencies as a lump sum without language specifying how much should be spent by each agency office or program;
- Making permanent the administrative funding pilot, which allows agencies to use up to 3 percent of total program funding for administrative uses, including those that enhance commercialization (such as I-Corps) and diversity among applicants (such as DOE's application assistance program), as the administrative pilot is currently scheduled to sunset in 2022, inhibiting agencies' long-term planning[79];
- Allowing a greater portion of SBIR awards to be used by small businesses for commercialization activities, such as agreements with vendors for technical and business assistance, as Congress passed language to this effect in the John S. McCain National Defense Authorization Act for FY 2019, but further clarification is needed to both require agencies to offer this opportunity and better define acceptable uses for these funds[80];
- Requiring that agencies consider adjusting the criteria for and composition of SBIR review panels to increase the weight of a project's potential for commercialization in funding decisions;
- Directing SBA to develop guidance on commercialization metrics so that agencies may better assess the commercial outputs of their programs over time, and better understand the impacts of their program administrations; and

- Increase government-wide funding for R&D to increase the impact of the SBIR program, because, as ITIF has noted, government-wide spending on R&D as a share of gross domestic product has continued to slide, decreasing in 22 of the past 28 years since 1990, which is not nearly commensurate with today's technological and competitiveness challenges.[81]

America faces pressing innovation needs. The nation cannot afford to miss opportunities to help innovative, commercially focused companies succeed. The SBIR program provides an important funding pipeline for growth-oriented small businesses. Federal agencies and Congress can and should do more to strengthen the commercial outputs of SBIR, and NSF's program can help serve as a compelling model to this end.

APPENDIX: COMPANIES AND AGENCIES INTERVIEWED

Interviews for this study included two current and former NSF program directors; four agency officials managing or involved in the SBIR programs at DOE, NASA, NIH, and DOD; a pair of SBIR consultants; and eight founders of small businesses who had received SBIR awards.

Company/Agency	Name	Position
Agencies		
DOD/USAF	Donna Stacy	SBIR/STTR Program Manager, Air Force Sustainment Center
DOE	Manny Oliver	Director, SBIR/STTR Programs Office
NASA	Jenn Gustetic	Program Executive, SBIR
NIH/NCI	Michael Weingarten	Director, NCI SBIR Development Center
NSF	Benaiah Schrag	Senior Program Director, SBIR/STTR
NSF	Errol Arkilic	Former SBIR/STTR Program Manager
Companies		
Accelerate Wind	Erika Boeing	Founder and CEO
CinderBio	Jill Fuss	Founder and CTO/COO
ClearFlame Engines	BJ Johnson	Cofounder and CEO
Emergy Foods	Justin Whiteley	Cofounder and CTO
Inspiralia	Amalia Reyes/ Michael Conry	Innovation Process Manager/Senior Innovation Consultant
Introspective Systems	Kay Aiken	Cofounder and CEO
Mosaic Materials	Thomas McDonald	Cofounder and CEO
Opus 12	Etosha Cave	Founder and CSO
Tierra Biosciences	Zachary Sun	Cofounder and CEO

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ABOUT ITIF

The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy. Recognized as the world's leading science and technology think tanks, ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress.

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