

Innovation policy and practice: a comprehensive view of NASA's SBIR/STTR programs

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ABSTRACT

This monograph describes the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs as implemented at the United States National Aeronautics and Space Administration (NASA). The programs' evolution is traced through the public solicitations over the last twenty-five years, and a descriptive analysis is presented. Proposal-level data, including declines, are used to illuminate the selection process, including the roles of firm size, technology maturity and gender. Subsequent patent rates are explored. Finally, two distinct real options approaches – one computational, the other analytical – consider the optimality of the current programmatic structure.

Keywords Research and development, Real options, Technology readiness levels, Small business innovation research, National aeronautics and space administration

Paper type Research paper



1. Introduction

Curiosity in the skies and space reaches back to the dawn of human history. In the last century, American interest – military, civil, and commercial – has coalesced in the National Aeronautics and Space Administration (NASA), which achieved legendary status by successfully transporting the first humans to the Moon in 1969. Despite changes in American budget priorities, involvement in space, and thus in NASA, has remained strong ever since. NASA is naturally a particularly important leader in developing “dual-use” technologies – namely, those with applications in military, civil, and private spheres.

At its inception, NASA was charged with disseminating its work and results. The sheer audacity of the agency’s mandate – to demonstrate technical command of space – required deep relationships with industry to develop novel solutions. Consequently, from the beginning, NASA sought partners as it addressed the previously unrecognized challenges of space operations. Black and Decker helped design the first handheld vacuum [1], and Foster Grant licensed NASA’s scratch-resistant lens coating [2]. Many lesser-known but equally effective companies successfully inaugurated new products and entire categories, such as baby formula supplements [3], memory foam mattresses [4], and ear thermometers [5].

Less attention has been paid to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs as innovation mechanisms at NASA, although they have been extensively studied in other agencies. Yet success abounds. For instance, Photobit spun out of the Jet Propulsion Laboratory (JPL) after its founders invented the first complementary metal-oxide-semiconductor

(CMOS) active pixel sensor chip, which later underpinned cameras in cell phones, webcams, and most modern imaging systems. NASA funded Photobit with an SBIR award in 1996, after which it grew rapidly until its acquisition by Micron Technology just five years later. Likewise, Honeybee Robotics created several technologies with SBIR funding from NASA starting in 1991. After more than 100 SBIR/STTR awards from the Department of Defense (DOD) and NASA over a fifteen-year period, Blue Origin acquired Honeybee Robotics in 2022.

These examples only scratch the surface of technology transfer to and from NASA [6]. For instance, the SBIR/STTR programs generated several technologies used in the Perseverance Rover (Figure 1), which launched in 2020 and is operating on the Mars surface (at the time of this document).

NASA serves as an excellent laboratory to study the SBIR/STTR programs because the challenges of supporting space operations lead naturally to major technology development. It is therefore a worthy setting to examine how these programs meet their legislatively defined objectives of driving innovation and expanding access to the federal research enterprise. In recent years, several studies of the SBIR/STTR programs as implemented at NASA have shed light on the architecture, management, and outcomes of innovation initiatives. In the spirit of Link (2023), one can consider both the success in meeting the program's stated objectives (assessment) and the social

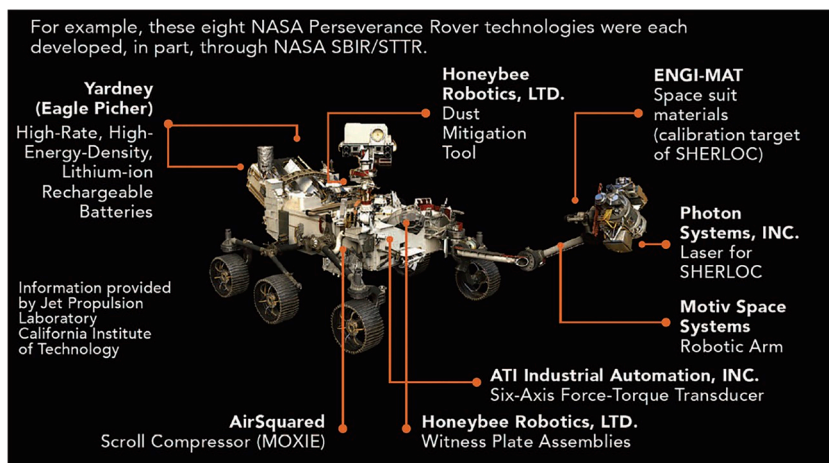


Figure 1. A drawing of the Perseverance Rover that indicates eight technologies partially developed from NASA SBIR/STTR awards

Source(s): www.nasa.gov/wp-content/uploads/2023/09/nasa-op-vignette-sbirsttr-pro-gram.pdf

benefits/costs (evaluation). It is useful to start with the context of both NASA and the SBIR/STTR programs, both described in Section 2, as well as the evolution of the program structure, the review criteria, and award rates.

For the assessment discussion, two of the stated objectives can be discussed in detail: stimulating innovation and expanding access for underserved groups. In service of the first objective, Section 3 summarizes results on the innovation products of the award portfolio as viewed through the lens of technology readiness level (TRL), a measure used frequently in the aerospace and defense sectors. Section 4 outlines one aspect of the program's success in expanding access through the lens of gender differentials in proposal review.

Evaluation of the program's benefits draws from the spillover and technology transfer literature. Section 5 describes the impacts of the program's funding on subsequent patent activity. Section 6 takes a high-level view of the program architecture and uses two real options model to estimate drivers of portfolio value. Section 7 concludes with recommendations for both policy initiatives as well as avenues of research.

2. Historical context

This section reviews the history of NASA and its role in technology development in the United States. This is followed by a brief discussion of the SBIR/STTR programs, and then the NASA implementation and how it has evolved in terms of specific requirements of the proposers and the review criteria. Finally, the summary award statistics are presented.

2.1 Federal interest in air and space flight

In the decade following the Wright Brothers' first powered flight in 1903, aircraft evolved quickly and military agencies began investigating the possibility of aerial operations. At the beginning of World War I in 1914, the United States military only had six airplanes, paltry in comparison with the United Kingdom (29), Germany (46), and particularly France (260) ([U.S. National Park Service, 2025](#)). Thus it became imperative for the US to prioritize aircraft development and production as the sky became an operating theatre for the first time in history.

To support this need, the United States government formed the National Advisory Committee for Aeronautics (NACA) in 1915. Because the American business and university communities did not yet see the benefit of conducting research in this emerging discipline, NACA initiated its own research program and in 1917 the group broke ground on its first facility in Virginia, soon to become Langley Research Center ([NASA, 2023](#)). Soon thereafter, World War II dramatically demonstrated the strategic importance of aerial power. During this era, NACA built the facilities that became Ames Research Center (1939) and Glenn Research Center (1942), while the Army

built the Jet Propulsion laboratory (1943) following experiments at the California Institute of Technology.

As the Cold War began, interest in advanced aircraft intensified, and in 1946, NACA developed its last laboratory, later to become Armstrong Flight Research Center. But the Soviet Union continued driving its own research program and in 1957 it successfully launched Sputnik, beating the United States to space.

Sputnik absolutely catalyzed the formation of NASA. President Dwight Eisenhower established NASA in the National Aeronautics and Space Act of 1958 (known as the “Space Act”). The Space Act called for the transformation of NACA’s activities into an agency with a broader purview than a federal advisory committee. This new agency, NASA, was formulated as a civilian agency distinct from the Department of Defense and charged to (Section 203.a):

- Plan, direct, and conduct aeronautical and space activities.
- Arrange for participation by the scientific community in planning scientific measurements and observations to be made through use of aeronautical and space vehicles, and conduct or arrange for the conduct of such measurements and observations.
- Provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.

NASA’s annual budget grew rapidly and peaked in the mid-1960’s at roughly \$30 B (in 2020 dollars) (CSIS [Aerospace Security Project, 2022](#)) as it worked toward the 1969 Moon landing achieved in the Apollo program. However, Apollo’s end triggered a loss of focus for the agency ([Hamaker, 1999](#)) and a budgetary decline. In 1976, the Viking spacecraft failed to discover evidence of biological processes on Mars; after that disappointment, interest in space exploration – and the associated budgets – further declined precipitously.

The 1990’s brought a new era of space exploration. NASA promoted a new “Faster, Better, Cheaper” strategy ([Hamaker, 1999](#)) that prioritized distributing risk across more numerous and smaller missions. Although it has been somewhat maligned for losses that followed, some argue that on a financial basis, this strategy indeed paid off ([Ward, 2010](#)). One of these lighter missions was Mars Pathfinder, bearing the Sojourner Rover with a payload of newer technologies than those borne by the 1970’s spacecraft. Simultaneously, researchers reported evidence of life on the Antarctic Allan Hills meteorite ALH84001 that originated at Mars [7]. These developments

conspired to create new excitement in space exploration as NASA began placing multiple assets in orbit around Mars and on its surface.

Unfortunately, public priorities changed. The Space Shuttle (formally known as the Space Transportation System, or STS), was the first reusable system for manned space flight. The STS program operated from 1981 to 2011 and was eventually retired for several reasons, ranging from safety concerns to cost. Yet NASA continued sending astronauts to the International Space Station (ISS), operating as a laboratory for many nations ([Link and Maskin, 2016](#)). NASA's cost to send humans to the ISS increased dramatically when the Space Shuttles no longer operated because NASA contracted with Roscosmos, the Russian counterpart, to provide seats on the Soyuz vehicle. The cost of a round-trip seat increased from roughly \$21 M in 2006 to \$86 M by 2020 ([NASA, 2019](#)) (much faster than inflation).

A new company, Space Exploration Technologies (known as SpaceX), stepped into this breach and developed a partially reusable launch system. In 2010 SpaceX became the first company to launch and recover a spacecraft, prompting the so-called “New Space Renaissance” and the expansion of the industrial base to new entrants such as Blue Origin, Virgin Galactic, and others. The most important metric in assessing the feasibility of space as a domain for military, civil, or private operations is the per-kilogram launch cost. In the years that the Space Shuttle operated, this cost remained relatively flat at roughly \$19 k/kg ([Jones, 2018](#)). In 2010 the SpaceX Falcon 9 rocket began operating at \$2.7 k/kg, a factor of six decrease. By 2018 the Falcon Heavy reduced the cost further, to \$1.4 k/kg, though these costs could potentially be misleading as other support services are needed beyond the simple launch cost ([Kim, 2025](#)).

As the government continued actively considering space resources, the Commercial Space Launch Competitiveness Act of 2015 increased the focus on the private sector. Subsequent revisions up to and including the National Space Policy of 2020 articulate goals that include to “encourage commercial space innovation and entrepreneurship through targeted investment in promising technologies that improve the Nation’s leadership in space operations” (p. 7) and to “strengthen interagency and commercial partnerships” (p. 12) (National Space Policy of the [United States of America, 2020](#)).

Reduced launch costs enabled new business models, especially in Low Earth Orbit (LEO) where orbital assets could be accessed and leveraged effectively. Consequently, venture capital interest in space increased dramatically in the ensuing years ([Lerner et al., 2016](#)).

2.2 NASA organization

Today NASA implements its mandate through two broad sets of activities: Research and Development (R&D) and operations. The R&D activities are carried out through four Mission Directorates ([Table 1](#)), known today as Science, Exploration, Space Technology (or Technology), and Aeronautics. These Directorates have evolved over the years in concert with NASA's priorities. For instance, NASA merged Earth science and space science into the Science Mission Directorate (SMD) in 2004. Within SMD, funding may be allocated between Earth science and the Lunar/Mars/solar system exploration activities. More recently, the Space Technology Mission Directorate was formally created in 2013, in part to spotlight the role of advanced technologies in enabling the science missions – but also the overarching objective of exploration. The Directorates are explicitly named in the annual Congressional appropriation process. In recent years, NASA has operated with a budget of roughly \$20-25 B in 2022 dollars ([Table 2](#)).

Each Directorate has its own appropriation line and, perhaps more importantly, its own community. The involvement of the broader research ecosystem varies with Directorate. For instance, the Science Directorate tends to have strong engagement with university researchers and its Science Plan, released regularly, is developed in concert with the community. In contrast, the Human Exploration Mission Directorate generates fewer consensus communications with the national academic enterprise.

NASA distributes its responsibilities among the organizational units represented in the Mission Directorates. However, this work must then be carried out at the Centers.

Table 1. NASA Mission Directorates

Name	Example topics
Science (S)	Robotic Exploration Technologies Sensors, Detectors and Instruments
Exploration Systems (X)	Human Research and Health Maintenance Entry, Descent, and Landing Technologies
Space Technology (Z)	Space Technology for Cross-Cutting Applications Modeling and Measurements for Propulsion and Power
Aeronautics Research (A)	Air Vehicle Technology Ground and Flight Test Techniques

Note(s): Current names for Mission Directorates are used

Table 2. NASA budget in \$ Billions (in constant 2022 dollars)

	Science	Exploration	Technology	Aeronautics	Operations	Other	Total
2000	5.7	1.9	0.0	0.9	8.8	4.1	21.4
2001	5.8	2.4	0.0	0.9	8.3	4.5	21.9
2002	5.8	2.4	0.0	1.0	8.5	4.8	22.5
2003	6.7	2.9	0.0	0.9	7.6	4.8	22.9
2004	6.5	3.2	0.0	1.2	6.8	4.9	22.6
2005	6.2	2.5	0.0	1.1	8.0	5.0	22.8
2006	5.8	3.4	0.0	1.0	7.6	5.0	22.7
2007	6.1	3.8	0.0	0.8	6.8	4.1	21.6
2008	6.2	4.3	0.0	0.7	7.1	4.5	22.6
2009	5.8	4.5	0.0	0.6	7.4	5.8	24.1
2010	5.7	4.6	0.4	0.6	7.8	4.7	23.9
2011	6.2	4.8	0.6	0.7	6.4	4.5	23.1
2012	6.2	4.5	0.7	0.7	5.1	4.5	21.8
2013	5.8	4.5	0.7	0.6	4.5	4.2	20.3
2014	6.1	4.9	0.7	0.7	4.5	4.1	20.9
2015	6.1	4.1	0.7	0.8	5.4	3.9	21.0
2016	6.5	4.6	0.8	0.7	5.8	3.9	22.3
2017	6.6	4.8	0.9	0.7	5.6	3.7	22.4
2018	7.5	5.3	0.8	0.8	5.3	3.9	23.7
2019	7.5	5.5	1.0	0.8	5.1	3.6	23.5
2020	7.1	6.0	1.1	0.8	4.1	3.5	22.6
2021	7.7	6.2	1.1	0.8	4.1	3.5	23.5
2022	7.6	6.7	1.1	0.9	4.0	3.7	24.0

Note(s): Budget data drawn from www.aas.org/sites/default/files/2022-09/NASA.png. Current Directorate names are used

The NASA Center system consists of the four laboratories that NACA built, the two transferred from the Army, and four created under the aegis of NASA itself (Goddard Space Flight Center, Johnson Space Center, Kennedy Space Center, and Stennis Space Center). These ten institutes house the NASA internal research enterprise. The California Institute of Technology manages JPL, a Federally Funded Research and Development Center (FFRDC), but the rest are federal laboratories managed by the

United States government. The Centers and Directorates do not have a one-to-one match, but some Directorates are more localized in specific Centers, such as the Science Mission Directorate, which is more concentrated at the Jet Propulsion Laboratory and the Goddard Space Flight Center.

In other words, NASA's funding is distributed through its Directorates, but the activities are executed at the Centers, three of which are located in California while the rest are distributed principally in the east and in Texas. Unlike other agencies, NASA's influence across the country is somewhat uneven. While the United States has ninety federal laboratories, sixty-three are associated with the DOD and seventeen with the Department of Energy (DOE). NASA's ten Centers represent a small fraction of the federal laboratory system.

2.3 The SBIR/STTR programs

The history of the SBIR and STTR programs have been extensively documented (c.f. Link, 2023). In 1982, Congress established the SBIR program with four principal objectives:

- (1) Stimulate technological innovation.
- (2) Meet federal research and development needs.
- (3) Foster and encourage participation in innovation and entrepreneurship by socially and economically disadvantaged small businesses (SDBs) and women-owned small businesses (WOSBs).
- (4) Increase private-sector commercialization of innovations derived from federal research and development funding.

Agencies with extramural research budgets greater than \$100 million must set aside 3.2% for the SBIR budget. In addition to NASA, the following federal agencies participate in SBIR: Department of Agriculture (USDA), Department of Commerce (DOC), DOD, DOE, Department of Education (ED), Health and Human Services (HHS), Department of Homeland Security (DHS), Department of Transportation (DOT), Environmental Protection Agency (EPA), and National Science Foundation (NSF). The STTR program, established in 1992, has the additional objective of stimulating partnerships between small businesses and research institutions, and those agencies with extramural research budgets exceeding \$1 billion – namely, DOD, DOE, HHS, NSF, and NASA – must reserve 0.45% for STTR. Because the allocations track with R&D budgets, agency participation varies significantly (Table 3). Participating

Table 3. SBIR and STTR total obligations in Fiscal Year 2021

Agency	Budget (\$000s)
<i>Panel A: SBIR</i>	
Department of Defense	1,519
Health and Human Services	1,108
Department of Energy	314
National Science Foundation	217
National Aeronautics and Space Administration	194
Department of Homeland Security	20
Department of Agriculture	28
Department of Transportation	15
Department of Commerce	23
Education	14
Environmental Protection Agency	6
<i>Panel B: STTR</i>	
Department of Defense	280
Health and Human Services	154
Department of Energy	40
National Science Foundation	30
National Aeronautics and Space Administration	25

agencies collaborate through the Interagency Policy Committee (IPC) created by the SBIR/STTR Reauthorization Act of 2011. The IPC is co-chaired by the Small Business Administration (SBA) and the White House Office of Science and Technology Policy (OSTP).

The SBA provides guidance to the agencies through the SBIR/STTR Policy Directive (“the Policy Directive”), the key source of implementation guidelines. The program is organized in two Phases, with Phase I envisioned as a feasibility study and Phase II as a prototype. Generally only Phase I awardees are eligible to apply for Phase II; however, certain agencies are authorized to issue so-called “Direct to Phase II” contracts if they are awarded in a competitive process. The SBA sets the maximum award sizes for both Phases, and each agency has the freedom to structure its program – from strategic vision to contract architecture and modification processes – to meet its needs. For instance, NSF issues grants in Phase I and cooperative agreements (Cas) in

Phase II, in part because Cas enable the agency to monitor alignment with agreed-upon milestones. With a more rigorous set of requirements, NASA typically issues firm fixed-price contracts.

The Policy Directive defines a “Phase III” contract as “work that derives from, extends, or completes an effort made under prior SBIR/STTR Funding Agreements, but is funded by sources other than the SBIR/ STTR programs.” These Phase III contracts represent “commercialization” even though they may not yield typical performance outcomes, such as sales. Phase III contracts are potentially important because they can be awarded with simple sole-source justifications – that is, they are not competed. Moreover, this right has several important characteristics, as it:

- persists through a corporate transaction (e.g., a merger or acquisition);
- survives the firm’s growth even if the firm becomes too large to be eligible for SBIR/STTR awards; and
- has no expiration date.

A Phase III contract may be awarded simply with a sole source justification specifying the SBIR/STTR heritage. In fact, the 2023 SBIR/STTR Policy Directive states: “If pursuing the Phase III work with the Awardee is found to be practicable, the agency must award a non-competitive contract to the firm.” Although some agencies do not award Phase III contracts, NASA does utilize this mechanism.

Each agency retains the right to use the SBIR/STTR programs to meet its own needs. For instance, NSF usually does not purchase technologies developed through its SBIR/STTR programs. For the first thirty years of the programs’ life, NSF met its mission by funding technologies to benefit the American public. However, as economists determined that startups are particularly effective in spurring job growth ([Haltiwanger et al., 2013](#)) and that the United States entrepreneurship rates were declining ([Decker et al., 2016](#)), NSF turned its attention to funding startups [8], a move institutionalized with the first cohorts of the Innovation Corps “I-Corps” training program in 2011.

In contrast to NSF, DOD funds research and development (R&D) organizations to develop solutions for the warfighter, necessitating longer research programs that sufficiently retire risk to transition fundamental discoveries into fielded capabilities. In principle, some SBIR/STTR awardees could become DOD vendors and participate in procurement processes, but this is challenging because defense procurement can require production at the scale of millions of units, conceivably out of the range of small company manufacturing processes.

NASA's needs fall between the extremes of NSF and DOD, in that new technologies face a high-risk environment similar to that of DOD, but with production needs at much smaller volumes. Because NASA seeks to develop technologies [9] for its own use, the agency distributes a list of technical topics within the requests for proposals or solicitations.

At least annually, each agency “must issue a Program Solicitation that sets forth a substantial number of R/R&D topics and subtopic areas consistent with stated agency needs or missions.” Each agency has the authority to determine the scope of its solicitations as well as the specific review criteria. Specifically, the Policy Directive states that “agency criteria used to evaluate SBIR/STTR proposals must give consideration to the scientific and technical merit and feasibility of the proposal along with its potential for Commercialization. Considerations may also include program balance with respect to market or technological risk or critical agency requirements.”

2.4 SBIR/STTR at NASA

From the beginning, the Space Act called for active industry partnerships. Section 203.a.1 states that the agency shall “provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof.” Amendments to the Space Act, such as the Commercial Space Launch Act of 1984, called for partnerships with the private sector. These were principally the defense industrial base giants, like Martin Marietta and Grumman Aircraft Company, which had been working with NASA for decades.

It is natural for NASA to seek partners in the SBIR/STTR programs. As discussed above, a significant private space sector took shape beginning in the early 2010s. The venture capital industry evolved during those years toward firms with space technologies (Lerner *et al.*, 2016). Thus, it became imperative for NASA to both respond to and spur further growth in small businesses with relevant technologies.

As noted earlier, the solicitations must describe topics and subtopics aligned with the agency's needs. Proposals responding to NASA's topics are distributed to the ten Centers discussed above, in agreement with their areas of expertise. This represents another difference with the SBIR/STTR programs as implemented at other agencies, such as NSF. Proposals are reviewed at the Centers and recommendations are aggregated at NASA headquarters. In this fashion, the review is more tightly coupled to the associated research that could leverage the proposed technologies.

NASA's partnership goals are communicated in the annual call for proposals or solicitation. Over time, these solicitations serve as a window into the transformation of NASA's SBIR/STTR programs. Unfortunately, early solicitations prior to the internet era are difficult to obtain. Nonetheless, the solicitations of the last twenty-five years are available and illuminate how the programs have evolved to meet the current environment. The changes are evident in two distinct solicitation elements:

- (1) proposal submission guidelines; and
- (2) evaluation criteria.

2.4.1 Proposal submission guidelines. 2.4.1.1 Phase I. Proposal submission guidance at Phase I evolved considerably over the last twenty-five years. In 1998 the language focused generally on the firm's capabilities. By 2008 language appeared asking for information on customer identification. In the next ten years the solicitation called for a description of the competitive marketplace and barriers to entry. Finally, by 2023 the agency sought a high-level strategic discussion and a broader explanation of the business model. The specific language follows:

- 1998.

"[...] [O]fferors will discuss in this section the broad commercial applications they contemplate for their project results and their plans to bring the technology to commercial application. Offerors should discuss the following: (a) the specific commercial products or services contemplated and the corresponding target market niche; (b) expected unique competitive advantage of the commercial products or services; (c) nature of the corresponding contemplated commercial venture; (d) importance of the contemplated commercial venture to the offeror's current competitive position and to its strategic planning; and (e) the offeror's capability and plans to bring the necessary physical, personnel, and financial resources to bear, in a timely way, to result in a viable commercial venture in the reasonable near term subsequent to Phase II (if awarded). Offerors should also describe how they would seek non-SBIR funding needed for Phase II and Phase III activities."

- 2008.

"The Phase I proposal shall (1) forecast the potential and targeted application (s) of the proposed innovation and associated products and services relative to NASA needs (infusion into NASA mission needs and projects) [...], other Government agencies and commercial markets, (2) identify potential

customers, and (3) provide an initial commercialization strategy that addresses key technical, market and business factors for the successful development, demonstration and utilization of the innovation and associated products and services. Commercialization encompasses the transition of technology into products and services for NASA mission programs, other Government agencies and non-Government markets.”

- 2018.

“Commercialization is defined as the transition of technology into products and services for NASA mission programs, other government agencies and non-government markets. Discuss (1) potential and targeted applications of the technology and paths to infusion in future NASA missions and/or programs (2) possible applications in other government agencies and (3) potential non-government markets. Provide a preliminary commercialization strategy that addresses key technical, market and business factors pertinent to the successful development of the proposed innovation, and its transition into products and services for NASA mission programs, other government agencies and non-government markets. If feasible, discuss potential barriers to entry, potential competitors, risks, and existing and projected commitments for Phase III funding, investment, sales, licensing, and other indicators of commercial potential and feasibility. Please also discuss your experience and record in technology commercialization, as applicable.”

- 2023.

“The purpose of this section is for Phase I offerors to describe the potential commercialization opportunities for the innovation. The SBIR program is mandated to move funded innovations into commercial markets including both federal markets and private sector commercial markets. In addition, offerors who start to address the market opportunities early will be better positioned to address additional commercialization metrics under future SBIR efforts including Phase II and Phase III. Phase I offers should address each of the following:

- Discuss the business economics and market drivers in the target industry.
- How has the market opportunity been validated?
- Describe your customers and your basic go-to-market strategy to achieve the market opportunity.
- Describe the competition.

- How do you expect the competitive landscape may change by the time your innovation enters the market?
- What are the key risks in bringing your innovation to market?
- Describe your commercialization approach.
- Discuss the potential economic benefits associated with your innovation and provide estimates of the revenue potential, detailing your underlying assumptions.
- Describe the resources you expect will be needed to implement your commercialization approach.”

2.4.1.2 Phase II. Phase II submission guidelines have changed over the years as well. The 1998 solicitation requested a traditional business plan. By 2008, the solicitation added new language regarding intellectual property, details about the potential NASA applications, and additional capital formation strategies (presumably informed by the rapid growth of the venture capital sector in the preceding decade). Ten years later, the proposal had to report information about the commercial potential, intent, and capability of the proposed technology. And finally, the 2023 solicitation called for a Commercialization Plan with much more detail about the market analysis, the envisioned financial strategy, and the team’s plans to obtain mentoring.

- 1998.

The 1998 solicitation included the following language:

“Describe: plans for commercialization (Phase III) in terms of each of the following areas:

- Product or Service Commercial Feasibility: Provide a description of the (a) contemplated commercial product and/or service, the corresponding commercial venture, and the unique competitive advantage of both; and (b) technical obstacles to commercial applications, as well as plans to address these obstacles.
- Market Feasibility and Competition: Describe: (a) the target market niche including the distinction between U.S. Government and other markets; (b) the estimated potential market size in terms of revenues to be realized by the offeror from U.S. Government markets and, separately, from other markets; (c) the competitive environment in terms of present and likely competing similar and alternative technologies, and corresponding competing domestic and foreign entities; and (d) significant developments

within the targeted business sector; (e) offeror's ability, if any, to protect relevant technology with patents or rights to exclusive access.

- Strategic Relevance to the Offeror: Describe the relevance of the targeted commercial venture to the offeror's: (a) current business segments; (b) relative position with respect to its competitors; and (c) strategic planning for the next 5 years.
- Key Management and Technical Personnel and Organizational Structure: Describe: (a) the skills and experience of key management and technical personnel relevant to bringing innovative technology to commercial application, (b) current organizational structure, and (c) plans and timeline for obtaining the balance of all necessary key business development expertise and other staffing not currently in-house.
- Production and Operations: Describe: (a) business development progress to date regarding the contemplated commercial venture; (b) obstacles, plans, and associated timetable of key milestones regarding all key business development elements; and (c) sources and components of private physical resources committed to date and plans for obtaining the balance of the necessary physical resources.
- Financial Planning: Describe: (a) the amounts and sources of private financial resources expended and committed to date with respect to the technology development project, and separately, with respect to business development of the targeted commercial venture; (b) significant requirements of potential investors, creditors, and insurers of the venture; (c) pro forma statement of cash flow with respect to the targeted commercial venture that includes best estimates of at least the following major components and timing thereof: capital investment, revenues, principal and interest payments, depreciation of relevant assets, other operating expenses; and (d) evidence of the offeror's current financial strength."
- 2008.
New language for the 2008 solicitation included the following:
 - "Intellectual Property: Describe plans and current status of efforts to secure intellectual property rights (e.g., patents, copyrights, trade secrets) necessary to obtain investment, attain at least a temporal competitive advantage, and achieve planned commercialization."

- “[...] [F]urther specify the potential NASA and commercial applications of the innovation and the associated potential customers, such as NASA mission programs and projects, within target markets. Potential NASA applications include the projected utilization of proposed contract deliverables (e.g., prototypes, test units, software) and resulting products and services by NASA organizations and contractors.”
- “Capital Commitments Addendum Supporting Phase II and Phase III. Describe and document capital commitments from non-SBIR/STTR sources or from internal SBC funds for pursuit of Phase II and Phase III. Offerors for Phase II contracts are strongly urged to obtain non-SBIR/STTR funding support commitments for follow-on Phase III activities and additional support of Phase II from parties other than the proposing firm. Funding support commitments must show that a specific, substantial amount will be made available to the firm to pursue the stated Phase II and/or Phase III objectives. They must indicate the source, date, and conditions or contingencies under which the funds will be made available. Alternatively, self-commitments of the same type and magnitude that are required from outside sources can be considered. If Phase III will be funded internally, offerors should describe their financial position.”
- 2018.
This solicitation required more information on the commercial attributes of the technology and the associated plan to transition to practice:
 - “*Commercial Potential – Market*: Describe (1) market segmentation and analysis, by providing the scope in dollars, and describe the commercial Total Addressable Market (TAM) that is appropriate to the proposed innovation, the segment in dollars of the TAM addressable by the proposed innovation and the projected percentage of the offeror’s market share in 2-3 years after entry into the identified market; (2) the proposed innovation in terms of target customers (e.g., NASA, other federal agency, commercial enterprise); and (3) the competitive landscape, by identifying potential competitors by company name within the identified market, discussing the barriers to entry and how many years it would take a competitor to enter this segment in terms of capitalization, technology, and people, and describing how the proposed innovation is different from the potential competition.

- *Commercial Intent – Plan*: Describe (1) the commercial development plan by providing a development timeline to bring technology to market, discuss consultants, incubators and research institutions to achieve the plan; (2) the applicable business model (spinout, license, OEM) the offeror would use to bring the innovation to market, the channels of distribution (direct sales, distributors, etc.) that would be used in bringing the innovation into the identified market, the pro-forma 2-3 year revenue dollar projections based on the proposed innovation's penetration of the identified market and any follow-on development (long term > 5 years) plans to expand your proposed innovation's market presence; (3) the risks to the commercial development plan and what mitigations, if any, can be taken over a reasonable period of time to lessen the risks and (4) Intellectual Property protection methods, plans or processes within your company.
- *Commercial Capability – Execution*: Describe (1) the current and future company capitalization by discussing the technical, operations/ manufacturing and business staff conducting the project; the physical plant, including facilities and the capital equipment, tooling and test equipment used to conduct the investigation; how the innovation will enter into production (i.e., in house or through a licensee) and what changes (if any) will be made to company capitalization for commercialization; (2) existing and future business relationships in terms of any formal Partnerships, Joint Ventures, Licensing Agreements with other companies/organizations and; (3) as applicable, the approach, path to market and revenues from past commercialization(s) resulting from SBIR/STTR awards disclosed in the CMS" [10].
- 2023.

This request for proposals had the following language:

"The Commercialization Plan should provide the following information to communicate and validate that the firm has the knowledge and ability to commercialize the innovation being proposed ...

- *Market Feasibility and Competition Strategy*: Describe (a) the target market(s) of the innovation and the associated product or service; (b) the competitive advantage(s) of the product or service; (c) key potential customers and applications, including NASA mission programs, prime contractors, and non-NASA commercial customers as applicable; (d)

projected market size (NASA, other Government and/or non-Government); (e) the projected time to market and estimated market share within five years from market-entry; and (f) anticipated competition from alternative technologies, products and services and/or competing domestic or foreign entities.

- *Commercialization Strategy*: Present the commercialization strategy for the innovation and associated product or service and its relationship to the offeror's business plans for the next five years. Describe experience and record in technology commercialization, and any existing and projected commitments (e.g., Government Phase III funding, Industry Investment, etc.).
- *Financial Strategy*: Delineate private financial resources committed to the development and transition of the innovation into market-ready product or service. Describe current investment, sales, licensing, and other indicators of commercial potential and feasibility. Describe the projected financial requirements and the expected or committed capital and funding sources necessary to support the planned commercialization of the innovation. Provide evidence of current financial condition (e.g., standard financial statements including a current cash flow statement).
- *Intellectual Property*: Describe plans and current status of efforts to secure intellectual property rights (e.g., patents, copyrights, trade secrets) necessary to obtain investment, attain at least a temporary competitive advantage, and achieve planned commercialization.
- *Assistance and Mentoring*: Describe the plans for securing needed technical or business assistance through mentoring, partnering, or through arrangements with state assistance programs, Small Business Development Centers (SBDCs), Federally funded research laboratories, Manufacturing Extension Partnership Centers, Federal programs, or other assistance providers. Identify if any assistance and mentoring are being requested under TABA [11] and provide details in this section of the Commercialization Plan. The TABA needs assessment is reviewed separately from the Commercialization Plan."

2.4.2 Proposal Evaluation Process. 2.4.2.1 Overview. The SBIR/STTR program requires a "simplified, standardized funding process" and the solicitations must advise proposers of the evaluation criteria. As discussed above, the solicitations explicitly call

for specific information. However, another dimension of the program changes is the weighting scheme assigned to the responses. Notably, there is no so-called “pay line” at NASA. Historically, proposals with Technical Scores exceeding 85 were considered for funding but are not necessarily selected. As a result, some econometric techniques, such as regression discontinuity design, may not be appropriate for causal inference studies. Moreover, qualifying proposals were reviewed carefully for a number of factors post-scoring. The scoring process and these complementary factors evolved over the last twenty-five years.

2.4.2.2 Phase I. At NASA, the Phase I criteria have remained fairly consistent from 1998 to the present date, and are defined as:

- “*Factor 1.* Scientific and technical merit and feasibility of the proposed innovation; relevance to the subtopic; benefit to NASA; and the specific objectives and approaches. Innovation and originality are essential considerations.
- *Factor 2.* Experience and qualifications of the offeror, the Principal Investigator and other key personnel, consultants, and subcontractors, if any; and adequacy of instrumentation and facilities to be available for the project.
- *Factor 3.* Soundness of the proposed work plan, budget, and schedule for meeting the Phase I objectives of determining the feasibility and merit of the proposed innovation preparatory to proceeding to Phase II.
- *Factor 4.* Commercial potential of the proposed innovation in terms of future commercial products and services and the likelihood of the offeror to bring successfully developed technology to commercial application” [12].

These Factors are weighted as shown in [Table 4](#). Proposals are rated on a 100-point scale, with half the weight assigned to scientific merit; and the other half equally split between evaluations of the team and the plan. This aggregate number forms the Technical Score. The commercialization potential (Factor 4) historically has been assessed separately on a five-point adjectival rating of Excellent, Very Good, Good, Fair, or Poor.

In 2022, NASA introduced a new Phase I program called Ignite, specifically to attract firms developing technologies with high relevance to both NASA and the broader commercial market (known as “dual-use” technologies). The Ignite program assesses proposals on the same criteria, but they are re-ordered and weighted differently. Specifically, the commercialization potential is quantitatively evaluated

Table 4. NASA Phase I criteria, 2023–2024

Factor	Criterion	Weight (%)	
		Standard phase I	Ignite
1	Scientific/Technical Merit and Feasibility	50	30
2	Experience, Qualifications, and Facilities	25	20
3	Effectiveness of the Proposed Work Plan	25	20
4	Commercialization	Adjectival	30
Total Technical Score		100	100

Note(s): The adjectival rating scale is: Excellent, Very Good, Good, Fair, or Poor

Source(s): 2023 NASA SBIR Phase I solicitation, 2024 NASA Ignite solicitation

and worth 30% of the total Technical Score. Meanwhile, the scientific feasibility is reduced to 30%, and the other two criteria are reduced slightly by 5%.

2.4.2.3 Phase II. The Factors referred to in these descriptions are those of [Table 4](#) as the Standard Phase I criteria.

- 1998.

Originally, Phase II proposals were evaluated identically as in Phase I. Commercialization was given as a simple rating on the five-point adjectival scale and was not incorporated in Technical Scores.

“Factors 1, 2, and 3 will be scored numerically. Factors 2 and 3 are of equal importance, while Factor 1 is more important than either 2 or 3. Proposals receiving high numerical scores will be evaluated and rated for their commercial potential using the criteria listed in Factor 4 and by applying the same adjectival ratings as set forth for Phase I proposals.”

- 2008.

At this point, the weighting factors were identical to those of 1998. However, additional language indicated that the commercial potential would be evaluated *only* for the proposals with Technical Scores of 85% or higher:

“Proposals receiving numerical scores of 85 percent or higher will be evaluated and rated for their commercial potential using the criteria listed in Factor 4 and by applying the same adjectival ratings as set forth for Phase I proposals. Where technical evaluations are essentially equal in potential, cost to the Government may be considered in determining successful offerors. For Phase II proposals, commercial merit is a critical factor.”

- These Factor 4 assessment criteria were restated as:
 - *“Commercial Potential and Feasibility of the Innovation:* This includes assessment of (a) the transition of the innovation into a well-defined product or service; (b) a realistic target market niche; (c) a product or service that has strong potential for meeting a well-defined need within the target market; and (d) a commitment of necessary financial, physical, and/or personnel resources.”
 - *Intent and Commitment of the Offeror:* This includes assessing the commercialization of the innovation for (a) importance to the offeror’s current business and strategic planning; (b) reliance on (or lack thereof) Government markets; and (c) adequacy of funding sources necessary to bring technology to identified market.
 - *Capability of the Offeror to Realize Commercialization:* This includes assessment of (a) the offeror’s past performance, experience, and success in technology commercialization.”

- 2018.

By 2018, the Factor 4 language was preserved, but the Phase II selection criteria were stated as: “Factors 1, 2, 3, and 4 will be scored numerically with Factor 1 worth 45 percent, Factors 2 and 3 each worth 25 percent, and Factor 4 worth five percent”. In other words, the commercialization now contributed to the Technical Score for all proposals, rather than being assessed only for a subset of proposals. Indeed, the commercialization could be used to contribute to the minimum score of 85 – a change from prior policy.

- 2023.

Here the agency kept the scoring process of 2018: “Factors 1, 2, 3, and 4 will be scored numerically, with Factor 1 worth 45 percent, Factors 2 and 3 each worth 25 percent, and Factor 4 worth five percent. The sum of the scores for Factors 1, 2, 3, and 4 will constitute the Technical Merit score.” However, the solicitation goes on to say: “After ranking proposals using the Technical Merit score, the agency may consider additional programmatic balance factors such as portfolio balance across NASA programs, centers and mission directorates, available funding, first-time awardees/participants, historically underrepresented communities, and geographic distribution, to recommend proposals to the Source Selection Official (SSO).” NASA redefined the Factor 4 more comprehensively as “Commercialization and Business Planning”, with six items:

- “*Commercial Potential—Quantitative Market Analysis*, including (a) The market segmentation and the commercial Total Addressable Market (TAM); (b) The proposed innovation in terms of target customers (e.g., NASA, other Federal agency, commercial enterprise); and (c) The competitive landscape, by identifying potential competitors.
- *Commercial Intent—Value Proposition*, including (a) The commercial development plan by providing a development timeline to bring the innovation to market; (b) The applicable business model (spin-out, license, OEM, etc.) the offeror would use to bring innovation to market; and (c) The risks to the commercial development plan and what mitigations, if any, can be taken over a reasonable period of time to lessen the risks.
- *Commercial Capability—Pro Forma Financial Projections*, including (a) The current and future company capitalization efforts; and (b) as applicable, the description of the approach, path to market, and revenues from past commercialization(s) resulting from SBIR/STTR awards.
- *Intellectual Property (IP)*, including how the offeror will protect the IP that results from the innovation.
- *Assistance and Mentoring*, including (a) existing and future business relationships in terms of any formal partnerships, joint ventures, or licensing agreements with other companies/organizations; and (b) plans for securing needed technical or business assistance through mentoring, partnering, or through arrangements with state assistance programs, Small Business Development Centers (SBDCs), Federally funded research laboratories, Manufacturing Extension Partnership Centers, Federal programs, or other assistance providers.
- *Capital Commitments Addendum*, including (a) Any letters of commitment describing follow-on funding, product sales, or matching funding to be provided for a future post-Phase II opportunity application; (b) Letter of intent or evidence of negotiations to provide funding should the Phase II project be successful, and the market need still exists; (c) A specific plan to secure Phase III funding.”

2.4.2.4 Subsequent Funding Opportunities. In 1998, NSF pioneered the use of SBIR/STTR funds to support commercialization through a partial (1:2) match of third-party investment funds as a modification of a Phase II contract, known as a Phase IIB

supplement. In the last decade, NASA has implemented similar initiatives to encourage similar activities. The principal extensions are:

- *Phase II-Extended contracts* offer a 1:1 match of investor funding of \$25,000-375,000 to encourage further technology development.
- *Phase II-Sequential extensions* provide \$2,500,000-4,000,000 for infusion of technologies into NASA missions.
- *Civilian Commercialization Readiness Pilot Program (CCRPP)* provides \$500,000-2,500,000 in matching funds for technologies with a high degree of relevance to NASA and strong near-term use cases either in or out of NASA.

2.5 NASA SBIR/STTR Portfolio Overview

Summary statistics are derived from publicly available data at [SBIR.gov](https://www.sbir.gov) [13]. Figures 2 and 3 show the numbers of SBIR and STTR awards, respectively, with Phases 1 and 2 shown independently, whereas Figures 4 and 5 show the average award size for both programs. Throughout the 2000's, NASA issued approximately 300 (150) SBIR Phase I (II) awards, and approximately 40 (20) STTR Phase I (II) awards annually.

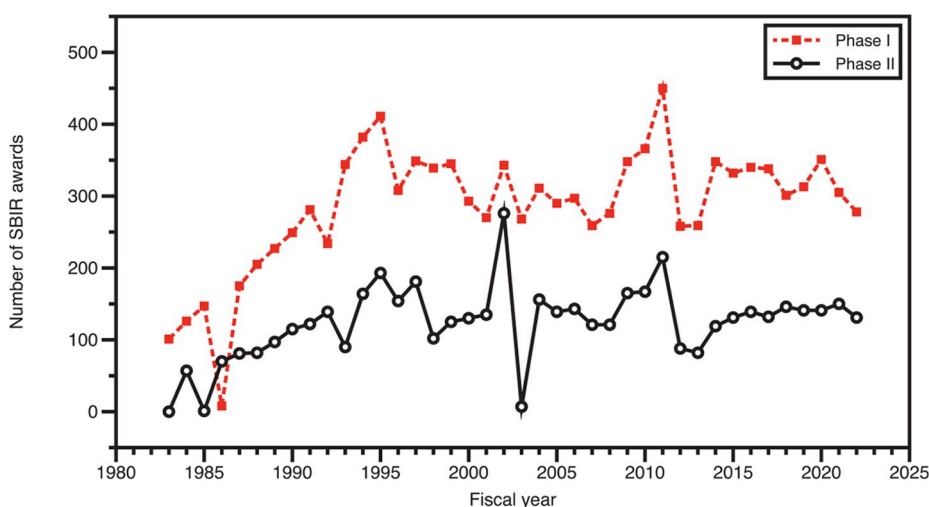


Figure 2. The number of NASA SBIR awards from 1983 to 2022, shown separately for Phase I (red dotted line with closed squares) and Phase II (black solid line with open circles)

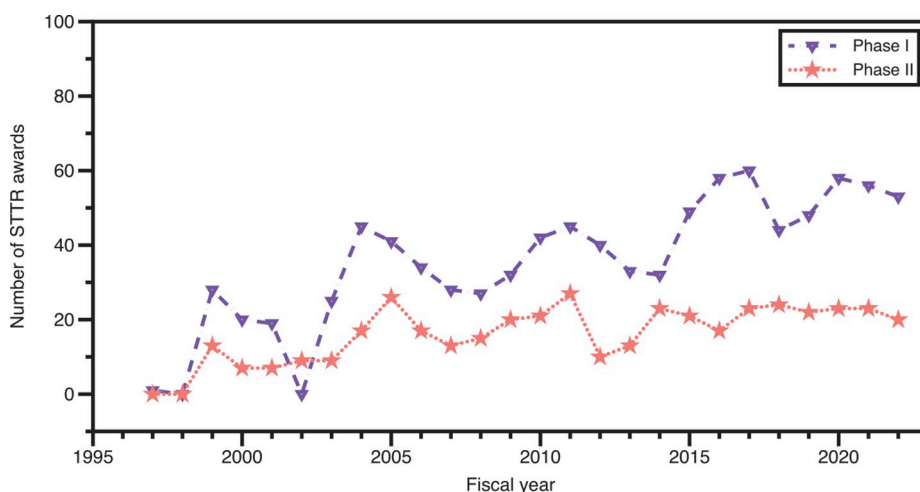


Figure 3. The number of NASA STTR awards from 1997 to 2022, shown separately for Phase I (purple dashed line with triangular data) and Phase II (orange dotted line with starred data)

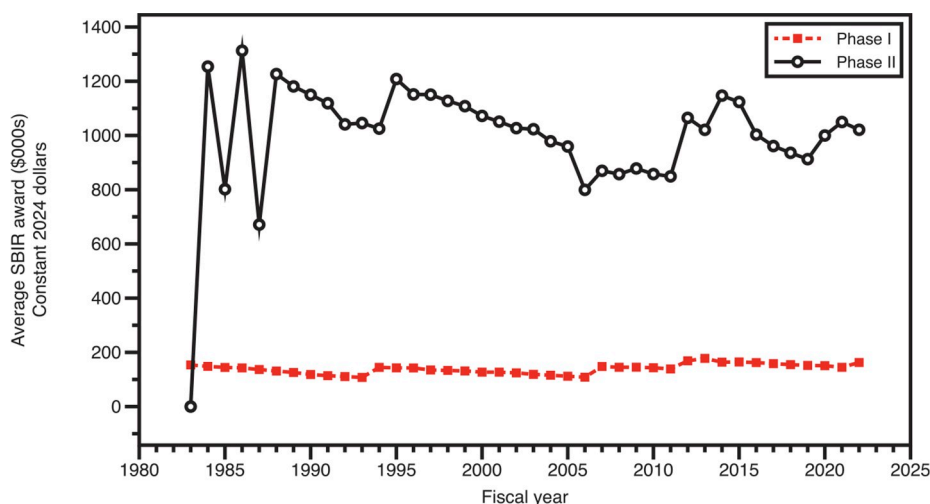


Figure 4. The average size of NASA SBIR awards from 1983 to 2022, shown separately for Phase I (red dotted line with closed squares) and Phase II (black solid line with open circles)

2.6 Summary

Over the years, the program has adapted to the changing environment and the general national focus toward startups. In 1998 the STTR/STTR programs sought fairly traditional business plan elements. This was reflected in the assessment criteria, which

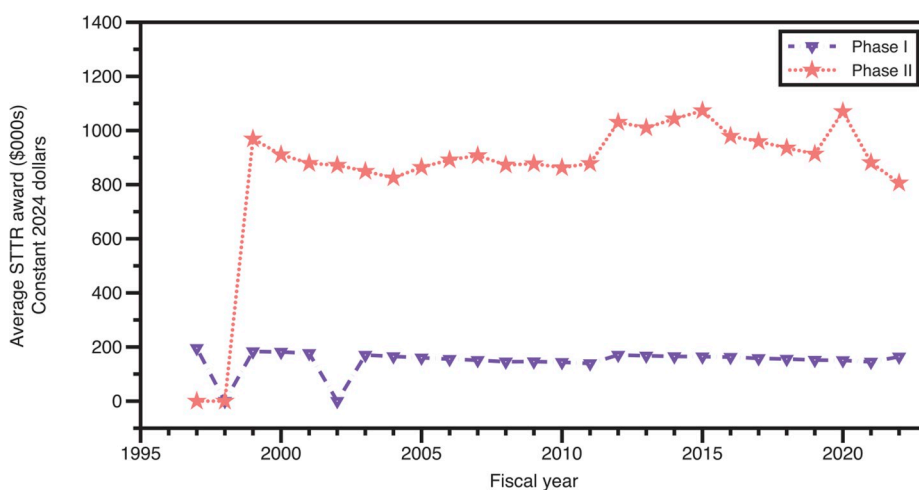


Figure 5. The average size of NASA STTR awards from 1997 to 2022, shown separately for Phase I (purple dashed line with triangular data) and Phase II (orange dotted line with starred data)

specified commercialization as an “adjectival” descriptor without a quantitative contribution to the scoring process. By the early 2000’s, the agency recognized that commercialization could include solutions to other federal agencies and increasingly to the growing private space marketplace. As a result, the solicitations were expanded to require language describing the firm’s commercial strategies in terms of intellectual property, defined value propositions, mentoring relationships, and other elements common in the broader entrepreneurial ecosystem. In parallel, the scoring rubric has evolved.

While NASA typically has not initiated significant new funding opportunities within the federal government, they have adopted best practices from other agencies, most notably NSF. Multiple additional funding extensions now exist to accelerate infusion for NASA’s needs. Thus, the program has made progress toward alignment to the new population of companies beyond traditional contractors.

3. Technical advancements

Typically, SBIR/STTR program assessments focus on specific outcomes easily observable in publicly available data, such as awards made to under-represented groups, geographic distributions of awards, and related measures. Few studies directly examine the output of the research activity, even though technology advancement lies at the heart of the SBIR/STTR promise. This is due principally to the paucity of standardized data to provide “apples-to-apples” comparison of technologies.

3.1 Context

NASA relies heavily on the ordinal Technology Readiness Level (TRL) scale ([Héder, 2017](#); [Mankins, 2009](#)) to assess technology progress. This universal scale ranges from one to nine ([Table 5](#)). At NASA, technologies must reach TRL 6 for use in flight projects ([NASA, 2007](#)). Although the TRL scale offers no information on the solution’s integration level (e.g., component, subsystem, or system) nor the severity of the problem addressed (e.g., enabling vs. enhancing technologies) ([Terrile et al., 2014](#)), it still contains important insights for proposal evaluation.

Advancing by a single TRL increment generally takes about a year ([Kenley et al., 2023](#); [Peisen and Schulz, 1999](#)), making a two-year program an awkward fit for a technology to advance from discovery (TRL 2 or 3) to infusion readiness (TRL 6). This simple truth – that the development cost profile far exceeds a typical SBIR/STTR award – drives some of the dynamics associated with the program, such as processes that maintain advantages for incumbent awardees and so-called “SBIR mills”.

Table 5. Definitions of technology readiness levels (TRLs)

TRL	Definition
1	Basic principles observed and reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof of concept
4	Component and/or breadboard validation in laboratory environment
5	Component and/or breadboard validation in relevant environment
6	System/sub-system model or prototype demonstration in a relevant environment
7	System prototype demonstration in an operational environment
8	Actual system completed and 'flight qualified' through test and demonstration
9	Actual system flight proven through successful mission operations

Note(s): From [Mankins \(2009\)](#)

Therefore, it is important to understand the role of TRL in the selection process and the portfolio as a whole.

Because of its central role in the NASA ecosystem, TRL enables a meaningful view into the program's role in stimulating technical innovation. In NASA SBIR/STTR proposals, the principal investigator (PI) reports the project's initial TRL and the anticipated final TRL. NASA staff then evaluate the final TRL at the project conclusion. The internal database contains these measures in the proposal records.

3.2 Analysis

Using data from 2009 to 2016, when TRL data are consistently available, [Belz et al. \(2019\)](#) reported on the progression of proposals in the SBIR/STTR programs [14]. They define a "microfirm" as one with 1-10 employees, in contrast to "standard small businesses" (SSBs) of 11-499 employees. At Phase I the selection rate for microfirms is 19%, whereas for SSBs it is 25% ([Table 6](#)). This estimate naturally leads to questions regarding the selection process.

These differences can be examined in detail with TRL as an indicator ([Table 7](#)). Initial TRL levels can be used to predict selection at each Phase, as shown in [Table 7](#), stratified for microfirms (SSBs) with 1-10 (11-499) employees, respectively. At TRL 1-3,

Table 6. Univariate firm size proximity and review outcomes

	Microfirms (1-10)		Standard Small Businesses (11-499)		<i>p</i> -value
	<i>N</i>	Mean	<i>N</i>	Mean	
Phase I Technical Score	3350	84.09	4747	87.09	0.00
Phase I Selection	3350	0.19	4747	0.25	0.00
Phase II Technical Score	565	92.26	1092	92.54	0.45
Phase II Selection	565	0.38	1092	0.42	0.21

Note(s): Descriptive statistics are evaluated for the NASA SBIR/STTR proposal database of 2009-2016. *T*-tests are used to test the equality of means, and increasing *p*-values indicate statistical equivalence

proposals from SSBs are more likely to be selected than microfirms at the lower TRL values, while at Phase 2 such differences appear only at TRL 3.

To better understand this, the authors conducted a multivariate logistic regression with selection as an outcome. However, to observe this robustly it is necessary to account for potential intrinsic differences in quality. An analytical tool known as entropy balancing (Hainmueller, 2012) (EB) can be used to weight select observations [15]. In principle, EB is related to Propensity Score Matching, in which covariates that can impact outcomes through a treatment are identified. The observations are then stratified into treated and untreated groups, and the untreated observations are weighted so that the covariate distributions are statistically similar to those of the treated observations. These distributions can be verified with *t*-tests. Entropy balancing preserves sample statistics and weights can be re-estimated with stratified sub-samples. Such features have expanded its use in management research (Ardianti *et al.*, 2022; Denoo *et al.*, 2024; Hendricks *et al.*, 2019).

To understand differences in microfirms and larger firms, one can conduct EB and weight the observations of larger firms. As covariates one can use:

- the firm history, namely the number of years since the first Phase I award; and
- the number of patents that the PI has prior to the proposal.

They considered three predictors:

- (1) firm size;
- (2) the initial TRL, as reported by the PI in the proposal; and

Table 7. Selection variations with initial TRL, stratified by firm size

Initial TRL	Headcount				<i>p</i> -value
	<i>N</i>	1-10 Sel. (%)	<i>N</i>	11-499 Sel. (%)	
<i>Phase I</i>					
0	71	0.14	64	0.14	1.00
1	558	0.16	626	0.22	0.01
2	1331	0.20	1986	0.25	0.00
3	958	0.19	1504	0.27	0.00
4	291	0.21	425	0.24	0.36
5	104	0.18	93	0.25	0.27
6	31	0.19	36	0.36	0.13
7	5	0.20	13	0.15	0.84
8	1	0.00	0	0.00	1.00
9	0	0.00	0	0.00	1.00
<i>Phase II</i>					
0	0	0.00	1	0.00	1.00
1	8	0.25	14	0.50	0.26
2	52	0.33	104	0.33	1.00
3	246	0.33	519	0.40	0.04
4	198	0.44	349	0.46	0.70
5	39	0.46	81	0.37	0.35
6	19	0.47	22	0.45	0.91
7	3	0.67	2	1.00	0.42
8	0	0.00	0	0.00	1.00
9	0	0.00	0	0.00	1.00

Note(s): Selection rates are reported at each initial Technology Readiness Level (TRL) for NASA SBIR/STTR proposals of 2009-2016. *T*-tests are used to test the equality of means, and increasing *p*-values indicate statistical equivalence

- (3) the anticipated difference in final and initial TRL, known as the TRL Improvement Level (TIL) (Alexander, 2018; Ma, 2021).

One can estimate Average Marginal Effects (AMEs) from logistic regressions of the probability of selection. Standard errors are clustered by firm. They find that Phase I

Table 8. Average Marginal Effects (AME) for selection

Factor	Phase I		Phase II	
	AME (pp)	<i>p</i> -value	AME (pp)	<i>p</i> -value
Log (headcount)	2.54	0.00	1.03	0.28
Initial TRL	0.69	0.13	3.57	0.00
Anticipated TIL	−1.85	0.00	−2.05	0.12
Year fixed effects	Yes		Yes	
Observations	8097		1657	
Tjur D	0.02		0.09	

Note(s): The probability of selection estimated with logistic regressions, using 2009–2016 NASA SBIR/STTR proposal data. Initial TRL = Technology Readiness Level as reported by the PI in the proposal. Anticipated TIL = Anticipated TRL Improvement Level as stated in the proposal. The treatment group is microfirms (1–10 employees) and untreated observations are weighted with the entropy balancing algorithm using the firm history and the number of patents as covariates. Standard errors are clustered by firm. Average marginal effects (AMEs) are reported in percentage points. The figure of merit is Tjur’s coefficient of discrimination *D*

selection is associated with larger companies (Table 8), such that a tenfold growth in headcount increases the probability of selection by three percent ($p < 0.005$). In contrast, at Phase II firm size is not statistically relevant, but the initial TRL is, such that each TRL increment increases the selection by 3%. As Table 7 indicates, the application pool is weighted toward lower TRL values, and thus this is likely more impactful than estimated across the entire domain. At Phase I, large TIL values are negatively associated with selection. This could reflect the evaluators’ concern that large TIL values are overly ambitious, given the typical cost profile of TRL advancement discussed above.

Belz *et al.* (2019) then model the final TRL, as estimated by NASA staff at project conclusion, using linear regressions [16]. Controlling for the initial TRL, they find that the final TRL is inversely related to the size of the company, with smaller firms reaching higher values (Table 9) at Phase I.

Finally, to estimate the outcomes of the entire portfolio, Belz *et al.* (2019) aggregate the distributions of the final Phase II TRL and link them back to the initial TRL at project inception. The resulting transition matrix (Table 10) is the most direct observable output of the SBIR/STTR programs. It demonstrates that the program principally funds technologies advancing from TRL 3–4 to 4–5, known as the “Valley of Death”.

Table 9. Final TRL variation

	Phase I	Phase II
Log(headcount)	−0.06*** (0.02)	−0.02 (0.05)
Initial TRL	0.44*** (0.02)	0.29*** (0.06)
Year fixed effects	Yes	Yes
Observations	1834	671
R2	0.22	0.07

Note(s): *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Final Technology Readiness Level (TRL) as reported by NASA, estimated using linear regressions of the 2009–2016 NASA SBIR/STTR award data. The treatment group is microfirms (1–10 employees) and untreated observations are weighted with the entropy balancing algorithm using the firm history and the number of patents as covariates. Standard errors are clustered by firm. Initial TRL is reported by the PI in the proposal

Table 10. TRL transition probabilities through Phases I and II

		Final TRL at the end of Phase II							
	1	2	3	4	5	6	7	8	9
<i>Initial TRL at the beginning of Phase I</i>									
1	–	–	0.5 ± 0.3	0.5 ± 0.3	0.2 ± 0.2	0.2 ± 0.2	–	–	–
2	–	0.5 ± 0.3	2.1 ± 0.7	2.8 ± 0.8	1.6 ± 0.6	0.7 ± 0.4	0.2 ± 0.2	–	–
3	–	0.7 ± 0.4	3.4 ± 0.8	14.4 ± 1.7	13.1 ± 1.6	8.3 ± 1.3	1.6 ± 0.6	0.2 ± 0.2	–
4	–	–	12.5 ± 0.5	13.1 ± 1.6	12.0 ± 1.6	10.1 ± 1.4	1.6 ± 0.6	0.5 ± 0.3	–
5	–	0.2 ± 0.2	–	0.5 ± 0.3	2.1 ± 0.7	3.0 ± 0.8	1.4 ± 0.6	–	–
6	–	–	–	–	0.2 ± 0.2	0.2 ± 0.2	1.4 ± 0.6	0.7 ± 0.4	0.5 ± 0.3
7	–	–	–	–	0.2 ± 0.2	–	–	–	–
8	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–

Note(s): The transition matrix for all Phase II projects in the 2009–2016 NASA SBIR/STTR programs. Phase II final Technology Readiness Level (TRL) as assessed by NASA is related to the Phase I initial TRL reported by the PI

3.3 Summary

The NASA SBIR/STTR program selection process is favored toward larger small businesses in Phase I, particularly at low TRL values. However, firm size does not affect Phase II selection. In contrast, the initial TRL does not impact selection at Phase I but it does at Phase II. Particularly in Phase I, anticipated large jumps in TRL Improvement Level are disfavored in the selection process.

The outcomes show interesting variations as well. Smaller firms are associated with higher values for the final TRL, an important finding that may be aligned with the role of startups in sparking economic growth ([Decker *et al.*, 2016](#); [Haltiwanger *et al.*, 2013](#)). Importantly, the program largely funds technologies advancing from TRL 3-4 to 4-5, in concert with its mission of sourcing innovation.

4. Expanding access to female researchers

One of the explicit goals of the SBIR/STTR programs is to enhance the participation of underrepresented groups in the federal research enterprise. At the firm level, companies of interest include Women-Owned Small Businesses (WOSBs), Historically Underutilized Business Zones (HUBZones), and socially disadvantaged businesses (SDBs). The few disadvantaged businesses that participate in the program show statistically significant increases in the mean number of awards received over the 1983-2022 time period, indicating that qualified firms may be repeatedly selected (Table 11). This effect is consistent throughout both Phases of the SBIR program but only at Phase I of STTR; however, the STTR Phase II award pool is quite small. For instance, only seven HUBZone firms were given Phase II STTR awards in forty years. Table 11 suggests that a few firms are heavily favored, but it does not illuminate the selection process.

4.1 Context

A competitive selection process can lead to lower representation of a disadvantaged group in three ways (Murray *et al.*, 2019):

- (1) *Disparities* occur when competition pools have unequal composition.
- (2) *Bias* takes place when differential evaluation standards are applied to two groups.
- (3) *Inequities* result when selection rates reveal differences.

Lower representation of women has been observed in the SBIR/STTR program, in that WOSBs generally receive less Phase II funding (Joshi *et al.*, 2017). Importantly,

Table 11. Mean number of awards for disadvantaged businesses

Group	In Group		Not in Group		<i>p</i> -value
	<i>N</i>	Mean	<i>N</i>	Mean	
<i>Phase I SBIR</i>					
WOSB	211	11.07	3082	3.62	0.00
HUBZone	46	16.33	3247	3.50	0.00
SDB	175	11.98	3118	3.59	0.00
<i>Phase II SBIR</i>					
WOSB	100	6.30	1720	2.81	0.00
HUBZone	17	10.29	1803	2.73	0.05
SDB	94	6.35	1726	2.80	0.00
<i>Phase I STTR</i>					
WOSB	47	3.89	438	1.97	0.02
HUBZone	13	4.31	472	1.92	0.05
SDB	54	3.56	431	1.99	0.02
<i>Phase II STTR</i>					
WOSB	19	2.05	247	1.62	0.30
HUBZone	7	1.57	259	1.59	0.97
SDB	26	2.04	240	1.63	0.21

Note(s): Award data drawn from SBIR.gov for 1983–2022. Mean values are given for the number of awards to each unique firm in the category for Women-Owned Small Businesses (WOSB); Historically Under-utilized Business Zones (HUBZones); and socially disadvantaged businesses (SDBs). *T*-tests are used to test the equality of means, and increasing *p*-values indicate statistical equivalence

funding outcomes are insufficient to identify bias in the process (Bol *et al.*, 2022), as corrective redistribution may be used to reverse unobserved bias (Graddy-Reed *et al.*, 2019).

As noted in Section 2, the review criteria have consistently included evaluation of the technical team. This motivates a study of the principal investigator (PI), who also serves as the team lead. A study of gender effects in proposal scoring and selection outcomes could demonstrate how the SBIR/STTR programs fulfill the objective of enhancing the participation of women in the federal research enterprise.

4.2 Analysis

A study of female PIs (FPIs) can generate insight because an audit of NASA SBIR WOSB awardees indicated that one-third had fraudulent status (NASA, 2013). Thus, the PI gender should be more reliable as a measure of potential gender effects. It is also more germane to the question of the three methods of lower participation discussed by [Murray et al. \(2019\)](#). Notably, gender is irrelevant to the proposal evaluation criteria discussed in Section 2.

[Belz et al. \(2022a\)](#) used the NASA proposal database of 2009-2016 [\[17\]](#) to examine possible gender bias or inequities by following female Principal Investigators (FPIs) [\[18\]](#). They used a combination of automated processes and manual confirmation to predict the gender of the proposing PI's first name. Less than 10% of proposals are submitted by FPIs. Univariate descriptive statistics indicated that the mean Technical Score (TS) at Phase I was 84.9 (85.9) for female and male PIs, respectively; and 90.4 (92.6) at Phase II ([Table 12](#)). As described in Section 2, the TS is used to identify candidates for funding, with a minimum value of 85 required for consideration in some years [\[19\]](#).

Bias would result if a reviewer incorporated gender in the proposal evaluation process, even though the proposal's technical merit should be unrelated to gender. In principle, this might be less likely with PIs known to the reviewer, either through his/her firm's history with the SBIR/STTR programs or through his/her own application process.

To correct for potentially confounding endogenous differences between male and female PIs, the authors used the entropy balancing algorithm of Section 2. The authors used PI gender as the treatment and balanced the data with firm-level covariates, namely:

- the firm headcount, shown in Section 3 to impact selection;
- a binary variable set to one if the firm was in California or Massachusetts because geographical differences are linked to innovation propensity ([Guzman and Stern, 2015](#)); and
- a binary variable indicating if the firm had previously submitted proposals by both male and female PIs.

As a fourth balancing covariate, the authors included the number of patents issued to the PI [\[20\]](#) in the ten years preceding the Phase I application because patents are

Table 12. Univariate review and selection outcomes stratified by PI gender

	Female PI		Male PI		<i>p</i> -value
	<i>N</i>	Mean	<i>N</i>	Mean	
Phase I Technical Score	544	84.91	7553	85.92	0.05
Phase I Selection	544	0.21	7553	0.23	0.32
Phase II Technical Score	107	90.40	1550	92.59	0.01
Phase II Selection	107	0.36	1550	0.41	0.27

Note(s): Descriptive statistics are evaluated for the NASA SBIR/STTR proposal database of 2009–2016. *T*-tests are used to test the equality of means, and increasing *p*-values indicate statistical equivalence

reported in the proposal and may serve as a signal for technology firms ([Conti et al., 2013](#); [Hsu and Ziedonis, 2013](#)).

The authors estimated the TS with linear regressions and controlled for the headcount, the PI's patents, and the NASA Center receiving the proposal. The standard errors were estimated by clustering the observations by PI because quality could be correlated for multiple submissions by the same author. The authors proposed that the bias represents an example of status characteristics theory, the use of a heuristic that assigns importance to an observable characteristic irrelevant to the task in question ([Berger et al., 1972, 1977](#); [Foddy and Smithson, 1996](#)), and that this shortcut would be strongest for unknown firms or PIs ([Bitektine, 2011](#)). Consequently, they considered a firm-level moderator of its prior NASA SBIR/STTR award history, as well as the PI's prior applications within the database.

The authors measured a bias of approximately two points at each Phase of the program ([Table 13](#)), which was indeed strongly moderated by the PI's application history with the program at Phase I, but only weakly moderated at Phase II by the firm history.

A similar analysis was conducted for the probability of selection ([Table 14](#)), with the Technical Score added as a control. The statistically significant bias seen in Technical Score was largely absent in selection, suggesting a corrective redistribution process ([Graddy-Reed et al., 2019](#)) that recognizes and ameliorates biases imposed in the evaluation process. However, there is evidence of a remaining bias moderated by the firm's history with the SBIR/STTR programs.

Table 13. Gender effects in Technical Score (linear regression)

	Phase I			Phase II		
	(1)	(2)	(3)	(4)	(5)	(6)
PI gender	-1.26** (0.55)	-1.87** (0.91)	-2.62*** (0.78)	-1.66** (0.85)	-2.32* (1.32)	-2.97** (1.44)
History		0.04 (0.03)			0.07* (0.04)	
PI gender × history		0.06 (0.06)			0.06 (0.09)	
PI applications			-0.06 (0.07)			0.22 (0.31)
PI gender × applications			0.45*** (0.15)			0.84 (0.68)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8097	8097	8097	1657	1657	1657
PIs	3501	3501	3501	1118	1118	1118
Adj. R^2	0.05	0.05	0.05	0.10	0.10	0.09

Note(s): *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Technical Scores are estimated with linear regressions. Data are drawn from NASA SBIR/STTR proposal database from 2009–2016. Observations with male PIs are weighted by an entropy balancing algorithm. PI gender is set to one for female PIs. Controls include patents, headcount, and reviewing Center. History indicates the number of years since the proposing firm's first award from the NASA SBIR/STTR programs. Applications indicate the number of proposals by the PI in the proposal database. Standard errors are estimated by clustering by PI

Table 14. Gender effects in selection (logistic regression)

	Phase I			Phase II		
	(1)	(2)	(3)	(4)	(5)	(6)
PI gender	0.05 (0.13)	0.25 (0.19)	0.02 (0.19)	-0.11 (0.30)	-1.23** (0.46)	0.39 (0.58)
History		-0.01 (0.01)			-0.03* (0.02)	
PI gender × history		-0.02 (0.01)			0.11*** (0.03)	
PI applications			-0.01 (0.02)			0.02 (0.09)
PI gender × applications			0.02 (0.04)			-0.35 (0.37)
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8097	8097	8097	1657	1657	1657
PIs	3501	3501	3501	1118	1118	1118
Tjur D	0.41	0.41	0.40	0.28	0.28	0.28

Note(s): *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Selection outcomes are estimated with logistic regressions. Data are drawn from NASA SBIR/STTR proposal database from 2009–2016. Observations with male PIs are weighted by an entropy balancing algorithm. Controls include patents, headcount, reviewing Center, and the Technical Score. History indicates the number of years since the proposing firm's first award from the NASA SBIR/STTR programs. Applications indicate the number of proposals by the PI in the proposal database. Standard errors are estimated by clustering by PI. The figure of merit is Tjur's Coefficient of Discrimination D

4.3 Summary

The SBIR/STTR program has an explicit goal of increasing participation of businesses and individuals historically less represented in the scientific enterprise. A peer review competition is widely considered the gold standard in creating a meritocratic process that identifies excellence. However, a study of an intermediate quantitative outcome – the Technical Score, a key determinant of selection – suggests that the NASA SBIR/STTR peer review process does not consistently evaluate proposals from equivalent male and female PIs. Instead, a gender disparity of one or two percent is seen in the Technical Score, an evaluation metric constructed for the explicit purpose of selecting awardees. This penalty appears to be moderated by the history of either the PI or the proposing firm, in line with status characteristics theory. Moreover, it manifests less in the final selection decisions, in concert with corrective redistribution. These findings have significant implications for policies and practices to provide opportunities for historically disadvantaged groups, particularly within the SBIR/STTR programs.

5. Subsequent patent generation

Patents point to technological novelty and innovation ([Conti et al., 2013](#); [Hottenrott et al., 2016](#); [Hsu and Ziedonis, 2013](#)) and are therefore an important innovation output of the technology-rich aerospace industry ([Ardito et al., 2016](#)). It is natural to consider them as an outcome following the SBIR/STTR programs. Patents can be considered as a potential spillover or a technology transfer mechanism.

5.1 Context

To date, scholars have principally examined patents following DOE SBIR/STTR awards. [Howell \(2017\)](#) reported that a Phase I award is linked to a subsequent patent increase of 30% and that half of the effect occurs within two years, but the Phase II award has only a small positive effect on patents. Separately, [Myers and Lanahan \(2022\)](#) reported that each patent generated by DOE SBIR/STTR recipients yields another three from geographic spillovers.

The results of the DOE program might not be generalizable for several reasons. First, [Howell \(2017\)](#) observed that only 40% of the DOE 1995–2013 Phase I awardees applied to Phase II; in the latter years of that time period, significant venture capital activity drove the energy sector. If the Phase II proposal population was depleted of firms that sought venture capital to finance patent activities, then patent production subsequent to Phase II could have been depressed. In contrast, more than 90% of recent NASA Phase I awardees submit Phase II proposals. In addition, patents confer benefits that vary with industry ([Hoenig and Henkel, 2015](#)), and thus the importance of patenting may look different for aerospace firms.

Table 15. Patent outcomes of Phase II awards

	Headcount			
	0-499	1-9	10-49	50-249
<i>Panel A: Average Marginal Effect of Probability of Patenting</i>				
Win Phase II	0.067***	0.073**	0.012	0.023
Observations	1,683	572	642	156
Controls	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes
p-value	0	9e-10	4e-9	2e-3
<i>Panel B: Average Marginal Effect of Probability of Patenting for Firms Without Prior Patents</i>				
Win Phase II	0.042	0.064*	0.133**	
Observations	760	324	195	
Controls	Yes	Yes	Yes	
Weights	Yes	Yes	Yes	
p-value	3e-4	0.012	0.017	
<i>Panel C: OLS Regression Estimating ln (Forward Patents) (If Any)</i>				
Win Phase II	-0.113	0.500	-0.128	0.212
Observations	354	61	171	65
Controls	Yes	Yes	Yes	Yes
Weights	Yes	Yes	Yes	Yes
Adj. R^2	0.148	0.007	0.198	0.018

Note(s): *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. Patent outcomes are reported for the NASA SBIR proposal pool of 2002–2012. The outcome in Panels A and B is the Average Marginal Effect of the probability of patenting for the full sample (Panel A) and the firms without prior patents (Panel B). The subsample of the largest firms in Panel B is excluded for statistical reasons. Panel C reports the coefficients of an OLS regression on the number of forward patents, conditional on patenting. The treated (with Phase II award) observations are compared to untreated (not selected for Phase II award) with a Propensity Score Matching methodology. Controls include year fixed effects and fixed effects for the NASA Center receiving the proposal

5.2 Analysis

Giga *et al.* (2021) studied patent generation following the NASA SBIR/STTR Phase II award, using proposals in the 2002-2012 time frame [21]. Using a Propensity Score Matching (PSM) technique to address potential endogeneity issues, Giga *et al.* (2021) conducted logistic regressions on the outcome of the probability of patenting. The

PSM instrument was the likelihood of selection for a Phase II award, with propensity covariates of firm headcount (which impacts firm selection, as discussed in Section 3), the number of prior Phase II awards (Section 4), and the number of prior patents.

Using this instrument, [Giga et al. \(2021\)](#) found that receiving a Phase II award increased the probability of patenting by roughly 7%, but only for the smallest firms of 1-10 employees ([Table 15](#), Panel A). A subsample of firms without prior patents revealed a consistent effect that was less statistically significant (Panel B), but an effect appears for the firms of 11-49 employees. Conditional on patenting, the number of subsequent patents did not vary with the Phase II award. It therefore appears that the Phase II award helps those with prior patents as they know how to put the money to work, and they generate new patents.

5.3 Summary

Patents are an important outcome of an innovation program, especially in the aerospace industry. In the NASA SBIR/STTR program, the vast majority of Phase I awardees participate in the Phase II competition. The Phase II award increases the probability of patenting, particularly for the smallest firms. However, conditional on patenting, it does not increase the number of patents issued to the awardee firms. This motivates further studies of subsidies geared specifically toward innovation and patenting.

6. Program structure

The SBIR two-stage structure has operated since program inception, but limited research has explored whether this construct is optimized. The absence of counter-examples limits empirical investigations, and thus models are needed. [Bhattacharya \(2021\)](#) framed the DOD SBIR/STTR program as a contest with a Phase III award as the incentive to study the program structure, and he found that some changes, such as increased incentives and expansion of the competitive field, would improve the social return. It is desirable to expand these studies to understand the program as a whole.

6.1 Context

One challenge of the SBIR/STTR programs is that they have objectives wherein monetary considerations may be secondary. For instance, the results of Section 2 suggest that the proposal pool of Phase I differs strongly from that of Phase II, such that firm size is an important observable that characterizes risk. Therefore, funding smaller firms may be difficult. Alternatively, specific technical needs may motivate financing riskier, early-stage technologies that could be more expensive. Such trade-offs are not easy to capture in a straightforward financial analysis, and yet they drive the portfolio management.

A useful strategic tool is to frame the problem in terms of real options, a construct derived from the finance literature ([Trigeorgis and Tsekrekos, 2018](#)). Real options describe that how the funding manager has the right, but not the obligation, to fund a project at each competition round. This approach enables the portfolio manager to accomplish several goals:

- the analysis can incorporate weighting schemes to represent the relative importance of various strategic alternatives; and
- it can accommodate a staggered funding architecture to exploit information gained after one tranche, which can then influence the next funding decision.

It is appealing to frame the SBIR/STTR programs, a two-stage funding system, through the lens of real options. With such a perspective, it is possible to formulate the multiple parallel funding decisions as an optimization problem. Alternatively, one can model the system as a set of discrete decision trees and associated cash flows, with discount rates that capture the variations in risk as more information is obtained.

6.2 Analysis

Belz *et al.* (2025) [22] formulated the SBIR/STTR programs in a real options framework by creating an objective function to estimate portfolio value. This function varied under various constraints, including the final TRL and the TRL Improvement Level (TIL). They created a third constraint to represent the opportunity that one would fund the top technologies at low TRL if they held enough potential, which they termed creating “diversity” of promising technologies across all TRLs.

The authors used the previously measured TRL transition matrices (Belz *et al.*, 2019) discussed in Section 3, disaggregated separately for microfirms (1-10 employees) and standard small businesses (SSBs). These matrices were consolidated at the high and low ends due to poor statistics, and thus four TRL bins were created, defined in terms of initial TRL at Phase I as (0-1, 2, 3, 4+) and at Phase II as (0-2, 3, 4, 5+). Using a mixed-integer formulation, they created an approximation to the true real options problem and estimated the fraction of projects funded in each TRL transition bin for each class of firms (microfirms and SSBs).

Belz *et al.* (2025) created a base case (labeled A) and estimated the impact on the objective function of two distinct variations (Table 16): (Case B) Enhancing the population of microfirms by increasing its weight by 10%, relative to SSBs; and (Case C) allowing the Phase I/II budget ratio to vary.

They examined the impact of these structural changes on the portfolio (Table 16) and found that favoring the microfirms by 10% yields the expected commensurate increase in the number of microfirm projects -29% at Phase I, and 65% at Phase II. Importantly, this affects the estimated portfolio objective function value by less than 2%. That is, many more microfirms can be funded without impacting the portfolio

Table 16. Portfolio variations with real options models

Model	A	B	C
Description	Base case	Microfirm enhanced	Flexible allocation
Headcount weighing	Equal for microfirms and SSBs	1.05 for microfirm/ 0.95 for SSB	Equal
Budget allocation (%) Phase I/total budget	32	32	Varies
<i>% Change in microfirm projects</i>			
Phase I		+29	-73
Phase II		+65	-26
<i>% Change in SSB projects</i>			
Phase I		-15	-37
Phase II		-35	+30
<i>% Change in portfolio value</i>			
		-1.7	+14

Note(s): SSB are Standard Small Businesses with 11-499 employees, in contrast to microfirms with 1-10 employees. For Cases B and C, relative differences from Case A are shown. Case B increases the weights for the microfirms by 10% but uses the same Phase I/II budget ratio as Case A. Case C maintains the headcount weights of Case A, but allows the budget ratio to vary. The changes in the number of projects funded are reported for Cases B and C, as are the changes in the portfolio value function. All changes are reported in percent

value because of the results of Section 3: smaller firms are associated with higher final TRL.

The authors showed that varying the budget ratio leads to a strong increase of funded Phase II projects from SSBs (+30%) in order to generate a 14% increase in portfolio value. In other words, the program currently experiences a 14% penalty in portfolio by funding vastly more Phase I projects -73% more projects from microfirms and 37% from SSBs. This effectively demonstrates the tradeoff between diversifying the program's performer base and advancing the technology portfolio, both of which are central programmatic objectives.

Next, they estimated the fraction of projects funded in each TRL transition bin (Table 17). Projects that start at lower TRL bins in Phase I are more likely to be funded for both microfirms and SSBs. As expected, increasing the weight of microfirms (Case B) causes more microfirms to be funded – but only for the lower TRL bins. This takes place at the expense of the SSBs at mid-TRL bins. Notably, varying the budget allocation in Phase I (Case C) improves the funding rate for both the microfirms and the SSBs at

Table 17. Variations with TRL bin of funding rates in real options models

Initial TRL bin		Microfirms			SSB		
Phase I	Phase II	A	B	C	A	B	C
1	1	0.0	–	1.0	0.0	–	–
1	2	0.5	–0.1	0.5	0.3	–	0.7
1	3	1.0	–	–	1.0	–	–
1	4	1.0	–	–	1.0	–	–
2	1	0.0	–	–	0.0	–	–
2	2	0.0	–	1.0	0.0	–	1.0
2	3	0.9	0.1	0.1	1.0	–	–
2	4	1.0	–	–	1.0	–	–
3	1	0.0	–	–	0.0	–	–
3	2	0.0	–	–	0.0	–	–
3	3	0.0	0.3	–	0.5	–0.5	0.5
3	4	1.0	–	–1.0	1.0	–	–
4	1	0.0	–	–	0.0	–	–
4	2	0.0	–	–	0.0	–	–
4	3	0.0	–	–	0.0	–	–
4	4	0.0	1.0	–	0.0	–	–

Note(s): Fractions are estimated separately for microfirms and standard small businesses (SSBs) for the three cases defined in Table 4.3. TRL represents consolidated bins, not actual TRL. Columns labeled Cases B and C report absolute differences from the Case A. For instance, projects starting at TRL bin 1 in Phase I and TRL bin 2 in Phase II, Case B funds 10% fewer microfirm projects than Case A, and Case C funds 50% more microfirm projects than Case A - namely, all the projects

lower TRL bins, indicating that with more flexibility it is desirable to fund earlier-stage technologies.

A related application of the real options framework is to estimate the value of a single project in the SBIR/STTR portfolio. This is possible because a real options problem can be framed as a traditional discounted cash flow (DCF) model, with discount rates modified to incorporate the changing risks as the project progresses. Indeed, a central objective of a staged program is to capture new information of the risks as they evolve and are mitigated. Therefore, such a model is highly relevant to estimating value in the SBIR/STTR programs, where a primary focus is to develop solutions with a high degree of technical risk. [Belz and Giga \(2018\)](#) created such a model [23] using a simple decision tree framed from the perspective of the

SBIR/STTR program manager. They assumed that the two Phases represented cash outflows that were followed by two further inflows: Supplemental funding of \$2 M, and ultimately a payoff funding from a flight project of \$3 M. Using standards of the aerospace industry, they assigned a liquidation value to projects declined at each funding stage.

With such a model, the authors determined that the average project value is on the order of -\$100-200 K. The sign is important as it indicates that it would not be rational to invest in these projects, and therefore the program likely does not crowd-out private investors. The magnitude of the value indicates the average Phase I project is effectively an outflow from the perspective of the program. Next, they considered that for these firms, the average cost of capital (usually on the order of 25-33%) is considerably higher than a risk-free rate, and they estimated the impact of a funding delay. A simple model suggested that a delay of just three months in Phase II funding is equivalent to a \$20 K reduction in the size of the award. Finally, they conducted a sensitivity analysis ([Table 18](#)) and found that reducing the Phase II award size counter-intuitively increases the average project value by 2% because so many projects fail. Likewise, increasing the fraction of projects that advance to Supplemental funding increases the average project value by over one percent because the Supplemental funding is a cash inflow for the SBIR/STTR program.

6.3 Summary

Most SBIR/STTR studies are rooted in empirical analyses of outputs and outcomes. Less attention has been directed to the program structure, although [Bhattacharya \(2021\)](#) determined that increases in incentives and the competitive population improve the performance of the program.

A real options framework captures the value of the important flexibility conferred by the two-stage SBIR/STTR program architecture. A computational approach that leverages the information about technology maturity can presume that both the TRL and the related TRL Improvement Level are important drivers of portfolio value; such an analysis finds that the program currently operates near its optimum. However, this optimum may be broader than previously understood. Notably, favoring microfirms in the review process yields a distinct set of projects with *de minimis* impact on portfolio value, because the smaller firms are more likely to reach higher final TRL in Phase I.

Table 18. Estimated drivers of average project value

Parameter	Parameter base value	Parameter value with 1% change	Relative change in project value
<i>Probability of advancement</i>			
Phase II	0.5800	0.5742	0.50%
Supplemental	0.2500	0.2525	1.42%
Flight	0.2500	0.2525	0.41%
<i>Timeline (years)</i>			
Phase I	0.500	0.505	0.06%
Phase II	1.500	1.485	0.80%
Supplemental	2.00	1.98	0.33%
<i>Award size (\$)</i>			
Phase I	100,000	99,000	0.55%
Phase II	600,000	594,000	2.00%
Supplemental	2,000,000	2,020,000	1.06%
Flight	3,000,000	3,030,000	0.49%
<i>Liquidation values (\$)</i>			
Phase I	15,000	15,150	0.05%
Phase II	120,000	118,800	0.15%
Supplemental	500,000	505,000	0.25%

Note(s): Changes of 1% were made to the base value of each parameter, and the impact on the average project value is reported. Parameters were changed to increase the value of the project and thus some changes were positive and others negative

The second finding uses a simple decision tree with realistic discount rates to show that the project value is negative. This analysis shows the importance of public resources to take on the risk that the private market cannot. Such a model also shows that even short bureaucratic delays can be catastrophic for a small company because of the high cost of capital.

7. Summary and policy considerations

With forty years of history and thousands of awardees, the SBIR/STTR programs have been studied extensively for many reasons. Technology innovation offers the promise of rippling economic development, and government subsidies enable the public to take risks unsupportable by rational private investors. To date, these programs have been examined widely as a source of intellectual spillovers of various kinds, such as patents, trademarks, publications, and of course products – none of which are specified as desired outcomes in the underlying legislation. In addition, as interest has grown in the role of startups in driving economic growth ([Decker et al., 2016](#); [Haltiwanger et al., 2013](#)), these programs have been somewhat – and at times, awkwardly – repurposed toward funding startups, creating some dissonance of goals that may operate in direct conflict with one another.

The studies herein were largely conducted with a database that includes declines, and therefore this opens the door to a complete view of the realization of selection criteria. As described in Section 2, the criteria have evolved over the years to meet many needs. Because the records contain TRL estimates reported initially by the proposing PI and later by the evaluating NASA official, it is possible to estimate quantitatively how the projects fare in advancing innovation.

The works described here paint a fascinating picture of the SBIR/ STTR programs as implemented at NASA. The findings and associated policy recommendations are:

- *Prepare teams for business success prior to proposal submission:* The programs' criteria have evolved over the last twenty-five years toward a greater focus on commercial strategic activities such as customer discovery, value

proposition definition, intellectual property management, and related topics critical to the success of modern new enterprises. Additional training along these lines would help potential proposers articulate stronger business models that include NASA. Notably, the NSF I-Corps program was designed to prepare academic researchers to develop stronger SBIR/STTR proposals. However, NASA does not make currently this opportunity available until after the award is made. Creating a pathway to I-Corps or similar training prior to proposal generation would be impactful.

- *Capture proposal-level data to link sequences and technical outcomes:* The NASA database structure enables straightforward studies from Phase I to II. The embedded TRL information is invaluable in evaluating the progress of the funded technology – the immediate outcome of the program. Data for the SBIR/STTR programs across the government should encompass these links, and TRL or related metrics should be maintained with proposal records.
- *Fund more microfirms:* When the SBIR program was founded in the early 1980s, a headcount of 500 represented a “small” company. The dramatic reduction in the cost of starting and managing the smallest firms at the smallest scales has led to reduced business risk in awarding federal funds to them. Currently, selection favors larger companies at Phase I, and more advanced technologies at Phase II. However, microfirms are more likely to advance further in Phase I, and more can be funded without compromising portfolio value. In addition, these are the firms for which the Phase II award is catalytic in spurring patent generation.
- *Make larger Phase II awards:* The SBIR/STTR programs absolutely address the Valley of Death, as defined by the TRL distance traversed. Unfortunately, the funds are insufficient to carry a typical technology across the finish line from discovery to implementation, leading to the dynamics of multiple award winners and other processes that favor incumbents. Larger Phase II awards could provide the resources to make greater progress in the actual technology advances.
- *Conduct transparent and fair review processes:* Strong signs of a gender bias manifest, but it appears to be somewhat reversed at the award stage via a corrective redistribution process. These effects appear to be partially mitigated when the proposer or the firm is known to the program staff. In addition, little is known publicly about the composition and onboarding of the NASA review

panels and boards. The SBIR/STTR program staff could increase its outreach to new proposers and firms, inviting them to serve as reviewers as well as proposers. NSF has conducted such efforts for many years, with great success.

Many interesting policy questions remain. For instance, several dimensions of access remain unexplored, such as underprivileged firms beyond those with women PIs, and increasing proposal flow from less active regions of the country. How do these firms fare in the review processes, and do they proceed to further procurement from the federal government? The supplemental or Phase III outcomes have yet to be systematically explored in the NASA context.

In addition, the NASA database has firm size but not age. Linking these data to other sources could illuminate some of the concerns regarding the need to support startups. Moreover, the venture capital databases could be harvested to see how these sources of capital are complements or substitutes.

These data could also be linked to observations from other agencies, particularly the DOD as it develops technologies that are often similar in character. How do DOD and NASA funding sources overlap, and where do opportunities for cross-pollination between the agencies exist?

Notwithstanding the concerns about bias in the review process, the NASA SBIR/STTR programs have contributed strongly to developing transformative technologies.

NASA has rightfully owned a place of pride in the national technology ecosystem. Hopefully, the studies about these programs will influence scholars and policy leaders alike to accelerate further infusion of privately developed technologies for civil use in space.

Acknowledgements

Thanks to the National Aeronautics and Space Administration and the California Institute of Technology/Jet Propulsion Laboratory for the opportunity to analyze these data, the National Science Foundation I-Corps Program, and the University of Southern California Undergraduate Research Associates Program. The statements made here are solely the opinion of the authors and do not represent the views of these organizations.

I am grateful to my collaborators: Jeremy Eckhause, Aleksandar Giga, Isabel Hanewicz, Michael Kawas, Richard Terrile, and Fernando Zapatero; the reviewers who improved this work; the many students who contributed to Patentopia; and Al Link for encouraging this synthesis. Thank you to Lucy Wiseman for exceptional editorial review and, more importantly, for keeping me on track. I am especially appreciative of Alexandra Graddy-Reed for serving as a partner in creative thought as well as leadership of the Management of Innovation, Entrepreneurial Research, and Venture Analysis (MINERVA) group at the University of Southern California – together we created a model of interdisciplinary learning across policy and engineering.

Most of all, I thank my sons, Nicholas and Stephen, and my partner, Bill LaFontaine – all of whom have demonstrated exceptional patience as I pulled this together.

Notes

- [1.] <https://spinoff.nasa.gov/node/9520>
- [2.] <https://spinoff.nasa.gov/spinoff1996/43.html>
- [3.] https://spinoff.nasa.gov/Spinoff2008/ch_8.html
- [4.] https://spinoff.nasa.gov/Spinoff2005/ch_6.html
- [5.] <https://spinoff.nasa.gov/node/9433>
- [6.] An extensive set of examples can be seen at <https://spinoff.nasa.gov/>
- [7.] This is still an active topic of scientific research and a consensus has not been reached.
- [8.] This strategy was reinforced by the American Innovation and Competitiveness Act (AICA) of 2017, which indicates the seven goals for the Broader Impacts merit review criterion required for any NSF proposal. They are: (1) increase American economic competitiveness; (2) advance health and welfare of the American public; (3) support national defense; (3) enhance academic-industry partnerships; (5) develop a national science, technology, engineering, and mathematics (STEM) workforce; (6) improve public science literacy; (7) expand participation of women and under-represented groups in STEM. Because startups have been shown to contribute to the national economy, supporting them meets the first goal of the AICA. Moreover, the NSF SBIR/STTR portfolio is expected to contribute broadly to the national welfare in service of the second goal.
- [9.] While some technologies may have multiple applications, including national security, NASA and other agencies do not accept SBIR/STTR proposals with classified information.
- [10.] CMS is the Commercialization Metrics Survey to which awardees are asked to respond.

- [11.] TABA is Technical and Business Assistance, a supplement authorized beginning in 2019.
- [12.] Separately, the 1998 solicitation defines “commercialization as: the process of developing markets and producing and delivering products or services for sale (whether by the originating party or by others). As used here, commercialization includes both government and non-government markets.”
- [13.] Records reporting $\{\{\text{\textdollar}\}\} 0$ were removed from the dataset.
- [14.] Earlier versions of the tables presented here were reported in [Belz et al. \(2019\)](#).
- [15.] The original work was published without EB weighting. The data have been reprocessed for this work. All the principal findings are consistent and robust.
- [16.] A categorical variable with more than five steps may be approximated with a linear function ([Rhee and Leonardi, 2018](#)).
- [17.] Earlier versions of the tables presented here were reported in [Belz et al. \(2022a\)](#).
- [18.] Disparities were noted in that the fraction of proposals authored by FPIs was 6.7% (6.5%) in Phase I (II).
- [19.] As noted in Section 2, projects scoring above the line are not guaranteed funding, and thus an empirical study using the threshold of 85 would not make an appropriate regression discontinuity design (RDD) study. Moreover, as discussed below, corrective redistribution may alter the selection process on both sides near the line – thereby violating one of the key RDD assumptions.
- [20.] Patents were not included in the database but instead were extracted with a software tool linked to the US Patent and Trademark Office PatentsView platform ([Belz et al., 2022b](#)).
- [21.] Earlier versions of the tables presented here were reported in [Giga et al. \(2021\)](#).
- [22.] This work appeared in *Annals of Operations Research* in a special issue on “Optimization Modeling in Business and Government”, in honor of Princeton University Professor John M. Mulvey, on the occasion of his 80th birthday, for his many contributions to large-scale optimization modeling and its applications to support decision-making by businesses and governments. Earlier versions of the tables presented here were reported in [Belz et al. \(2025\)](#).
- [23.] Earlier versions of the tables presented here were reported in [Belz and Giga \(2018\)](#).

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