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Dual Approach to Examining Success in the Air Force Small Business Innovation Program

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DUAL APPROACH TO EXAMINING SUCCESS IN THE AIR FORCE SMALL BUSINESS INNOVATION PROGRAM

THESIS

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Abstract

Innovation is critical enough to the Department of Defense (DoD) that it is called out in both the National Defense Strategy as well as the Air Force Vision. This research takes a dual approach to consider how to improve innovation in the Air Force Small Business Innovation (SBIR) program. An investigation will be conducted to assess the relationship between perspective, incentive, innovation type and innovation success. This will be followed by an investigation to determine company characteristics that influence innovation commercialization. This document is presented in the form of two articles drafted for publication.

The first article investigates the definition of innovation success by building a construct to use in considering perspective, type of innovation, and incentives. The simplified framework determined the perspectives of private organization with the incentive of Gold (financial), public organization and academic with the incentive of Good (public benefit), and innovator with all incentives (financial, public benefit, personal challenge, recognition). The Air Force SBIR office should consider multiple incentives when determining success of a program.

The second article examines organization factors influencing commercialization rates of Air Force phase II, SBIR programs. Smaller businesses showed a higher rate of commercialization than larger businesses and no learning effect of businesses was observed. New entrants outperformed incumbents. The Air Force SBIR office should focus programs on smaller businesses and not consider incumbency an advantage.

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Kaitlyn E. Ryan

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DUAL APPROACH TO EXAMINING SUCCESS IN THE AIR FORCE SMALL BUSINESS INNOVATION PROGRAM

I. Introduction

Background

Innovation is key to the future success of any commercial organization in a continually changing environment. New products and processes help companies develop or maintain a competitive advantage. As important as innovation is to the commercial world, it is also key to military dominance, providing technological advantage in warfighting as opposed to a competitive advantage. Innovation has allowed the U.S. Department of Defense to retain its tactical edge and is specifically identified in the 2018 National Defense Strategy as part of the defense objectives and the strategic approach. American technological innovation is part of what "will generate decisive and sustained U.S. military advantages" (Mattis, 2018). It makes sense that innovation is also part of the Air Force vision statement "The World's Greatest Air Force—Powered by Airmen, Fueled by Innovation." The vision continues with "Through shared values, key capabilities and upholding our Airman's Creed, we continue to achieve our mission and aim high in all we do" (*U.S. Air Force - Vision*, n.d.). Innovation is needed to provide military advantages and ensure those key capabilities. The equipment used by warfighters is often developed or improved through innovation, from the first powered aircraft of the Wright brothers to the fifth-generation F-35 Lightning.

One of the ways that the United States Air Force (USAF) invests in innovation is through the Small Business Innovation Research (SBIR) program. The Small Business Administration (SBA) started the SBIR program in 1977 "to support scientific excellence

and technological innovation…in critical American priorities to build a strong national economy" (*About | SBIR.Gov*, n.d.). In fiscal year 2019, the Department of Defense (DoD) contributed $1.8 billion to the SBIR office's $3.28 billion investment in innovation contracts. The Air Force contributes approximately 25% -- or $450 million -- of the DoD's SBIR investments. With such a large financial investment and innovation's role in national defense, it is worth considering the performance of the Air Force SBIR office.

Innovation is "the implementation of a new or significantly changed product or process" (Gault, 2018). The types of innovation include product, process, radical, incremental, competence-enhancing, competence-destroying, architectural, and component (Schilling, 2017). These types of innovation are neither mutually exclusive nor collectively exhaustive. The first powered aircraft created by the Wright brothers is a radical product innovation. Subsequent improvements on the aircraft were incremental product innovations and could have consisted of individual components. In manufacturing aircraft, the creation of a new production process is considered radical innovation while small changes to an existing process would be incremental innovation. The initial powered aircraft did not destroy other travel methods based on land or water, so it is not competence-destroying, but it also did not expand existing technologies, so it is not competence-enhancing. Despite the first powered aircraft is categorized, it was an innovation, and innovation is key to providing a warfighting advantage and thus military dominance.

Problem Statement

With such a large financial investment and innovation's role in national defense, it is worth considering the return on investment of the Air Force SBIR office. It is important to understand the output of the investment as well as the performance. Without knowing performance, one cannot know if changes to SBIR programs are warranted. Through innovation motivations, the benefits from the Air Force SBIR program can be assessed. Additionally, by historical data of Air Force SBIR program it may be possible to predict the likelihood of success in future programs.

Research Focus

A key step before determining the success of the Air Force SBIR program is determining how to assess innovation. Investigation must determine what benefits of innovation are present and determine a framework for consistent assessment. Two questions will be asked. The first question is: What incentives are present with innovation? It is hypothesized that financial incentive is not the only incentive present with innovation. In determining the incentives present, it was found that a more thorough definition of the problem was needed. This led to the second question: How does the measure for innovation change? It is hypothesized that the measure of innovation will change with perspective, incentive, timeline, and type of innovation.

From a framework to assess innovation, research moves to predicting the performance of Air Force SBIR phase II projects. By understanding those characteristics associated with successful, companies can be more carefully selected. One question will be asked: What company characteristics does the government know ex ante that influence

commercialization of Air Force SBIR phase II projects? While additional innovation assessment incentives are determined in the previous research, the data set only contains information on commercialization (a financial incentive). It is hypothesized that increased company size is a characteristic of non-commercialized Air Force SIBR phase II projects. It is also hypothesized that incumbency is a company characteristic of commercialized Air Force SBIR phase II projects.

Research Objectives/Questions/Hypotheses

Research Objective: Determine a framework for Air Force SBIR innovation assessment.

Questions

- What incentives are present with innovation?
- How does the measure for innovation change?

Hypotheses

- Financial incentive is not the only incentive present with innovation.
- Measure of innovation will change with perspective, incentive, timeline, and type of innovation.

Research Objective: Predict the performance of Air Force SBIR Phase II projects.

Question

- What company characteristics does the government know *ex ante* that influence commercialization of Air Force SBIR phase II projects?

Hypotheses

- Increased company size is a characteristic of non-commercialized Air Force SBIR phase II projects.

- Incumbency is a company characteristic of commercialized Air Force SBIR phase II projects.

Methodology

Two articles were developed using different methodologies to gain insight into companies' effectiveness with SBIRs. The first article is a survey of extant literature with the goal of defining the categories to be used in analysis. Their results were recorded and compared. These initial categories (Table 1) are perspective, innovation, timeline, and incentive. The data set evaluated against the categories was comprised of research studies on innovation. The studies were sourced from journals and books related to innovation, economic, management, and research policy. Papers were read and the presence and type of each category was documented in the table created from the literature review. The findings were then analyzed and then we developed a framework to synthesize the SBIR data.

Table 1 Construct Definitions

Perspective	Innovation	Timeline	Incentive			
			Good	*Glory*	*Guts*	*Gold*
An individual's functional relationship through which they derive benefit from an innovation	Implementation of a new or significantly changed product or process. Types of innovation include product, process, radical, incremental, competence-enhancing, competence-destroying, architectural, and component. *This set of types is neither mutually exclusive or collectively exhaustive.	The duration of the benefit from an innovation	Intrinsic motivation such as a social benefit	External validation or recognition	The challenge of innovation itself	Resource, whether monetary or non-monetary

The second article uses a data set of 433 Air Force SBIR phase II topics with closed contracts reported during DoD fiscal years 2015 to 2018. Each data point contains characteristics of the topic including company size, experience, and commercialization rate. Increased company size was theorized as a characteristic of non-commercialized programs and incumbency was theorized as a characteristic of commercialized programs. The variables were analyzed through logistic regression. Variables were further analyzed using graphs and quartile comparisons due to the size of the data set size and number of successes present.

Assumptions/Limitations

The first article is limited to those books and research articles found through internet search and available through the Air Force Institute of Technology (AFIT) library. Analysis is limited to the researcher's ability to interpret book and journal results. Other researchers may have different interpretations. The findings in this article are also limited to the dimensions evaluated. This research developed a construct for evaluating incentive and perspective with innovation. Additional analysis on type of innovation and innovation market could provide additional dimension to findings. This could further the findings or change the interpretation found in this article.

The second article is limited by the size of data available and variables present for possible analysis. When conducting analysis on company size and incumbency, there were not sufficient data points between the variables and positive commercialization to compare. This limited the research to quadrant comparisons for both company size and incumbency related to commercialization. The information known about each contract in

the data set limited possible variables to evaluate. The data set time period was chosen because it represented a period of continuous leadership. This means the data set was less likely to vary over the time period, thus leading to either artificially high or low rates of commercialization that could skew variable influence.

Implications

Research suggests the Air Force SBIR office should consider their vision for SBIR outcomes as well as change the selection process for awarding SBIRs. First, the Air Force SBIR office should re-evaluate their motivation for innovation based on perspective. The Air Force SBIR office should consider if their innovation incentive of commercialization is the only incentive needed. An evaluation of additional perspectives and incentives in relation to the program's overarching goals should be considered. Further research is needed to better define the Air Force SBIR program's goals and then this defined goal can be compared with the perspective/incentive construct. This comparison may shed light on the measure of success used by the Air Force SBIR office.

Next, the office should consider changing eligibility criteria for small business programs. This includes limiting both the size and number of past contracts of companies applying for Air Force SBIR phase II contracts. This could be completed on a controlled set of SBIR topics and then compared to others not limited. This is an area for further research likely in the form of experimentation in limiting companies eligible to apply for those Air Force SBIR phase II contracts.

Thesis Outline

This paper will present two journal articles on innovation. The first article conducts exploratory analysis for use in determining success of innovation as shaped by the incentives and perspectives present. An in-depth literature review is conducted, and a construct theorized. The second article analyzes factors that influence Air Force SBIR phase II programs. Previous research is replicated, and further analysis conducted.

II. Article I – Innovation, is it for Glory, Gold, Guts, or Good?

Chapter Overview

The Small Business Innovation Research (SBIR) office determines the success of an individual program by its commercialization. An example of a successful SBIR program is the work of IntraLase in support of LASIK. The research team received seed funding during the period of 1992-2002 from the SBIR office and the company was acquired in 2007. IntraLase used their SBIR funding to develop "laser technology that is used to create the corneal flap required in LASIK surgery." This eliminated a need to create a corneal flap with a metal blade (*America's Seed Fund: A Review of SBIR and STTR*, 2020). At acquisition IntraLase's technology was combined with other technology and effectively commercialized. Looking past the commercialization of IntraLase's technology, there is a public health benefit that is present. Should the definition of successful SBIR program be more than commercialization?

The following article explores the first research objective: Determine a framework for Air Force SBIR innovation assessment. This article investigates the definition of innovation success by building a construct to use in considering perspective, type of innovation, and incentives. Investigation will attempt to answer the research question: What incentives are present with innovation? It is hypothesized that financial incentive is not the only incentive present with innovation, although it is considered a success to the Air Force SBIR office. The answer will assist in additional investigation answering the second research question: How does the measure for innovation change? It is hypothesized that the measure of innovation will change with perspective, incentive,

timeline, and type of innovation. The framework will provide a basis for consideration in further research and evaluation of innovation programs.

Publication Details

This article is in draft for submission to Defense Acquisition Research Journal.

Article

Innovation, is it for Glory, Gold, Guts, or Good?

Summary: This paper theorized a way to evaluate innovation literature based on perspective, innovation, incentive, and timeline to determine how to assess success. The results indicate private sector organizations focus on the financial success of innovation while public sector organizations look at the public benefit and user innovators define success with as financial/resources, public benefit, recognition, and satisfaction of personal challenge.

Abstract

The SBIR office determines the success of an individual program by its commercialization. An example of a successful SBIR program is LASIK related technology from IntraLase which received seed funding during the period of 1992-2002 from the SBIR office and was commercialized in 2007. Looking past the commercialization of this LASIK technology, there is a public health benefit present. Should the definition of successful SBIR program be more than commercialization though?

There is not a comprehensive structure for evaluating innovation success across viewpoints. This article theorized a framework to evaluate innovation literature based on

perspective, innovation, and incentive. The framework simplified several specific perspectives down to four general perspectives organized by size (individual or organization). The public sector organizations, academics, and private sector fell in the large size and innovators fell in the small size. The framework also categorized incentives into intrinsic and extrinsic. The results indicate private sector organizations focus on the financial or resource success of innovation (extrinsic incentive) while public sector organizations and academics look at the public benefit (intrinsic incentive). In between the two are user innovators who define success with all incentives: financial or resource, recognition, personal challenge, and public benefit. When the Air Force SBIR office funds programs, it should consider success associated with more incentives than only financial due to the presence of public sector, private sector, and innovator perspectives.

Keywords: Incentive, Motivation, Perspective, Innovation

Introduction

Doctors have performed over 40 million LASIK procedures worldwide and one of the contributors, Dr. Gerard Mourou, shared the 2018 Nobel Prize in Physics for his work in laser pulse, used in corrective eye surgery (*America's Seed Fund: A Review of SBIR and STTR*, 2020). Between 1992 and 2002, Dr. Mourou led the IntraLase team to develop ultrafast femtosecond laser technology which created "a smoother, more accurate, and more secure corneal flap than was possible with a metal blade" (*America's Seed Fund: A Review of SBIR and STTR*, 2020). The IntraLase innovation combined with the complementary laser technology of Advanced Medical Optics (AMO) made "all laser" LASIK possible by removing the need for a metal blade to create a corneal flap

(*America's Seed Fund: A Review of SBIR and STTR*, 2020). Where did IntraLase get its seed funding for work from 1992 to 2002? The Small Business Innovation Research (SBIR) program provided the initial capital.

The mission of the SBIR program is "to support scientific excellence and technological innovation…in critical American priorities to build a strong national economy" (*About | SBIR.Gov*, n.d.). The overarching goal is a successful innovation program, one which results in commercialization. IntraLase achieved this goal when AMO acquired the company for $877 million and its technology developed into today's LASIK (*Did You Know | NIH SBIR/STTR*, n.d.). The SBIR office defines commercialization as "the process of developing products, processes, technologies, or services and the production and delivery (whether by the originating party or others) of the products, processes, technologies, or services for sale to or use" (*Course6-Tutorial6.Pdf*, n.d.; *Tutorial 6: Phase I Commercialization Plans | SBIR.Gov*, n.d.). Projects go from initial technical merit to commercialization over the course of three phases. Phase I determines technical merit, Phase II continues research and development, and Phase III transitions to commercialization by the small business (*About SBIR | SBIR.Gov*, n.d.). IntraLase completed five Phase I and three Phase II SBIR grants with funding of approximately $2.2 million (*America's Seed Fund: A Review of SBIR and STTR*, 2020).

In FY2019, the Department of Defense (DoD) contributed $1.8 billion to the SBIR office's total of $3.28 billion in contracts. The Air Force makes up about 25% of the DoD's SBIR contributions and historically has a 7.6% commercialization rate (Rask, 2019). At face value, that seems like a small success rate. However, does defining

success by commercialization ignore other gains or longer-term benefits? How should the Air Force define successful innovation? Could the Air Force SBIR office consider in its definition of successful programs other tangible or intangible benefits? The SBIR program considers IntraLase a success due to its commercialization. However, IntraLase also provided a public benefit through LASIK's positive impact on world health, and Dr. Mourou may consider his Nobel Prize a personal success. This paper will investigate the definition of innovation success by building a construct to use in considering perspective, type of innovation, timeline, and incentives. This definition will provide a basis for consideration in further research and evaluation of innovation programs. Perhaps the Air Force SBIR programs are more successful than we realize.

Literature Review

Success can be defined as the "degree or measure of succeeding; favorable or desired outcome" (*Definition of SUCCESS*, n.d.). This paper develops a construct for assessing innovation performance. To do this, innovation performance must be defined. There is not a consensus in literature for determining successful innovation. Innovation success can be measured based on time, budget, and business objectives (Shenhar & Dvir, 2007). It can be investigated through factors that influence success such as resources, complexity, and management (Shenhar & Dvir, 2007). Innovation success can also be considered through fostering the ability to innovate and leading to the realization of business success (Dyer et al., 2009). This research paper focuses on measuring the end state of innovation, not factors that influence innovation. End state innovation depends upon perspective used, type of innovation, timeline, and incentive. Table 1 provides the

initial construct chart and definitions used to evaluate the innovation literature. The following section further discusses these concepts.

Table 1 Construct Definitions

Perspective	Innovation	Timeline	Incentive			
			Good	*Glory*	*Guts*	*Gold*
An individual's functional relationship through which they derive benefit from an innovation	Implementation of a new or significantly changed product or process. Types of innovation include product, process, radical, incremental, competence-enhancing, competence-destroying, architectural, and component. *This set of types is neither mutually exclusive or collectively exhaustive.	The duration of the benefit from an innovation	Intrinsic motivation such as a social benefit	External validation or recognition	The challenge of innovation itself	Resource, whether monetary or non-monetary

In a study of innovation, Massa & Testa (2008) determined that entrepreneurs, academics, and policymakers define innovation and its goal in different ways. Entrepreneurs viewed innovation as "anything that makes profits," policymakers considered it as "output of a dreamer," and academics defined innovation as "the quantic step" (Massa & Testa, 2008). Varied perspectives must be considered when characterizing innovation success. The different type of perspectives listed may not agree on why LASIK proved successful. Like the SBIR office, the entrepreneur would see commercialization (profit) as success while an academic would view the new laser technology as a success in and of itself. Perspective is a category of the construct to frame innovation success. Our operational concept uses von Hippel's definition of

perspective as an individual's "functional relationship through which they derive benefit" from an innovation (von Hippel, 1988).

Definitions of innovation type differ. Innovation is considered the implementation of a new or significantly changed product or process (Bloch & Bugge, 2013; Gault, 2018). In total, our construct identifies eight types of innovation that are neither mutually exclusive nor collectively exhaustive: product, process, radical, incremental, competence-enhancing, competence-destroying, architectural, and component (Fagerberg et al., 2005; Myers et al., 1969; Schilling, 2017; Tidd, 2006). These types of innovation define the output, practices, degree of innovation change, effect on competencies, and level of design change (Schilling, 2017). The initial creation of laser technology is a radical, product innovation. Small changes to LASIK technology over time represent incremental product innovation. Changes to how lasers are built overtime represents incremental process innovation. After perspective and type of innovation, the result timeline further determines the measure of success.

The proposed construct for determining innovative success describes the concept of timeline as how long a benefit endures, measured by months, and which is further categorized based on the data available. The construct purposefully leaves timeline loosely defined because the specific industry may have an effect. Innovation in pharmaceuticals may last for years while innovation in electronics may last only a few months. To define a rigid timeline before data analysis may limit the construct.

The final measure of success is to investigate the incentives of innovation. From the business sector comes the idea that "the only thing that matters is whether an innovation creates wealth" (Massa & Testa, 2008; More, 2011) also interpreted as the

direct rate of return for expended R&D funds (Lanjouw & Schankerman, 2004). Research has also measured innovation with indicators such as patents but found that this can be a misleading output (Lanjouw & Schankerman, 2004). Still concerned with the idea of wealth or return on investment, literature on innovation sometimes considers the creation of customer value as success (Dobni, 2008). The definition of incentive for innovation will be refined into four categories for simplification: Good, Glory, Guts, and Gold (Boudreau et al., 2011; Gallus et al., 2020; Holoubek, n.d.). These categories cover intrinsic and extrinsic incentives thus ensuring that the construct covers those incentives not associated with profit or traditional return on investment. Good refers to an intrinsic motivation such as a social benefit. Glory is the external validation or recognition that will be received. Guts refers to the incentive of the challenge of innovation itself. Gold is a resource incentive, whether that be monetary or non-monetary. Through these four categories, the construct represents the main incentives for innovation.

Perspectives differ on how to view innovation and which incentives drive motivation. This ranges from economics where customer value or wealth matters most, academia where scientific merit is ideal, and policy where the possible intangible dream can be considered (Massa & Testa, 2008). These incentives can additionally have varied timelines for the result. Innovation types also differ from output and degree of change to the design or competence impact. The literature does not attempt to set a standard template for measuring all facets of innovation considered important to varying groups. It is worth investigation to develop a comprehensive but standard definition of innovation success for use across viewpoints.

Methods

The diverse types of innovation identified by researchers makes it difficult to define a successful innovation. People's different perspectives further complicates innovation evaluation. Within each perspective, motivations or incentives also vary. Individuals often get what they measure – in innovation, this means that individuals will only see the type of success for which they are looking. This paper attempts to build a construct for defining successful innovation considering the varied factors of perspective, type of innovation, duration, and incentive.

The analysis of research studies on innovation obtained from innovation and management journals will shape this construct. Since these journals typically examine the commercial sector, U.S. defense (and other public sector organizations) innovation studies warrant special attention. Initial research focused on Google Scholar searches including the terms “innovation”, “measure”, “success”, “roles”, “incentives”, “perspective” and others. This approach did not identify any articles focusing on public sector innovation and led to an additional search specific to public sector innovation success. Sources include journals and books related to innovation, economics, management, and research policy. A review of the literature did not reveal a comprehensive construct to use in measuring innovation. Therefore, the standardized table, Table 2, documents the presence and type of perspective, type of innovation, duration, and incentive. The table does not include literature that did not clearly define success or measured some aspect surrounding innovation and not innovation itself. Examples of this include measuring culture surrounding innovation (Dobni, 2008), not defining success (Gault, 2018), and simply stating “the role of incentives is critical”

(Clancy & Moschini, 2013) without identifying perspective, innovation, and specific incentives. The qualitative review results in a proposed construct for consideration.

Analysis and Discussion

Table 2 shows the final construct chart. The structure differs from the original with some parts removed and others simplified. This section discusses the choices that led to this final chart.

Table 2 Innovation Construct

Source	Perspective	Innovation		Incentive			
		Product	*Process*	*Good*	*Glory*	*Guts*	*Gold*
(Riggs & von Hippel, 1994)	User	X		X			
	Manufacturers	X					X
(Agarwal & Shah, 2014)	Employee	X	X				X
	Academic	X		X			
	User	X		X			
(Teece, 1986)	Innovator	X	X				X
	User	X	X				X
	Imitator	X	X				X
	Suppliers	X	X				X
(Massa & Testa, 2008)	Entrepreneur	X	X				X
	Academic			X			
	Policy Maker			X			
(von Hippel, 2016)	(user) Innovator	X	X	X			
	Producer (innovator)	X	X				X
(von Hippel, 2006)	(user) Innovator	X	X	X			
	(Manufacturer) innovator	X	X				X
(Myers et al., 1969)	Innovation in general	X	X	X			X
(Boudreau et al., 2011)	innovator			X	X		X
(Bloch & Bugge, 2013)	Organization (public)	X	X	X			
(Arundel & Huber, 2013)	Organization (public)	X	X	X			
(Raymond, 1999)	(user) Innovator	X	X	X		X	

First, the literature only supports a high level of categorization of innovations. The initial literature provided detailed constructs of various types such as product,

process, radical, incremental, competence-enhancing, competence-destroying, architectural, and component. However, we were only able to consistently observe product and process in our review. The identified research made, at most, passing comments about radical innovation, but those comments did not support or negate the created construct. The lack of reference to previously established categories relating to radical, incremental, competence-enhancing, competence-destroying, architectural, and component led to their removal from the construct. The analysis will assume that any of the removed categories can be found within the product and/or process categories.

While the concept of timeline logically exists, we found no discussion of timelines or time horizons related to benefit from innovation in the literature, thus leading to its removal from the construct. Timelines referenced in the literature coincided with the time taken for innovation to take place or the ideal time to enter the market with an innovation. Notably missing within the literature was how long innovation incentives lasted and how that time may correlate with defined success. This could be common industry knowledge, but the reviewer did not find this apparent in the literature.

The literature strongly represented the incentives Good (intrinsic motivation such as public benefit) and Gold (resources, either monetary or non-monetary). While one source discussed Glory (external validation or recognition) in relation to contests, few discussed Guts (challenge itself). The strongest reference for Guts came from an article discussing open-source software and two different principles, first that "every good work of software starts by scratching a developer's personal itch" and "when you lose interest in a program, your last duty to it is to hand it off to a competent successor" (Raymond, 1999). The work in its entirety falls into the Good category but references to the

innovator's interest can be interpreted as innovation in the Guts category. Guts may also get tied into the Gold incentive. One can infer that the literature means innovators have a more centralized purpose whether it be the Good or Glory. A few times, authors discussing identical perspectives identified different incentives. Additionally, authors sometimes selected multiple incentives for perspectives.

The identified perspectives fell into the main categories of user, manufacturer, academic, supplier, policymaker, public sector organization, and general innovator. Manufacturer and supplier aligned with the Gold incentive category. Academic, policymaker, and public sector organization fell into the Good incentive category. User and general innovator fell into both Good and Glory. This seems to indicate that perspectives can retain a varied state of incentives but those traditionally aligned with financial gain (companies) will have a financial goal of innovation while those traditionally aligned with public service (academia, public sector, politicians) will have a public benefit innovation incentive. Interestingly, the user and innovator fluctuate between the two perspectives and lean either way.

Collapsing the perspectives into the simplest form results in four categories: innovator, private sector, academic, and public sector. Innovator comprises user and innovator, private sector comprises manufacturer and supplier, academic comprises educator and non-profit researcher, and public sector comprises policymaker and public sector organizations. Collapsing incentives as well will leave intrinsic versus extrinsic incentives with Good and Guts falling in the intrinsic category while Gold and Glory fall in the extrinsic category. The resulting reference framework, shown in Figure 1, overlays the refined perspectives and incentives, thus revealing their intersection. The figure

shows that as the size of a group grows (innovator to organization), perspective splits. Interestingly, as incentives change from intrinsic to extrinsic, the organization perspectives also differ. Public and private sector organizations may be the same size, but they do not have the same incentives. Public sector organizations and academics have intrinsic incentives whereas private sector organizations have extrinsic incentives. Innovators, the smallest size group, have incentives that span the whole range from intrinsic to extrinsic.

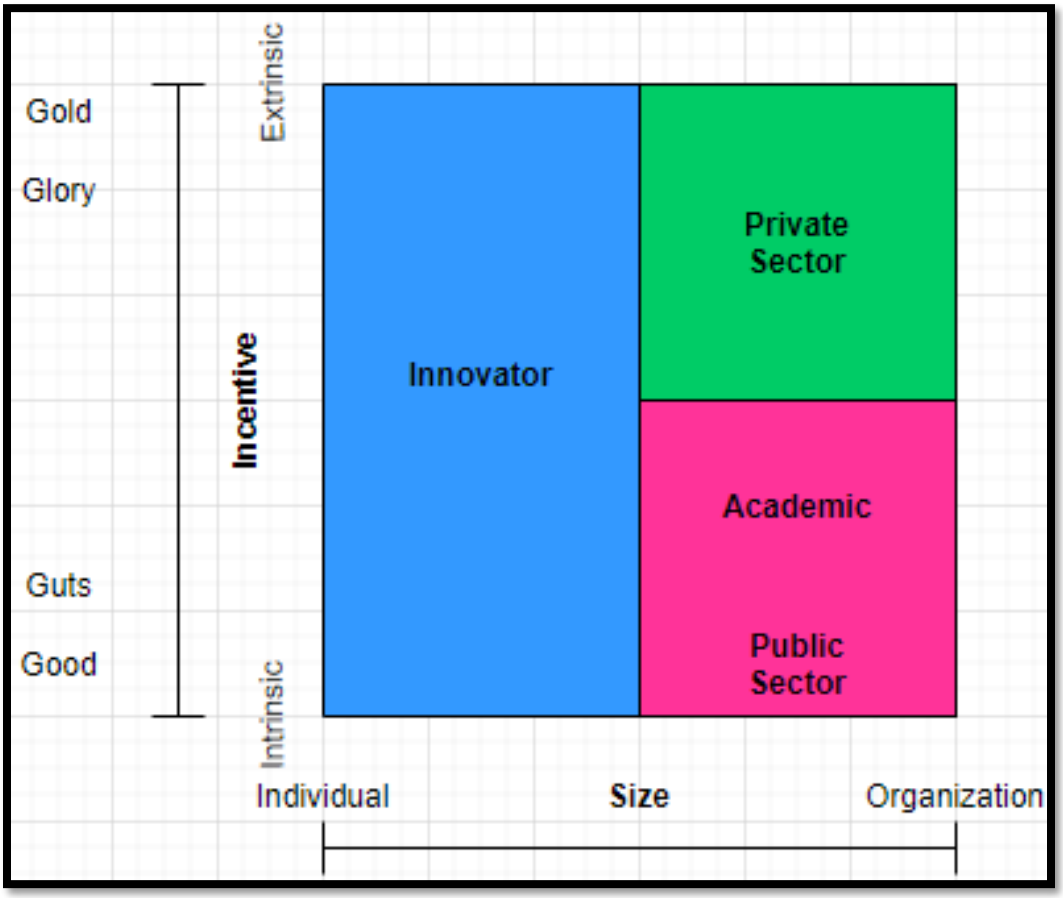

Figure 1 Perspective and Incentive Framework

The framework does not take into consideration product versus process innovation dimension, which is an area for future research. Such a framework would

offer a more robust understanding of these types of innovations different organizations strive to develop or which incentive aligns with that type of innovation. For example, if the SBIR office typically writes requirements for product innovations and individual innovators are more likely to achieve such innovations, then the incentives can have a broad range. However, if the SBIR office seeks to foster process innovations and the private sector is more likely to provide such innovations, then the incentive should be extrinsic. The examination of literature did not result in an obvious distinction between type of innovation and perspective, which is another area for future investigation. This work does not include a discussion of risk and reward associated with incentives, though this could provide further understanding. Applying this to the SBIR office, the success criteria of the program should consider the varying perspectives and incentives identified. Table 3 shows how to apply the innovation construct to the SBIR program and will be further discussed.

Table 3 Application of Innovation Construct to SBIR program

Perspective	**Innovation**		**Incentive**			
	Product	*Process*	*Good*	*Glory*	*Guts*	*Gold*
SBIR office (public sector)	X	X	X			
Manufacturer (private sector)	X	X				X
Innovator	X	X		X	X	

The first step is to determine appropriate perspectives that are present in every SBIR program. At a high level, these include the SBIR office, which is a public sector organization, the small business, which is a private sector organization, and the innovator. From observations in the construct developed and literature reviewed, we can theorize the

incentives that trace to those perspectives. We would likely see the Good incentive aligned with the public organization work, Gold aligned with private business, and all possible incentives associated with the innovator perspective. When the SBIR office funds programs, it should consider success associated with more incentives than only Gold. Our opening LASIK example anecdotally shows how more than monetary benefit can be achieved. Possibly, some of the 91% of Air Force SBIR Phase II programs that were not commercialized can be considered successful if compared to an incentive other than Gold. Future research should consider measuring innovation incentives related to Good, Guts, and Glory.

Summary

The business community currently lacks a comprehensive structure for evaluating innovation success across viewpoints. This paper theorized a way to evaluate innovation literature based on perspective, innovation, incentive, and timeline to determine how to view success. The final structure streamlined this model to include four perspectives, two types of innovation, and four types of incentives. The results indicate private sector organizations focus on the financial success of innovation while public sector organizations look at the public benefit. User innovators define success using all types of incentives. This research contributes a structure for the evaluation of innovation success as well as initial findings. These findings should be further explored and confirmed, particularly regarding the Guts incentive. Further research on this topic should also evaluate the context of innovation such as contests set up for innovation and the markets in which innovation occurs. These items could add a better understanding of the complexity of incentives for user innovations.

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Chapter Summary

There is not a comprehensive structure for evaluating innovation success across viewpoints. This article theorized a construct to evaluate innovation literature based on perspective, innovation, and incentive. A framework was created from the analyzed literature. The framework simplified perspectives down to four organized by size (individual or organization). The public sector organizations, academics, and private sector fell in the large size and innovators fell in the small size. The framework also categorized incentives into intrinsic and extrinsic. The results indicate private sector organizations focus on the financial success of innovation (extrinsic incentive) while public sector organizations and academics look at the public benefit (intrinsic incentive). In between the two are user innovators who define success with all incentive types: Gold, Glory, Guts, and Good.

This work met the research goal of: Determine a framework for Air Force SBIR innovation assessment. The hypothesis of financial incentives is not the only incentive present with innovation was supported. Extrinsic and intrinsic incentive types summarized as Gold, Glory, Guts, and Good were defined. The hypothesis of the measure of innovation will change with perspective, incentive, timeline, and type of innovation was partially supported. A framework was developed with perspective, incentive, and innovation was developed. Timeline and type of innovation did not factor into the framework.

When the Air Force SBIR office funds programs, it should consider incentives other than Gold due to the presence of public sector, private sector, and innovator perspectives. Further research on this topic should overlay type of innovation onto the

framework. Further research should also consider how to measure those innovation incentives related to Good, Guts, and Glory. This will provide a better understanding of the complexity of innovation incentives.

III. Article II – Innovation Transition Success; Bigger Isn't Better

Chapter Overview

In fiscal year 2019 the Department of Defense (DoD) obligated $1.8 billion in Small Business Innovation Research (SBIR) funding and previous research indicated commercialization rate of Air Force SBIR phase II contracts were approximately 8%. This article examines organization factors influencing commercialization rates of Air Force phase II, SBIR programs. Findings will indicate factors to further investigate to improve commercialization rates and possibly the return on investment for Air Force SBIR funding.

The following article explores the second research objective: Predict the performance of Air Force SBIR phase II projects. This article will examine a data set comprised of closed projects to attempt to answer the research question: What company characteristics does the government know ex ante that influence commercialization of Air Force SIBR phase II projects. It is hypothesized that increased company size is a characteristic of non-commercialized Air Force SBIR phase II projects. It is further hypothesized that incumbency is a company characteristics of commercialized Air Force SBIR phase II projects. The result of this research may provide guidance for eligibility criteria of future projects.

Publication Details

This article is in draft for submission to Defense Acquisition Research Journal.

Article

Innovation Transition Success; Bigger Isn't Better

Summary: Organization factors influencing commercialization rates of phase II, Small Business Innovation Research (SBIR) programs were examined. Commercialization rates of smaller companies were 2.5% higher than the rate of large companies; success of new entrants was greater than companies with repeated interaction with the government.

Abstract

Purpose – The purpose of this research is to determine project factors associated with commercialization under the Air Force Small Business Innovation Research program and thus improve the return on investment.

Design/methodology/approach – The data set used was the SBIR Phase II program data set which contains information on 433 SBIR topics with closed contracts reported during Department of Defense (DoD) fiscal years 2015 to 2018. Each data point contained characteristics of the topic including commercialization. Military capability or topic areas were hypothesized to have varying commercialization rates. Incumbency was theorized to be a characteristic of successful programs while increased company size was theorized as a characteristic of unsuccessful programs. Variables were analyzed through graphs and logistic regression.

Findings – Small businesses (1 to 31 employees) have a 2.5% increased commercialization rate compared to large businesses (32 to 499 employees); this increase is significant when compared to the 8.8% global success rate of SBIR projects. No learning effect was observed between companies new to the SBIR program (less than 14

contracts) and incumbents (15-419 contracts). The opposite was observed with new entrants outperforming incumbents. Commercialization rates among military capability area varies. High and low commercialization groups were determined.

Originality/value – In FY2019 the DoD obligated $1.8 billion in SBIR funding and previous research indicated commercialization rate of SBIR phase II contracts is approximately 8.8%. This exploratory research looks at factors and trends seen in successful programs. Findings indicate factors that may guide investment choices to improve commercialization rates.

Keywords – Small business, SBIR, Company Characteristics, Acquisition, Defense innovation

Introduction

Our focus in this research is the performance of Small Business Innovation Research (SBIR) investments in defense related technologies. Understanding performance of SBIR investments can provide insight into improved investment strategies, and thus more effective interaction with the commercial sector. The National Defense Strategy recognizes that many technological developments will come from the commercial sector (Mattis, 2018). Innovation has the potential to drive economic growth and international competitiveness (Balzat, 2006). While innovation involves the generation, adoption, implementation, and incorporation of new ideas, practices, and artifacts (Van de Ven et al., 1989), our measure of performance considers the actual adoption of innovation beyond early investment.

The Small Business Innovation Research (SBIR) program was created in the late 1970s to target and nurture a segment of the United States industrial base that contributes to our country's innovation and economic growth. Known as "America's Seed Fund," SBIR works to stimulate high-tech innovation in the United States while targeting specific research and development needs of the government. Through a competitive awards-based program, SBIR allows "small businesses to explore their technological potential and provides the incentive to profit from its commercialization" (*About | SBIR.Gov*, n.d.). As of 2020, the DoD along with ten other Federal agencies participate in the SBIR program. The DoD is one of the largest investors in the SBIR program, obligating $1.8 billion dollars in fiscal year 2019 alone.

Considering the degree of investment, there is value in understanding factors that can influence the success or failure of these programs. Success in SBIR programs

occurs when the programs transition from government seed funds to external funds, whether governmental or commercial. While ideation and prototyping are outputs of this process, innovation is considered successful when invention is implemented and adopted (Fagerberg et al., 2005). This transition, from seed funds to external, is defined as commercialization and it is the accepted measure of success for SBIR programs.

This research analyzes 433 Air Force SBIR projects from 2015 to 2018 to discern factors related to their transition success and failure. This set only includes programs that have both successfully demonstrated technical feasibility and completed a contracted research and development phase (e.g., Phase I and II completed). This three-year baseline is interesting as represents a time of relative stability, before the more recent phase of experimentation witnessed with AFWERX and other organizations. The stability of this baseline allows for a factor analysis across this broad set of projects; it also enables a stable point of comparison for recent efforts.

Our focus is on factors that are known pre-award; what pre-award factors correlate with transition performance? Based on what we can know, can we make choices that improve our success. Previous analysis found a baseline portfolio transition rate of 8.8% (Blake, 2020; Rask, 2019). Considering the number of projects and investment, small improvements matter in this space. As an example, achieving a transition rate of 10% represents 5 additional capabilities transitioning to use. If factors that correlate to success can be determined; policy can be shaped to target improvements and increase the capability that results from our SBIR investments.

We consider two levels of analysis, the entire portfolio and capability-based segments. Our investments are diverse, ranging from landing gear corrosion prevention

to Artificial Intelligence algorithms to bolster battlespace awareness. Segmentation permits a more nuanced comparison of investments and transition both within the portfolio and across military capability. Capability-based portfolio segmentation was accomplished in previous research (Rask, 2019) and leveraged the well-established Joint Capability Area (JCA) taxonomy.

Two independent factors are considered: the size of the small business and its experience working with the government. The primary finding of this paper relates to small business size; smaller businesses have a statistically significant transition advantage over their larger counterparts. Firms with 31 or fewer employees (n = 217) had a transition rate 2.6% higher than firms with 32 to 499 employees (n = 215). Our second finding relates to experience; there was no evidence to support a hypothesis that experience working with the government improves a firm's transition performance. Firms with an average of 5 contracts with the government (n = 217 projects) had significant improvement in performance when compared to those with an average of 73 or more contracts with the government (n = 215 projects).

Background

Our ability to effectively innovate is of strategic importance. The national security of the United States depends on the ability to gain access to and make the best use of innovations. This role of innovation is featured in the 2018 National Defense Strategy, "Success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its way of fighting" (President of the United States, 2018). Regardless of strategic focus, whether international terrorism or the rival powers of Russia and China, our ability to develop and infuse innovation is

crucial to our nation's defense.

While internal investments (ex. Air Force Research Laboratories) are important to developing defense focused technologies, our ability to foster and leverage innovation in our industrial base is vital. The DoD faces the challenges of attracting these external innovators and bringing their ideas to fruition in a way that enhances the capability of the armed forces. One of the many ways the DoD attempts to accomplish this external investment is through the SBIR program, a federal government program that deliberately invests research monies in small businesses.

The Small Business Administration (SBA) started the SBIR program in 1977 to support innovation through the investment of federal research funds in critical American priorities to build a strong national economy (*Birth & History of the SBIR Program | SBIR.Gov*, n.d.). Beyond the critical technologies and access to external innovators, SBIR investments serve as an economic stimulus to strengthen the industrial base. SBIR is one of the largest DoD-backed innovation programs in operation. In FY2019 the DoD obligated $1.8 billion in SBIR funding. SBIR investments target a specific segment of innovators within the domestic economy, small businesses.

Traditionally, the Air Force has followed a pull model of innovation with SBIR investments, broadcasting its needs to participating small businesses. These needs are based on topics generated throughout the Air Force. Capability needs (SBIR topics) are published and small businesses reply with proposals. Accepted proposals follow a three-phase program. Table 1 provides descriptions of the phases, their funding and timing.

Table 1 Phases of SBIR Programs

Phase	Objective	Funding	Period of Performance
Phase I	Establish technical merit, feasibility, and commercial potential; complete at least one third of required research.	<$150,000 (SBIR)	6 months
Phase II	Assess scientific and technical merit and commercial potential; complete an additional half of the required research for the program.	<$1,000,000 (SBIR)	24 months
Phase III	Commercialization	Other sources	N/A

To participate, firms must be eligible, have an adequate plan to accomplish the required research, and conduct the research within the United States. Eligibility for the SBIR program is restricted to business with 500 or fewer employees. Eligibility is established on initial application as well as through certifications at other times during participation. Participating firms must also provide plans to meet research requirements for Phase I and II. The research must be done in the United States unless the funding agreement officer recognizes a unique circumstance that demands otherwise. If the small business qualifies and these conditions are agreed to, then the business will be eligible to participate.

Programs considered for this research met the basic eligibility and planning for Phase I; additionally, they met more rigorous requirements established for Phase II. To secure Phase II award, all programs developed commercialization plans. Elements of SBIR commercialization plans can include company information, customer data, data on competition, market assessments, data regarding intellectual property, and financing. Further, award of Phase II requires the submittal of a business plan, executive summary, cost proposal, and technical proposal. This documentation undergoes rigorous peer

review process to ensure only the most meritorious scientific proposals are funded (Kelly & Sensenig, 2019).

A business' SBIR project is considered successful when the product is commercialized. Commercialization occurs when a project progresses beyond seed funding through SBIR to longer term governmental or commercial funding (*About | SBIR.Gov*, n.d.). Transition into Phase III represents this commercialization; programs in Phase III transition into the broader service branches or agencies that need them (Bresler, 2018). Air Force SBIR programs from 2015 to 2018, our data set, had a Phase II to Phase III transition rate of 8.8% (Blake, 2020; Rask, 2019).

Data Set

This research analyzes 433 Air Force SBIR projects from 2015 to 2018. This set only includes programs that both successfully demonstrated technical feasibility and completed a contracted research and development phase (e.g., Phase I and II completed). Further, the set only considers programs that reached the point of transition to Phase III; programs that either commercialized or did not.

The three-year baseline from 2015 to 2018 represents a time of relative stability. More recent innovation efforts have witnessed experimentation in investment strategies (e.g., AFWERX). The stability of this baseline allows for a factor analysis across this broad set of projects; it enables a stable point of comparison for recent efforts. Also, this data is less than 10 years old, allowing for follow-on research as needed. 10 years is considered to be recent enough to preserve accurate memories of key informants in the event follow-on interviews or interaction are required.

This population allows for a consideration of the performance of external

investments across a broad range of military capabilities and technologies. Consistent trends across the set and within capabilities permits generalization of the results beyond idiosyncrasies that may be present in certain technologies. The distribution of these investments across areas of military capability, and their relative success are shown in Table 2.

Table 2 SBIR Investments Across Military Capabilities

Joint Capability Area	Number of Investments	Percent Successful
Force Support. The ability to establish, develop, and maintain a mission ready Joint Force and build relationships with foreign and domestic partners.	9	22%
Battlespace Awareness. The ability to understand dispositions and intentions as well as the characteristics and conditions of the operational environment that bear on national and military decision making by leveraging all sources of information to include Intelligence, Surveillance, Reconnaissance, Meteorological, and Oceanographic.	74	12%
Force Application. The ability to integrate maneuver and kinetic, electromagnetic, and informational fires to gain a position of advantage and/or create lethal or nonlethal effects on designated targets.	82	7%
Logistics. The ability to project and sustain the Joint Force.	78	4%
Command and Control. The ability to exercise authority and direction by a properly designated commander or decision maker over assigned and attached forces and resources in the accomplishment of the mission.	7	0%
Communication and Computers. The ability to exercise authority and direction by a properly designated commander or decision maker over assigned and attached forces and resources in the accomplishment of the mission.	73	8%
Protection. The ability to preserve the effectiveness and survivability of military and nonmilitary personnel, equipment, facilities, and infrastructure by preventing, mitigating, and ensuring recovery from attacks, CBRN incidents, and other hazards.	19	10%
Corporate Management and Support. The ability to provide strategic senior level, enterprise- wide leadership, direction, coordination, and oversight through a chief management officer function.	90	11%

Factors Considered

In addition to a project's commercialization (our dependent variable), we sought factors that are known in advance of investment. Analysis of ex ante factors may reveal trends that can enable prediction and inform investment strategies. Three of these factors were considered: military capability area pursued (control variable), historical firm engagement with the government (independent variable), and firm size (independent variable). These areas were chosen due to data availability, qualitative observations of the data set, and theories from innovation research.

Our unit of analysis is individual SBIR Topics. An SBIR topic is a description of need which is released to prospective innovators for their subsequent bids. The topics spanned technologies from novel anti-corrosion coatings to global satellite command and control systems. Due to this diversity, a means to segment the portfolio for analysis was sought. Segmentation allows for cross portfolio and within segment analysis.

Previous research of this data set categorized each SBIR project based on the military capability area it satisfied (Rask, 2019). The Joint Staff's Joint Capability Area listing was used for this purpose. This choice of an existing, defense related taxonomy, allows for analysis focused on specific areas of military need.

The choice of capability-based segmentation blends two factors, technology and market segment for application. Certain capabilities rely on a limited set of technologies. Further, patterns of success and failure could be due to the maturity or market associated with a capability area. Where the Force Application capability area

is uniquely military, Communications and Computers has a wide range of applications and potentially a thriving commercial innovation base.

Our next two factors, incumbency and size, shift our attention from the technology sought to characteristics of the firms completing the work. Incumbency is a measure of historic interaction with the government. We operationalize incumbency as the number of government contracts held by a firm. Contracting with the government introduces complexities for small firms (Schilling et al., 2017). We hypothesize that increased experience working with the government reduces these challenges; through iteration a firm learns government processes and needs. As an extension, it is assumed that experience with the government should improve the probability of commercialization.

The size of a firm can have multiple effects on performance. Literature on innovation with the government points to administrative burdens that do not favor smaller firms (Schilling, 2017). However, innovation literature has observed higher performance in smaller and flatter organizations (Quinn, 1985). The larger an organization becomes, the more likely it is to develop a hierarchical structure that may reduce innovation performance (Kirsner, 2018). Further, with increased organizational size "effectiveness of internal knowledge flow dramatically diminishes and degree of intra-organizational knowledge sharing decreases" (Serenko et al., 2007). We hypothesize that smaller companies will perform better than larger companies, yet what small and large represent is not certain.

Methodology

The objective of this research is to understand factors that are correlated to SBIR project success with the aim of improved investments. Our data sources for this project include Air Force SBIR Program Company Commercialization Reports, DoD SBIR Topics, and relevant taxonomies within the Department of Defense. However, the primary data set used was the SBIR Phase II program data set which contains information on 433 SBIR topics with closed contracts reported during DoD fiscal years 2015 to 2018.

Analysis

Two methods were leveraged to analyze this data set, logistic regression and hypothesis testing associated with population comparisons. For the first method, logistic regression was selected due to the binary characteristic of the dependent variable (e.g., whether or not a project transition occurred). This analysis technique can provide a probability of success as a function of independent variables (company size and recidivism). Military capability areas were included as control variables. These military capabilities were assigned as part of previous research; a panel of raters categorized each project into one of 8 Joint Capability Areas (Rask, 2019).

We did not find a statistically significant relationship between transition success and the independent variables. Using the program R Studio, the probability of commercialization was estimated by fitting a logistic regression model with a sample selection. A summary of the results from this model are reported in Table 3. P-values of 0.05 or less are indicative of significant results, these were not found in the set.

Table 3 Logistic Regression Model Results

Variable	Coefficient	P - Value	Average Marginal Effect
Number_Employees	-0.000714	0.760	-0.0001
Total_Awards	-0.004566	0.326	-0.0004
JCA_1	1.055896	0.247	0.0823
JCA_2	0.101916	0.836	0.0079
JCA_3	-0.383365	0.483	-0.0299
JCA_4	-0.871345	0.206	-0.0679
JCA_5	-14.250346	0.987	-1.1101
JCA_6	-0.299243	0.584	-0.0233
JCA_7	-0.063236	0.939	-0.0049

This lack of correlation may be due to a lack of an effect. However, it may also be due to the variation within the data set even following segmentation. As mentioned earlier the capability-based segmentation has at least two factors within it, technology and market, the set may still be too noisy with too many effects to discern a relationship. Our second analysis method is a coarser analysis; allowing for a binary result. Are populations the same or different, and if different, to what extent? This technique is more resilient to noise in the data; however, it does not provide a relationship between the variables.

We have made comparisons of sub-populations within the set determining whether or not commercialization in those populations is significantly different or the same. Two separate analysis were completed with the data based on the independent variables of recidivism and company size. In both analyses, the performance of the upper and lower quartiles as well as the upper and lower halves of the sets were compared to determine if a difference existed.

The data included companies with no previous government interaction up to

companies with over 400 SBIR contracts awarded. The set was broken into nearly even quartiles and hypothesis testing was accomplished to compare the upper and lower quartiles (new entrants to experienced firms). This hypothesis testing was repeated with the set broken into two nearly even halves. The average number of contracts awarded was 39.

Table 4 provides the quartiles and halves and success rates for each. The lower quartile ranged from 1 to 4 awards (111 firms) while the upper quartile ranged from 36 to 419 awards (106 firms). The average success rates were 7.2% for the lower quartile and 7.5% for the upper quartile. There is no significant difference between new and high repeat firms ($p = 0.10$). The lower half ranged from 1 to 14 awards (217 firms) while the upper half ranges from 15 to 419 awards (215 firms). The average success rates were 10.1% for the lower half and 7.4% for the upper half. There is statistically significant difference between new and high repeat firms ($p = 0.10$). It was expected that experienced companies would outperform new entrants. However, it appears that there is no clear learning or improved performance as companies repeatedly interact with the SBIR program. The opposite, new entrants, appear to have improved performance with interacting with the SBIR program.

Table 4 Recidivism

Quartile	# Awards	# Commercialized	Success Rate	Quartile Size
1	≤4	8	7.2%	111
2	5 - 14	14	13.2%	106
3	15-35	8	7.3%	109
4	36 - 419	8	7.5%	106
Half	**# Awards**	**# Commercialized**	**Success Rate**	**Half Size**
1	≤ 14	22	10.1%	217
2	15 - 419	16	7.4%	215

Next, the population of projects was segmented based on size, where the lower quartile (companies with 1 to 14 employees) was compared to the upper quartile (from 96 to 500). The small companies did not have a statistically significant difference in performance from the large companies. The lower half (companies with 1 to 31 employees) was compared to the upper half (32 to 499 employees). Both quartiles and halves with the success rates are found it Table 5. The small companies had a commercialization rate of 10.1% whereas the larger companies had a rate of 7.4%. This difference was statistically significant ($p = 0.10$). Further, this finding is in line with the literature, we are finding that smaller companies perform better than larger companies.

Table 5 Company Size

Quartile	# Employees	# Commercialized	Success Rate	Quartile Size
1	≤14	11	9.4%	117
2	15 - 31	11	11.0%	100
3	32 - 95	7	6.5%	108
4	96 - 499	9	8.4%	107
Half	**# Employees**	**# Commercialized**	**Success Rate**	**Half Size**
1	≤ 31	22	10.1%	217
2	32 - 499	16	7.4%	215

Next for both independent variables, we consider performance within large portfolio categories. Comparisons between quartiles were accomplished (Table 6 thru 9), however, there were not enough points to yield a statistically significant result. We are only able to draw conclusions based on the entire population and not the segments.

Table 6 Battlespace Awareness

Quartile	# Awards	# Commercialized	Success Rate	Quartile Size
1	≤5	3	15.8%	19
2	6 - 16	3	15.8%	19
3	17 - 31	2	11.1%	18
4	32 - 419	1	5.6%	18
Quartile	**# Employees**	**# Commercialized**	**Success Rate**	**Quartile Size**
1	≤15	3	15.8%	19
2	16 – 33	3	16.7%	18
3	34 – 78	2	10.5%	19
4	79 – 334	1	5.6%	18

Table 7 Force Application

Quartile	# Awards	# Commercialized	Success Rate	Quartile Size
1	≤5	3	13.0%	23
2	6 – 13	2	11.1%	18
3	14 – 28	1	4.5%	22
4	29 – 419	0	0.0%	19
Quartile	**# Employees**	**# Commercialized**	**Success Rate**	**Quartile Size**
1	≤14	3	15.0%	20
2	15 – 25	2	9.5%	21
3	26 – 69	1	4.8%	21
4	70 – 482	0	0.0%	20

Table 8 Communication and Computers

Quartile	# Awards	# Commercialized	Success Rate	Quartile Size
1	≤5	2	10.0%	20
2	6 – 14	1	5.6%	18
3	15 – 47	1	5.9%	17
4	48 - 419	2	11.1%	18
Quartile	**# Employees**	**# Commercialized**	**Success Rate**	**Quartile Size**
1	≤15	3	14.3%	21
2	16 – 30	1	6.3%	16
3	31 – 110	1	5.3%	19
4	111 – 334	1	5.9%	17

Table 9 Corporate Management and Support

Quartile	# Awards	# Commercialized	Success Rate	Quartile Size
1	≤3	2	10.0%	20
2	4 – 6	2	13.0%	23
3	7 - 31	4	12.0%	25
4	32 - 151	2	9.1%	22
Quartile	**# Employees**	**# Commercialized**	**Success Rate**	**Quartile Size**
1	≤11	0	0.0%	23
2	12 – 34	6	27.3%	22
3	35 – 85	1	4.3%	23
4	86 – 494	3	13.6%	22

Discussion of Results

Our results focus on patterns with the two independent variables, recidivism and company size. Overall, we found that new entrants outperformed incumbents and small companies have an advantage over larger companies. No learning effect was observed between companies new to the SBIR program (less than 4 contracts) and incumbents (36-419 contracts). Further, new entrants (14 or less contracts) appear to have improved performance over incumbents (15-419 contracts). There is a bump in the second quartile that warrants further investigation. This bump represents companies with some experience but not extensive recidivism. We also found that small businesses (1 to 31 employees) have a statistically significant increased commercialization rate when compared to large businesses (32 to 499 employees). In addition to findings on small, new entrants, we found that the JCAs of Force Support, Battlespace Awareness, and Corporate Management and Support were top performers. These three areas had some of the highest rates of commercialization performing greater than the average of the data set.

We expected that experienced firms would have better performance, however, their performance was indistinguishable from new entrants when compared at the quartile. When halves were compared, experienced firms performed worse than new entrants. This result could be due to a variety of factors. Our original expectation was one based on a learning curve; firms with government experience should be able to better communicate with the government and overcome bureaucratic processes. One possible explanation is the phenomenon of "SBIR mills" (Link & Scott, 2009). SBIR mills are firms that exist, at least in part, for the purpose of securing SBIR awards. These firms may be less innovative and less likely to commercialize than less

experienced, and perhaps more entrepreneurial, firms that have a passion for an extraordinarily innovative idea and a commitment to seeing it through to commercialization (Link & Scott, 2009).

The goal of SBIR program is to encourage high tech innovation in the United States. Analysis indicates the average SBIR company in this data set had 39 contracts. This represents $6.7 million to $39 million in SBIR funding and 19.5-78 years in periods of performance. If there is no benefit to recidivism, or worse, if firms have less than earnest intents, a limit to recidivism should be considered. Reducing recidivism or setting limits on recidivism is in line with the intent of the SBIR program. Awards of over 100 contracts (or more than 400) to a single firm provide repeated stimulus for a single firm versus an industrial base.

Of interest, the data appears to have a spike in success rate in the second quartile of the recidivism table. Companies with some experience (5-14 awards) had a bump in success rate when compared to the newest entrants (4 or less awards) and more experience companies (15-35 awards). This bump is possibly a convolution of effects. It could represent those companies that have gained experience on how to effectively work with the government but are also not the previously defined SBIR mills. Alternatively, recidivism could still lead to increased commercialization but only to a point. The business model, SBIR mill or not SBIR mill, still may play a role in commercialization rates.

The data indicate that small companies yield higher transition rates by 2.5% as compared to large companies. While 2.5% may not seem high in the absolute, relative to the present performance of 8%, an increase of 2.5% represents a 31% growth in

performance. Considering the DOD's annual SBIR obligations, 2.5% represents $45 million. This observation may be as result of the flatter structure of small organizations or inter-organization knowledge sharing theorized in the literature. Further research can investigate the key dynamics of the observation. Future SBIR policy should consider favoring smaller businesses.

As this analysis shows, the Air Force SBIR Program has seen a high rate of failure, over 91%, in Phase II efforts that have completed funding within the last three Fiscal Years. The JCA assignment process and subsequent analysis identified several high and low performing groups. Force Support, Battlespace Awareness, and Corporate Management and Support JCAs were top performers while Command/Control, Logistics, and Force Application were low performers. Additionally, specific JCAs of high activity were determined. This gives insight into the type of markets where Air Force SBIR phase II contracts are awarded.

Recommendations

Further research should work with the SBIR program office and design an experiment to evaluate findings. Experimentation could take the form of deliberately targeting new entrants or limiting the number of previous awards allowed. Is the SBIR program meeting its goal by repeatedly funding the same small businesses with no increased commercialization rate? These actions would be taken in eligibility requirements or evaluation criteria of select programs. An investigation into the bump in commercialization rates in the second quartile would complement this further research as well.

Experimentation could also take place to further evaluate performance of "small"

businesses. Again, limitation through program eligibility requirements or evaluation criteria of select programs could assist in confirming findings. Additionally, research should refine "small" company size. There needs to be more gradation between a small company of 1 employee and a small company of 500 employees. With a larger data set those break points could be determined.

Comparison of commercialization rates of Air Force SBIR programs should be made to innovation programs in the commercial market. The approximately 8.8% rate of commercialization for Air Force SBIR programs may or may not be similar to the innovation rates of the broader market. Such a comparison would help determine successful the SBIR program. This future research could be furthered by comparing like areas of innovation of SBIR programs to commercial programs. Perhaps JCAs align with typical commercial markets and the success rates in JCAs are comparable. Alternatively, small commercial businesses may commercialize innovation at the same rate as small SBIR programs.

Finally, further research could determine the reason for the types of markets where Air Force phase II contracts are awarded. Comparisons of high activity JCAs to areas of high commercial activity could assist in determining why contracts in those JCAs are so often awarded. Similarly, comparison of top performing JCAs to top commercial innovation areas could provide insight.

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Chapter Summary

This work met the research goal of: Predict the performance of Air Force SBIR phase II projects. The first hypothesis was supported. Article findings indicate that smaller businesses (1 to 31 employees) have a 2.5% increased commercialization rate compared to larger businesses (32 to 500 employees). Although small, 2.5% represents potentially millions of dollars of investment. The second hypothesis was not supported. No learning effect was observed between companies new to the SBIR program (less than 4 contracts) and incumbents (35-419 contracts). This is counter intuitive as companies with 35 previous SBIR contracts would likely have years in contract time. The success of new entrants was greater than companies with repeated interaction with the government. Of interest, a bump in the data emerged between the newest entrants and those with some experience. The second quartile (5-14 awards) bump is possibly a convolution of effects and warrants additional research. Additionally, high and low areas of investment and commercialization groups were determined. This gives insight into those markets where AF SBIR phase II contracts are most awarded, an area for further research.

IV. Conclusions and Recommendations

Chapter Overview

This chapter will summarize the conclusions and recommendations determined in the articles.

Conclusions of Research

Two hypotheses were evaluated for the objective of: Determine a framework for AF SBIR innovation assessment. The first hypothesis, financial incentive is not the only incentive present with innovation, was supported. Analysis determined four incentives related to innovation: Gold, Glory, Guts, and Good. The second hypothesis, measure of innovation will change with perspective, incentive, timeline, and type of innovation, was partially supported and a simplified framework with perspective and incentive was created. A construct to evaluate innovation literature based on perspective, innovation, and incentive was theorized. Timeline was removed from the construct due to limited reference in the literature. From literature evaluation a simplified framework was created of perspective and incentive. The results indicate private sector organizations focus on the financial success of innovation (Gold) while public sector organizations and academics look at the public benefit (Good). In between the two are user innovators who define success with all incentives: financial, public benefit, personal challenge (Guts), and recognition (Glory).

Two hypotheses were evaluated for the objective of: Determine the performance of Air Force SBIR Phase II projects. The first hypothesis, increased company size is a characteristic of non-commercialized Air Force SBIR phase II projects, was supported.

Findings indicate that smaller businesses (1 to 31 employees) have a 2.5% increased commercialization rate compared to larger businesses (32 to 500 employees). The second hypothesis, incumbency is a company characteristic of commercialized Air Force SBIR Phase II projects, was not supported. No learning effect was observed between companies new to the SBIR program (less than 4 contracts) and incumbents (35-419 contracts). In fact, new entrants (less than 14 contracts) appear more successful in commercialization compared to incumbents (15-419 contracts). A bump in the commercialization rate was found between the new entrants and more experience incumbents. This group (5-14 contracts) represents a possible convolution of effects occurring. Companies in this group have more experience with the government than the new entrants but also do not have enough awards to be considered SBIR mills. There may be a sweet spot for company experience fostering commercialization of SBIR programs. Additionally, high and low areas of investment and commercialization groups were determined.

Significance of Research

Air Force SBIR office programs have a low rate of commercialization, but it is possible that by evaluating success through incentives and by other perspectives, programs are more successful than indicated. While looking for extrinsic benefits it is possible organizations miss intrinsic benefits that occur. IntraLase's success was comprised of both extrinsic (technology commercialized) and intrinsic (technology provides public health benefit) benefits but this could have not been the case. IntraLase could have developed health technology that provided public benefit but did not

commercialize. In this instance the SBIR office would have considered the program a failure due to the lack of commercialization. Defined perspectives and incentives are important for thorough evaluation.

Air Force SBIR phase II contract performances were evaluated using those variables available in the data set. It was found that small businesses have a 2.5% increased commercialization rate compared to large businesses. Although small, 2.5% increased commercialization represents a 31% growth in performance and potentially $45 million dollars of investment. This translates to a greater return on the DOD's annual SBIR obligations when funding is directed to more successful companies. It was additionally found that new entrants have an increased commercialization rate of incumbents. This translates to a lack of learning effect. A company with an average of 73 contracts did not appear to have increased commercialization over a company with an average of 5 contracts. In contractual time, companies with an average period of performance of 36.5-146 years did not outperform companies with an average period of performance of 2.5-10 years. This is counter intuitive as logically a learning effect would occur from years of experience.

Recommendations for Action

When the Air Force SBIR office funds programs, it should consider success associated with more incentives than financial (commercialization rates) due to the presence of public sector, private sector, and innovator perspectives. Additionally, the Air Force SBIR office should consider limits on the number of contracts awarded to companies. The average number of previously awarded contracts was 38. The Air Force

SBIR office could conservatively limit the number of previous awards to 50. The Air Force SBIR office should also consider limiting the number of employees in a small business. Both these actions could be taken in a pilot program and controlled through eligibility criteria in source selection.

Recommendations for Future Research

Further research on innovation perspective and incentives should overlay the type of innovation (product or process) onto the framework. Further research should also consider how to measure those innovation incentives related to Good, Guts, and Glory. This will provide a better understanding of the complexity of innovation incentives and how the Air Force SBIR office performance can be further assessed. Additionally, future research could assist the Air Force SBIR office in developing an experiment for limiting incumbency and company size. Future research should also investigate the bump in commercialization rate between the newest entrants and SBIR mills. This could align with the previously described experiment. Finally, high and low areas of investment and commercialization groups should be further investigated. This gives insight into those markets where AF SBIR phase II contracts are most awarded.

Summary

Innovation is key to military dominance through providing warfighting advantage. Innovation is specifically prioritized in the national defense strategy and is a part of the Air Force vision. One of the ways the Air Force fosters innovation is through the Air Force SBIR office. This research takes a dual approach to consider how to improve innovation in AF SBIR programs.

The first article investigates the definition of innovation success by building a construct to use in considering perspective, type of innovation, and incentives. The simplified framework determined the perspectives of private organization with the incentive of Gold, public organization and academic with the incentive of Good, and innovator with Gold, Good, Guts, and Glory. The Air Force SBIR office should consider multiple incentives when determining success of a program. Future research could overlay type of innovation on the framework and refine how to measure incentives.

The second article examined organization factors influencing commercialization rates of Air Force phase II, SBIR programs. Smaller businesses showed a higher rate of commercialization than larger businesses and no learning effect of businesses was observed. New entrants outperformed incumbents. There was a bump in the data that may indicate a sweet spot for experience. This bump warrants future research. The Air Force SBIR office should focus programs on smaller businesses and not consider incumbency an advantage. Future research could prove this finding with an experiment. Additionally, future research could investigate the market areas of high and low commercialization rates for Air Force SBIR programs.

As innovation is key, it is worth investigating those factors influencing innovation success such as company characteristics. It is also worth investigating how innovation success is shaped through perspective, incentive, and innovation type.

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14. ABSTRACT

Innovation is critical enough to the Department of Defense (DoD) that it is called out in both the National Defense Strategy as well as the Air Force Vision. This research takes a dual approach to consider how to improve innovation in the Air Force Small Business Innovation (SBIR) program. An investigation will be conducted to assess the relationship between perspective, incentive, innovation type and innovation success. This will be followed by an investigation to determine company characteristics that influence innovation commercialization. This document is presented in the form of two articles drafted for publication. The first article investigates the definition of innovation success by building a construct to use in considering perspective, type of innovation, and incentives. The simplified framework determined the perspectives of private organization with the incentive of Gold (financial), public organization and academic with the incentive of Good (public benefit), and innovator with all incentives (financial, public benefit, personal challenge, recognition). The second article examines organization factors influencing commercialization rates of Air Force phase II, SBIR programs. Smaller businesses showed a higher rate of commercialization than larger businesses and no learning effect of businesses was observed.

15. SUBJECT TERMS
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