IAC-09-D3.4.7

TECHNOLOGY DEVELOPMENT IN THE NASA INNOVATION SYSTEM: CHALLENGES AND OPPORTUNITIES IN THE SBIR/STTR PROGRAM

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***Abstract* — The NASA Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are mandated by Congress. This paper examines several SBIR/STTR projects as an initial attempt to begin to better understand how these projects are or are not infused into the mainstream NASA innovation system. For the cases studied herein, it seems that three factors were important: pre-proposal knowledge exchanges between companies and NASA, strong matching of a project with a relevant NASA COTR, and the availability of an actual infusion opportunity. Of course, the small business must also execute the project, and the technology must prove feasible and realistic.**

INTRODUCTION

In order to execute any future space exploration strategy, significant advances must be made along multiple dimensions of technological capability. To accomplish this, considerable investment in advanced research and technology (R&T) must continue to occur, leading to the important question of how best to distribute and manage the finite resources available. Despite a rich legacy of impressive technological achievements, US government-run space projects are increasingly suffering from schedule slips and cost overruns [1]. Part of the problem is that characteristics of the government space market, such as its monopsony-oligopoly structure and complex products, limit the effectiveness of traditional commercial/free-market innovation strategies to this sector. Previous work [2] argues that 5 fundamental issues characterize the space innovation challenge; namely: 1) generating bottom-up push in the predominantly top-down acquisition process; 2) representing the needs of a disaggregated buyer; 3) integrating fragmented sell-side knowledge; 4) matching the innovation environment to the stage of development; and 5) balancing risk aversion and the need for experimentation. While NASA's innovation system was not explicitly designed to address these specific challenges, it does address each to some degree. For example, multiple technology infusion/development programs exist within NASA, expressly to leverage the innovative capacity of entrant firms (e.g., the Small Business Innovative Research (SBIR) / Small Business Technology Transfer (STTR) programs, Centennial Challenges, etc…). However, although these programs have been relatively successful in accelerating the development of new "component" technologies, their record of infusion into the overall NASA innovation system is more ambiguous.

The SBIR/STTR program in particular, as a Congressional mandate, has received attention in the literature (c.f. [3-6, 8-9] among others). Congress articulated four goals for the program, which was first authorized in 1982 by the Small Business Innovation Development Act. These goals are:

1. To stimulate technological innovation.
2. To increase private-sector commercialization of innovations.
3. To use small business to meet federal research and development needs.
4. To foster and encourage participation by minority and disadvantaged persons in technological innovation [3].

Federal law mandates that eleven federal agencies each set aside 2.5% of their extramural research and development program to fund SBIR awards, with an additional 0.3% allocated for STTR awards. Five of these agencies – DOD, Health & Human Services (esp. NIH), NSF, NASA, and DOE – account for 96% of SBIR program awards. NASA's program is the fourth largest, overall, with $103 million in funding distributed in 2005. The SBIR and STTR programs each consist of two phases; the first is meant to be a feasibility assessment of the idea's scientific and technical merit, while the second is a larger-scale research and development push towards realizing an idea's scientific, technical, and commercial promise. At NASA, the typical Phase I award is roughly $60,000 for six months (with a maximum of $100,000), while a typical Phase II award is for a maximum of $600,000 for 2 years [3,7]. The STTR program is very similar, with the caveats that it must involve a University partner as well as a small business, and its Phase I awards are for 12 months instead of 6.

While Congress has several motivations for the SBIR and STTR programs, it is clearly in the sponsoring agency's interest to maximize the utility it derives from such a mandatory investment. This is particularly true for NASA, which has seen its research and development budgets squeezed significantly in recent years due, in part, to cost-overruns in major programs such as Constellation, the Mars Science Laboratory, and the James Webb Space Telescope. Therefore, when the NRC reports that only 15.9% of NASA SBIR Phase II projects[1] were known to have received some kind of follow-on funding (be it as direct procurement or as further development funding) from NASA [3], one is tempted to ask – can this return on investment be improved? Certainly, a 100% infusion rate should not be the goal, nor even a 50% rate, for such figures would indicate that the program probably was not investing in those inherently risky ideas that might result in radical innovation. However, it seems worthwhile to investigate whether improvements can be made to increase the infusion rate of successful projects while maintaining the risk-tolerance of the program. The National Research Council convened a symposium on this very topic in 2005 [5]; more recently, Keifer [8] and Anderson and Iacomini [9] shared some general suggestions from their companies' experience in this program, particularly with respect to NASA. The purpose of this paper is to inaugurate an effort expand on this work with respect to NASA's SBIR/STTR program, looking across multiple types of companies and technologies. Particular attention will be paid to the informal processes which help enable infusion at NASA, as well as the implications of these early case studies for the five proposed challenges of innovation in the government space sector.

Data Collection

This paper is an initial step in such an investigation. Through a preliminary series of case studies, in conjunction with a large number of interviews of NASA engineers and managers at all levels, the authors explore the relationship between NASA's SBIR/STTR program and its larger innovation architecture. In particular, the authors identify common characteristics of SBIR projects that ended in "successful" infusion of the final product into a further NASA effort. The implications of these cases for the five challenges of innovation in the government space sector identified by Szajnfarber, Richards and Weigel (2008) will also be discussed.

Six case studies of SBIR/STTR projects are described in this paper. Of these six, three of the projects (Cases B, C, and D) are from a single company, while the other three are each from a different company. For the foundational case, Case A, interviews were conducted with both the small business team and the NASA COTR (Contracting Officer's Technical Representative). These cases were not chosen to be representative of the many kinds of SBIR/STTR companies and projects, but rather as an initial dataset upon which later, more rigorous and detailed work would build.

Further, 22 interviews were conducted with NASA engineers and managers at three field centers (Goddard, JPL, and JSC) and Headquarters. These interviews were part of a larger research effort to understand NASA's macro-level innovation architecture, and the processes and programs by which an idea is developed and perhaps eventually incorporated into a flight project. COTRs and technologists were interviewed, SBIR/STTR program staff, and technology development leadership at the theme, center, mission directorate, and agency levels.

Methodology

The six case studies to be described in this paper will be examined across several intervals of the SBIR/STTR lifecycle. The lifecycle is divided as shown in Figure 1.

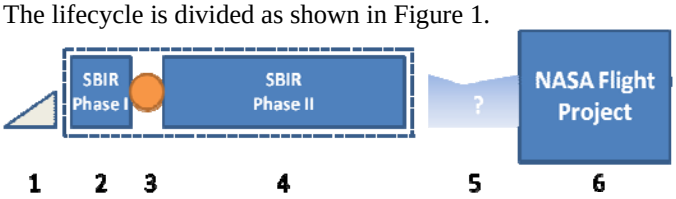

Figure 1: SBIR/STTR Project Lifecycle

In Figure 1, the various stages of an SBIR/STTR project are split into six different segments:

1) Initial brainstorming. (How did the company come up with the idea for the proposal?)
2) Experience of SBIR/STTR Phase I.
3) Transition from Phase I to Phase II.
4) Experience of SBIR/STTR Phase II.
5) Post-Phase II funding from NASA.
6) Infusion into NASA flight project.

Most SBIR/STTR projects will not survive to see all six stages, but many that are proven to be technically feasible will proceed to the end of Stage 4. After this stage, there is no longer any Congressionally-mandated funding (indicated by the dotted box) set aside for the SBIR/STTR programs. One

[1] 15.9% of 82 that responded to an NRC survey

of the key questions to be answered is how a technically-successful project is able to make the leap from Stage 4 to Stages 5 & 6.

SBIR/STTR PROJECTS – CASE A

Case A is the first and most comprehensive of the six SBIR/STTR projects that will be described in this paper. Case A is unique among the six because it is the only one to both attract Post-SBIR Phase II funding (Stage 5 in Figure 1) and be chosen for a current flight-project (Stage 6). Furthermore, for Case A, the authors were able to interview the key players from both the small business and NASA.

The story of Case A begins with failure. Company A is a very small business (less than 10 full-time employees) that was spun out from a larger corporation in the early part of this decade to focus exclusively on a specific remote-sensing technology. When the commercial market for this technology started to tighten up, the company reluctantly[2] turned to the SBIR program to supplement its other business. The company had early success with the DOD SBIR program, winning several Phase I awards and every Phase II which they applied for. However, this same success did not translate to its proposals to NASA; during this same time period, the company submitted three "blind"[3] proposals to NASA for Phase I SBIRs, and all three were rejected.

For roughly 15 years prior to this, a certain NASA technologist and several government colleagues had been working on this technology for space-based remote sensing applications. The technologist's efforts were initially funded by a $50,000 award from his Center's "Director's Discretionary Fund" (DDF), and then ramped up substantially by two subsequent grants (each 3 years in duration) from the relevant theme technology office in NASA's Science Mission Directorate.

Then, by coincidence, the CEO of Company A and this key NASA technologist met while both were attending a technical review meeting for the particular remote-sensing technology. The CEO and the NASA technologist talked about their work on this technology, and the technologist encouraged the CEO to submit another Phase I proposal to NASA. As it happened, the relevant NASA Phase I SBIR sub-topic manager was a colleague of the technologist and worked just down the hall, so the technologist told the sub-topic manager to expect the proposal and requested the opportunity to help review it. When the proposal came in, the technologist and his colleague were very pleased with its quality, and recommended it for SBIR funding. The technologist also volunteered to serve as the COTR (Contracting Officer's Technical Representative, the key NASA point-of-contact and overseer for the contract – an unfunded responsibility) if the project were to be receive an SBIR award. (All of this occurred in what is denoted "Stage 1" of Figure 1, above.)

The project was indeed chosen for a Phase I SBIR award, and the technologist was appointed the COTR. Company A performed very well throughout Phase I (Stage 2 of Figure 1). The company and technologist communicated regularly over the duration of the six-month contract, and the company thoroughly impressed the technologist by delivering working hardware by the end of the contract.[4]

Company A then submitted a proposal (Stage 3 in Figure 1) for a SBIR Phase II award. The technologist strongly supported this proposal, and recommended it for funding. Much to his surprise, however, the proposal was not funded. The technologist vigorously protested to the relevant NASA SBIR theme office, which happened to be located at his Center at the time. The technologist felt that Company A deserved such advocacy given the outstanding work which they had done during Phase I, and he felt that the technology held significant potential for NASA applications related to his own efforts. The technologist convinced the relevant SBIR program official that it was a mistake to reject Company A's Phase II proposal, and the official was motivated enough to dig up some SBIR money that had gone unclaimed in order to continue the project for 18 months. Roughly simultaneous to this protest, the NASA technologist also submitted a proposal to his Center's IRAD (Internal Research and Development) fund, but this proposal was not successful.

Nevertheless, the cobbled-together SBIR funding kept the project going, and as it continued to progress, an opportunity for true infusion began to develop. A certain sensor had been baselined for a politically-important science objective on an upcoming spacecraft. The sensor was not developing as planned, but the top levels of the US government insisted that the science objective be accomplished somehow. The NASA technologist working with Company A felt that their technology could serve as a viable alternative.

As the 18 months of quasi-Phase II funding came to an end, the NASA technologist again applied for IRAD funding to keep the work going, and this time he was successful. Thus, the project reached Stage 5 on the lifecycle diagram of Figure 1. Simultaneously, the technologist had also been talking with the troubled flight project mentioned above, and finally convinced them to adopt Company A's technology.[5] Consequently, after only a few months of IRAD funding, the technology was picked up and robustly funded by the flight project (Stage 6 of Figure 1). Asked to comment as to the SBIR's impact on the flight project's decision to adopt the technology, the NASA technologist stated, "Having a commercial company building these, actually, I think, added some level of credibility for it to be considered for a flight mission."

[2] The company was reluctant to do business with the government because it did not want to deal with the changes to its accounting system required by government cost-plus-fee contracts. It vastly preferred firm-fixed contracts.

[3] We define a "blind" proposal as one that was submitted without any prior consultation (pre-solicitation release) with interested NASA parties.

[4] Typically a Phase I contract is simply a "feasibility study" which results in little or no hardware.

[5] This task was no doubt made considerably easier by the political pressure to accomplish the particular science objective.

SBIR/STTR Projects – Case B

Case B is the first of three cases which deal with the same small business, denoted here at Company BCD. This company, for the entirety of Cases B and D, and the majority of Case C, was a space technology development firm with less than 15 employees. During the final year of its Phase II work in Case C, the company was acquired by a larger aerospace-focused small business with a few hundred employees. Before this acquisition, a majority of Company BCD's revenue came from NASA SBIR and STTR awards.

Case B bears some striking similarities to Case A. Described by the CEO of Company BCD as the 'best NASA SBIR that we've done', the Case B project started with a conversation about NASA's needs and Company BCD's technological expertise and ideas. The CEO of Company BCD spent several years at NASA before his time at BCD – including experience in the mission area relevant to the eventual proposal - and the conversation was with a former colleague who had become a manager in one of NASA's science technology development offices. During the conversation, the CEO and the NASA manager came up with an idea for an SBIR based upon a product that BCD had previously developed. Both company and customer were excited about the proposal, and the company subsequently proposed and won a Phase I award. Thus, again, the brainstorming in Stage 1 successfully transitioned to Stage 2.

This Phase I SBIR was assigned to the NASA science technology office which the CEO's former colleague managed, and this manager assigned as COTR a technologist who was "the" person at NASA working on exactly the technical area at which the SBIR was targeted. The CEO described this COTR as being very interested and engaged throughout the project. Never did more than 2 weeks pass between contact. The CEO reported that this helped the team to establish very firm and specific requirements early in the process. It also gave the company some additional motivation, the CEO reported. He knew that the COTR was going to thoroughly read all the reports that were generated, to the extent of calling to ask about a specific point on a particular page if the COTR didn't understand or agree with it. More importantly, the CEO stated that what gets his team "out of bed" is the chance to "fly things in space", and so having such clear interest from NASA was a significant motivation for them.

Phase I was very successful, and a Phase II contract was awarded. The CEO reported that his team "cranked out a lot more than $600k" worth of work for the Phase II, due to the convergence of factors described above. The NASA COTR and his manager were pleased with the work, and at the end of Phase II, their office funded a "Phase III" effort[6], equivalent to Stage 5 from Figure 1. For the Phase III, Company BCD and their NASA counterparts flew the project on NASA's reduced-gravity aircraft to collect data in that gravity regime. This too was successful. However, because the relevant flight project was delayed significantly into the future, no further work has been done with the project's results. The CEO is confident that, given the positive results, Company BCD will be a "major player" when it comes time to develop the relevant system for the flight project. Still, given the likely 10-15 year wait, Stage 6 infusion remains an open question.

SBIR/STTR Projects – Case C

Case C deals with another SBIR project that was conducted by Company BCD. This project is an interesting contrast with Case B, because although it builds on exactly the same previously-developed core technology as the Case B project, a few key characteristics of the project were different – as was the final result.

In Case C, Company BCD submitted a "blind" Phase I proposal to a NASA SBIR solicitation that looked promising. There was no prior contact between the company and any relevant individuals at NASA. The proposal was accepted for a Phase I contract, but the assigned COTR was not a good match. The project was only loosely related to the COTR's daily responsibilities, and he did not seem to even be intellectually interested in the technology that Company BCD was developing. Furthermore, at the time, NASA was still defining its own relevant plans in the area. Thus, the company found it very difficult to formulate fixed requirements in a timely fashion, and felt very much on its own. The CEO felt that the COTR's view was that Company BCD could do whatever it wanted – he (the COTR) didn't care. Also, the CEO noted that his team quickly learned to write the bare minimum for the required status reports, because unlike in Case B, this COTR never seemed to read them.

Company BCD was able to win a Phase II award for the project, but problems continued. Eventually, due to technical troubles and a continued lack of engagement from any customer, the CEO down-scoped the project in order to prevent Company BCD from taking a loss on the endeavor.

SBIR/STTR Projects – Case D

The third and final case study from Company BCD is Case D. This case is an interesting contrast to the first three cases, because it shares characteristics with both A/B and C, but has managed to transition to some semblance of Stage 5 after the end of Phase II several months ago. The project is still ongoing at the present time.

Case D was a blind proposal, with no prior relevant contact between the company and NASA, and was accepted for a Phase I STTR.[7] The NASA employee who was assigned as the COTR for the project was the person who had written the original solicitation. Company BCD's accepted project was not what the COTR had originally intended, but he willingly engaged with the project nonetheless.

[6] A "Phase III" award refers to a contract which an SBIR-funding agency can award as a follow-on to a Phase II, and which is exempt from the normal full and open competition requirements of the Federal Acquisition Regulations.

[7] Note that the primary difference between an SBIR and STTR is that the latter must include a University partner in addition to the small business. The length of the Phase I award is also 12 months instead of 6, and the program may be somewhat less competitive, but for all intents and purposes it is very similar to the SBIR program.

Phase I went well, and a Phase II proposal was accepted. However, about this time, the NASA COTR left for a different job. Also, as Phase II began, Company BCD and its university partner started to narrow the focus of the project to the NASA application for which the technology seemed most suited. Unfortunately, this area of application was the sole expertise of a different NASA Center than the one out of which the project was managed.

The technical work proceeded well, but maintaining NASA engagement proved quite difficult. The "replacement" COTR was not a member of the mainstream NASA technical staff, but rather from the tiny NASA Innovative Partnerships Program (IPP) field office at the Center. Despite repeated attempts, the team was unable to contact him until the very end of the Phase II contract, when it was time to arrange delivery of the hardware and final report. The only NASA customer contact that was available during the two-year Phase II was intermittent outreach initiated by the company/university project team and based entirely on the team's own network of contacts at NASA. Part of this outreach included an in-depth study of the relevant NASA program by the project team, in order to understand the customer's needs and guide the development of the prototype as well as the business case.

The project team successfully completed the Phase II work, and through its own due-diligence found and applied for the opportunity to conduct tests under a special program for a parabolic flight campaign with NASA's Reduced Gravity Office. This proposal was successful (thus a quasi-Stage 5 was achieved), as was the test campaign, and these combined results generated moderate interest from relevant NASA technical and programmatic officials. Discussions are currently in progress regarding a potential flight opportunity and the production of additional prototype systems. However, a key limiting factor in these discussions is the paucity of available NASA resources to fund any such work that would capitalize on the SBIR investments.

SBIR/STTR Projects – Case E

Case E illustrates the importance of maintaining technical continuity and buy-in for a particular project on the small business side of a project. The project was conducted by Company E, a firm of approximately 15 people that is focused on the development of the specific technology of Case E.

Stage 1 of Case E proceeded much the same as with Cases A and B. The key technical person for Company E met a relevant NASA technologist through prior relationships with the technologist's colleagues. This technical person and his company had done several previous SBIRs related to the technology in question, and he and the NASA technologist brainstormed some SBIR ideas based on the technologist's/NASA's needs and the company's interests and capabilities. The NASA technologist described his role as describing NASA's needs to the Company E representative, telling him, "If it did this, we could really use it, and here's the real application for it, so you gotta worry about this, this, this, and this. So I did not tell them how to build it or anything like that, it was more like a […] what do we want to do with it, and what does it have to be able to do for us to really use it." In the end, the two came up with a project that would combine, in a new way useful to NASA, several different things that the company had previously developed.

When Company E's Phase I SBIR proposal was accepted, the NASA technologist volunteered to serve as the COTR. He was keenly interested in the project, which was very relevant to his NASA responsibilities. As he explained, what the company had proposed to do was something that his NASA lab did not have the capability – nor the funding - to do: "We [were] definitely leveraging their ability." Furthermore, he noted, "we want to be able to buy these later anyway."

The Phase I SBIR went well, and the NASA technologist endorsed the company's proposal for a Phase II contract. This was awarded, and the technologist reported that things proceeded well until the key Company E employee, who had been working on the project originally, took a job somewhere else. After that, the technologist reported, he didn't hear from the company very often, and they didn't do a very good job finishing the Phase II. The NASA technologist reported that he had not seen a Phase III proposal from the company, and would probably not recommend them for such a proposal if it were to be forthcoming.

SBIR/STTR Projects – Case F

Finally, in Case F, we briefly explore another example of a project with some promise which was doomed by problems on the company side. This project was proposed by Company F, a brand-new start-up company that included only a few employees. Furthermore, when this company started work on the Phase I, it was not particularly close to being able to fabricate anything.

Still, the Phase I proposal was awarded, and the same NASA technologist as for Case E was tapped to serve as COTR. According to the technologist, this company did some good work early in Phase I, but then proceeded to "self-destruct". The Phase I project was not completed, and no Phase II was awarded or proposed. The company folded.

Analysis of Cases

Table 1, below, summarizes the six different cases, according to the lifecycle stages of Figure 1. From Table 1 and the preceding discussion of the cases, several important themes emerge with respect to successful SBIR infusion.

First, these cases seem to indicate the *value of pre-proposal (Stage 1) contact between the companies and potential NASA customers*. It is important to point out that three of the six cases studied here were Phase I proposals that were accepted with no such prior consultation; therefore, this work does not suggest that any kind of "favoritism" exists with respect to Phase I awards. However, it does appear that such pre-proposal contact can play a significant role in facilitating the company's understanding of NASA's potential needs and requirements; Company A, despite enjoying very high SBIR proposal acceptance rates with the DOD, went 0 for 3 on its first three proposals to NASA. Furthermore, pre-proposal contact seems to promote the matching of a project with an interested and relevant COTR. Of the six cases described in this paper, all three (Cases A, B, and E) which featured pre-proposal contact between the company and NASA were matched with strong COTRs, while all three which did not feature such pre-proposal contact were matched with COTRs who were less relevant and/or less interested in the particular project. It is worth noting that the DOD explicitly encourages such pre-proposal contact in its SBIR program[8] [4].

Relevant to this last point, a second theme that can be noted from these cases is the *importance of a relevant, interested, and engaged COTR*. In Cases A, B, and E, there was good alignment between the COTR's work, experience, and interests and the particular SBIR project. One can argue that two of these three Cases (specifically A and B) represent the most successful projects of the six, as both were taken up by the relevant NASA organizations for additional, post-Phase II development (Stages 5 and 6). While impossible to say with certainty, the third, Case E, seemed to be moving in that same direction until a disruption occurred at the project company.

The COTRs supported these projects in multiple ways. They provided information about NASA's needs and requirements, they provided technical guidance and suggestions, motivation, and when necessary they served as an internal-to-NASA advocate for the technology. Case A in particular – which was eventually infused into a priority flight

Table 1: Comparison of six SBIR/STTR projects.

	Case A	Case B	Case C	Case D	Case E	Case F
Stage 1	3 blind Phase I's rejected, Brainstormed w/ NASA technologist (eventual COTR) prior to successful Phase I application	Brainstormed w/ NASA technology manager prior to Phase I application. Add-on to previous work.	Blind proposal, Add-on to previous work.	Blind proposal, no prior experience with technology.	Brainstormed w/ NASA technologist, eventual COTR, prior to Phase I application. Add-on to previous work.	Blind proposal
Stage 2	Matched with very interested and relevant COTR, excellent results.	Matched with very interested and relevant COTR, very clear requirements provided, good results.	Matched with uninterested and irrelevant COTR, no req's provided, host program in flux.	Project not exactly what COTR intended, but he is interested and semi-engaged. Good results.	Matched w/ very interested and relevant COTR, clear requirements and good results.	Company did good work, but was a start-up that folded.
Stage 3	Phase II denied; COTR appeals and wins partial funding	Phase II awarded	Phase II awarded	Phase II awarded	Phase II awarded	None.
Stage 4	"Phase II" goes well, same COTR	Phase II goes well, produced "much more than $600k" of work	Phase II struggles, and team eventually de-scopes to avoid cost overruns. COTR remains disengaged.	COTR leaves, is replaced by IPP rep who is busy and not in contact. Wrong center for this work.	Good progress until key technical person left company, then sharp fall-off.	None.
Stage 5	COTR secures IRAD funds, but only needed for very short time	COTR / Technology manager provide Phase III funding for parabolic flight tests	None.	NASA FAST program, and team, funds parabolic flight tests	None.	N/A
Stage 6	Technology chosen for troubled and politically-charged instrument on priority flight project	Technology on shelf until the relevant flight project gets approved (5 to 10+ yrs)	N/A	Large effort by team to contact relevant people at relevant center for potential Phase III.	N/A	N/A

[8] DOD provides a post-solicitation-release period for questions and answers as well as a specific point-of-contact for each topic, with all questions and answers posted publicly.

project - would have died with the rejection of the SBIR Phase II application if the COTR had not intervened and vocally agitated for continued funding. Critically, the COTRs for Cases A and B also identified and secured Stage 5 (post-SBIR Phase II) funding; and for Case A also indentified the Stage 6 (flight-project infusion) opportunity, which Company A could not have done on its own. This support for the post-Phase II infusion process was notably lacking for Case D; if not for Company BCD's pre-existing set of NASA contacts, the project would likely have died from neglect at the end of Phase II, unnoticed by the relevant NASA officials (who were located at a different center than the one managing the contract). Finally, anecdotes suggest that an active and interested COTR can also serve as a motivator to help ensure that NASA receives maximum value from its awards. For example, the CEO of Company BCD noted that BCD put much more effort into the reports for Case B than they did for Case C and produced "much more than $600k" worth of work for that Phase II, simply because they knew that the Case B NASA COTR would carefully read each report and follow-up, whereas the Case C COTR never seemed to read anything that they sent him.

A third theme that emerges from this work is the *importance of a Stage 6 infusion opportunity*, in order for any project to be fully integrated into the mainstream NASA technology system. In Case A, the SBIR project was very fortunate to have a flight mission come along just as the technology was finishing its development period. The existence of this opportunity stands in contrast to the experiences of Cases B and D, the only other projects to successfully move into Stage 5. For Case B, the fundamental challenge to continued work is that the flight mission for which the technology is designed will not occur for another 10-15 years. Thus, while NASA gained valuable information for future design work from the SBIR effort, it may not be able to leverage the expertise of the Company BCD team when it comes time to actually build the flight system. In 10 to 15 years, people may have moved to other jobs at other companies, and/or simply not remember many of the details of the completed work.

Of course, there must also be funding to support the final development and testing necessary for such infusion. For Case D, a relevant flight mission currently exists, but there is very little NASA funding available to support the final development and certification of the technology is order to fly it. The Case D product would have clear benefits for this flight mission, and would deliver value that exceeds the required investment cost, but as of yet no source has been found that can provide the required demonstration funding.

Finally, for these cases it also seems important that such a flight project has some incentive for providing a flight opportunity to a new technology. Case A was fortunate that its particular flight mission was under considerable political pressure to conduct the measurement that the project's technology was designed for, because this pressure certainly made the project more willing/able to take up such a new technology with no prior flight heritage. By way of comparison, the relevant flight mission for Case D is under no special pressure to provide an opportunity for new technology.

Conclusion

In summary, this preliminary examination of NASA's SBIR program examined six different SBIR projects. Within this set of cases, three themes emerged. First, in all three cases for which there were pre-proposal conversations between potential companies and NASA customers, the accepted SBIR project was well-matched to an interested and relevant NASA COTR. Second, in these cases, an interested and relevant COTR seemed to be an important advocate, motivator and enabler of infusion. Third, the existence of an opportunity for infusion – and the funding and incentives to support it – were seen to be important to achieve final "spin-in" for the cases examined here.

As discussed in the opening, this work is only a first step in what should be a much more comprehensive effort to study a larger number and more diverse selection of companies and technologies. Such a study could help to develop a much more complete understanding of those factors which help enable infusion of SBIR (and other) innovation at NASA.

Acknowledgements

The authors would like to sincerely thank all those individuals at NASA and in the New England small business community who graciously volunteered their time to be interviewed for this work. The first author would also like to thank NASA for sponsoring his presentation of this work at the 2009 International Astronautical Congress in Daejeon, South Korea.

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