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An Analysis of Information Systems Technology Initiatives and Small Businesses in the DoD SBIR Program

10 September 2012

by

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ABSTRACT

In order to address rising costs, limited innovation, and an acquisition system that lacks the flexibility to design and field best-of-breed information technology systems, the Department of Defense (DoD) has implemented open systems architecture (OSA) initiatives in information technology acquisition. One benefit of open systems architecture is that it expands competition to many suppliers, including small businesses, to enhance innovation and reduce costs. The growing acceptance of open systems architecture initiatives in DoD acquisition creates a significant access opportunity for small businesses, particularly for those who already participate in the existing DoD Small Business Innovation Research (SBIR) program, which is congressionally mandated to provide research and development contracts specifically to innovative small businesses. However, successfully leveraging the SBIR program to advance open systems architecture initiatives requires that the DoD proactively communicate that intent to small businesses participating in the program.

This research examines the extent to which the DoD uses the SBIR program to incorporate small businesses in the acquisition of IT systems that advance open systems initiatives. Additionally, this research analyzes SBIR firms to better understand participant experiences as well as the characteristics of small IT businesses that participate in the DoD SBIR program to meet the IT R&D challenges of the DoD.

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LIST OF ACRONYMS AND ABBREVIATIONS

A-RCI/APB	Acoustic Rapid COTS Insertion/Advanced Processing Build
ARB	Advanced Processor Build
ATC	Architecture Technology Corporation
CAE	Component Acquisition Executive
CAI	Commercialization Achievement Index
CIO	Chief Information Officer
COTS	Commercial Off-the-Shelf
DAC	Decisive Analytics Corporation
DARPA	Defense Advanced Research Projects Agency
DAS	Defense Acquisition System
DAU	Defense Acquisition University
DAW	Defense Acquisition Workforce
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
DoN	Department of the Navy
DTAP	Defense Technology Area Plan
FAA	Federal Aviation Administration
FAST	Federal and State Technology Transfer
FPDS–NG	Federal Procurement Data System Next Generation
FY	Fiscal Year
GAO	Government Accountability Office (formerly General Accounting Office)
HUB	Historically Underutilized Business
IST	Information Systems Technology
IT	Information Technology
LCS	Littoral Combat Ship
MEMS	Micro-Electrical Mechanical Systems
MOSA	Modular Open Systems Approach
NAICS	North American Industry Classification System
NOA	Naval Open Architecture
NPES	Non-Propulsion Electronic System
NRC	National Research Council
NSS	National Security System
OA	Open Architecture
ODASD(SE)	Office of the Deputy Assistant Secretary of Defense for Systems Engineering
OPNAV	Naval Operations
OSA	Open Systems Architecture
OSBP	Office of Small Business Programs
OSD	Office of the Secretary of Defense
OSDBU	Office of the Secretary of Defense Business Utilization
OSJTF	Open System Joint Task Force
PEO	Program Executive Office

PEO–IWS	Program Executive Office for Integrated Warfare Systems
PI	Principle Investigator
PM	Program Manager
POC	Physical Optics Corporation
PS&T	Professional, Scientific, and Technical
R&D	Research and Development
RCIP	Rapid Capability Insertion Process
RDT&E	Research, Development, Test, and Evaluation
RFP	Request for Proposal
SBA	Small Business Administration
SBID	Small Business Innovation Development
SBIR	Small Business Innovation Research
SME	Subject-Matter Expert
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SOO	Statement of Objectives
SOW	Statement of Work
SSCI	Scientific Systems Company Inc.
STTR	Small Business Technology Transfer
TRL	Technology Readiness Level
VCOC	Venture Capital Operating Company
WSDL	Web-Services Description Language
XML	Extensible Markup Language

I. INTRODUCTION

The Department of Defense (DoD) currently spends in excess of $30 billion annually on information technology (IT) investment in a number of programs that support intelligence functions, weapons delivery, and decision-making (Fein, 2009). Yet, in a time when budget restrictions and cost-reduction strategies are an increasing concern throughout the federal government, the DoD is under mounting pressure to reduce costs and streamline programs to ensure tax dollars are spent both effectively and efficiently. As such, reforming the IT acquisition process within the DoD has become a particular concern for both the Secretary of Defense as well as the federal chief information officer (CIO; Hoover, 2009). The primary causal factor for reforming the IT acquisition process, and instituting a more "streamlined" process, is a result of the inability of the traditional acquisition process to support and keep pace with the rapid evolution of technology in the IT sector. John Weiler, executive director of the Interoperability Clearinghouse, stated in a recent interview, "We're stuck in a system that uses 1940s acquisition processes not designed for IT" (Hoover, 2009). Although significant advances in IT system technology and communications have continued at a considerable rate, allowing major transformational changes in IT every 18 months, the traditional acquisition process requires an average of 81 months to develop and field a system within the DoD. This disparity results in fielding obsolete technology with limited ability for future system upgrades to keep pace with evolving technologies.

The traditional DoD acquisition process is also inflexible in that it develops, fields, and manages IT systems in a "stove-piped" manner, with each system developed to meet specific requirements identified at the program's inception. As the contract to develop an IT system is fulfilled by one specific vendor, the result is often a localized system that relies on proprietary software, which limits options for vendors who supply these systems and prevents the sharing of information across different systems. As the requirement to leverage IT systems to share information continues to increase and communication between disparate systems is required, costs for the DoD escalate when middleware, or systems of systems, are required to be developed to facilitate communication between two stove-piped proprietary IT systems.

To address rising costs, limited innovation, and an acquisition system that lacks the flexibility required to design and field best-of-breed IT systems, the DoD has implemented open systems framework initiatives within the Defense Acquisition System (DAS) to encourage open systems architecture in IT acquisition in order to enhance innovation and increase competition among defense contractors. Open systems architecture (OSA) is based on the combination of open architecture and an open business model. Open architecture (OA) is a technical architecture used in system design that "adopts open standards supporting a modular, loosely coupled and highly cohesive system structure that includes publishing of key interfaces within the system and full design disclosure" (DoD Open Systems Architecture [OSA] Data Rights Team, 2011, p. 2). The enabler for open architecture is an open business model, which requires conducting business openly and transparently to leverage the collaborative innovation of numerous participants, including small businesses, to permit shared risk, to maximize asset reuse, and to reduce total ownership cost through industry competition (DoD OSA Data Rights Team, 2011, p. 2). The combination of open architecture and an open business model results in the acquisition of OSAs "that yield modular, interoperable systems allowing components to be added, modified, replaced, removed and/or supported by different vendors throughout the life cycle in order to drive opportunities for enhanced competition and innovation" (DoD OSA Data Rights Team, 2011, p. 2) Although the terms are often used synonymously, DoD open systems initiatives include modular open systems approach (MOSA), naval open architecture (NOA), and DoD open systems architecture (OSA). Additionally, service-oriented architecture (SOA) is a widely accepted open system framework used in industry.

A core characteristic of OSA in defense IT acquisition is that it enables small innovative businesses greater access to the IT acquisition process and encourages the use of small businesses to solve the most challenging IT problems faced by the DoD. OSA initiatives have been implemented in the DoD to reduce stove-piped proprietary legacy IT systems, enhance innovation in the research and development (R&D) of IT systems, and reduce program life-cycle costs by expanding the pool of vendors and incorporating small innovative high-tech businesses in defense IT acquisition. Particularly within the high-tech IT sector, small businesses have been consistently recognized as exceptional resources for

the R&D of cutting-edge technologies, have contributed significantly to U.S. economic growth, and have the potential to significantly contribute to solving the contemporary IT challenges that the DoD faces.

Existing literature consistently demonstrates that U.S. policy-makers and the DoD recognize the cost-reduction/cost-avoidance benefits of incorporating small businesses in defense acquisition by leveraging an open business model, as well as the innovative potential small businesses possess to meet the IT challenges faced by the DoD. Furthermore, the federal government has regularly sought to aid and assist small businesses, which has resulted in the congressional establishment of government-wide statutory goals for the government to purchase not less than 23% of goods and services from small businesses. In the DoD, the governing regulatory document for defense acquisition, Department of Defense Directive (DoDD) 5000.01, *The Defense Acquisition System* (Under Secretary of Defense for Acquisition, Technology, and Logistics [USD(AT&L)], 2007), provides explicit guidance to the DoD acquisition community to incorporate small businesses into DoD acquisitions by stating, "Acquisition strategies shall be structured to facilitate small business participation throughout a program's life-cycle through direct participation or, where such participation is not available, through fostering teaming with small business concerns" (p. 9). Furthermore, in describing the Technology Development Phase of the Defense Acquisition Management System, Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System* (USD[AT&L], 2008) instructs program managers (PMs) to maximize the use of small businesses in technology R&D efforts: "During Technology Development and succeeding acquisition phases, the PM shall give small business the maximum practical opportunity to participate" (p. 17).

An existing program explicitly designed to incorporate small business concerns into defense technology R&D and defense contracting is the Small Business Innovation Research (SBIR) program. The SBIR program was established in 1982 under the Small Business Innovation Development (SBID) Act (1982, § 881) to require all federal agencies with an annual extramural budget for research, development, test, and evaluation (RDT&E) in excess of $100 million, including the DoD, to create an SBIR program and set aside 1.25%

(currently 2.6%) of that R&D budget for funding small business research awards. The SBID Act (1982) outlined four broad congressional goals for the SBIR program:

- stimulate technological innovation;
- use small businesses to meet federal R&D needs;
- foster and encourage participation by minority and disadvantaged persons in technological innovation; and
- increase the private-sector commercialization of innovations derived from federal R&D. (§ 881)

Given the congressional objectives of the SBIR program to "stimulate technological innovation" in federal R&D and contracting by incorporating small businesses, and DoD OSA initiatives that seek to enhance innovation and increase competition among defense contractors, the DoD SBIR program provides the defense acquisition community with an attractive opportunity to advance open systems initiatives and incorporate small businesses in defense IT acquisition to enhance innovation and reduce costs. However, to do so requires that the defense acquisition community proactively leverages the SBIR program to advance open systems initiatives and communicates that intent to small businesses participating in the program. Existing research on the SBIR program mostly attempts to evaluate holistically the performance of the program by measuring overall effectiveness of achieving the congressional goals. The most notable of this research has been from the National Research Council (NRC), the Government Accountability Office (GAO), and the RAND Corporation and has included firms from every industry who participate in the SBIR program. No existing literature, however, has examined how well the DoD uses the SBIR program to advance open systems initiatives within the DoD, nor has past research limited the scope of research only to participating IT firms in order to better understand participant experiences, firm characteristics, and small innovative businesses' opportunities to participate in the SBIR program to meet the IT R&D challenges of the DoD.

A. PURPOSE

The purpose of this thesis is to examine the extent to which the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems to advance open systems initiatives. In addition, this thesis focuses primarily on exploring and analyzing SBIR IT

firms in an effort to better understand participant experiences and the characteristics of small IT businesses that participate in the SBIR program to meet the IT R&D challenges that the DoD faces.

B. BACKGROUND

The DoD acquisition process traditionally relies on inflexible processes and procedures that result in stove-piped IT systems that have typically performed well but have resulted in the development and fielding of localized IT systems that inhibit the sharing of information across different systems and platforms and result in vendor lock-in, which creates a situation where acquisition choices are limited and the organization becomes dependent on a single supplier for service. As a result, limited competition exists among vendors to drive down program costs, and the systems that are developed and fielded often have duplicative capabilities and are incompatible with other systems and platforms.

In an effort to develop more open systems, the DoD, led by the Navy, has adopted the use of OSA in its IT acquisition strategy as a method to quickly field integrated systems at a lower cost. In 2003, the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L], 2007) first mandated that a "modular, open system approach shall be employed" in all acquisition processes, which effectively mandated the use of MOSA principles in DoD acquisition processes. In 2005, the Deputy Chief of Naval Operations (OPNAV [Warfare Requirements and Programs, N6/N7]) published the *Requirement for Open Architecture (OA) Implementation* to establish the requirement to implement NOA principles across the naval enterprise. Subsequent efforts, led initially by the DoD Open System Joint Task Force (OSJTF), were designed to expand MOSA guidance and NOA implementation strategy and promote the use of DoD OSA principles throughout the DoD acquisition processes. In practice, the open systems initiatives have been demonstrated to be successful at rapid technology development and system deployment while reducing program life-cycle costs. For instance, examples of successful MOSA implementation most notably include the Acoustic Rapid Commercial Off-the-Shelf (COTS) Insertion/Advanced Processing Build (A-RCI/APB) conducted by the U.S. Navy in the late 1990s, as well as the

Virginia Class Non-Propulsion Electronic Systems (NPES) and the E-2 Hawkeye aircraft upgrade (Boudreau, 2006).

To adequately incorporate OSA principles into the DoD acquisition process and realize the potential cost savings and innovative potential of small businesses in the IT sector, the DoD can leverage the existing SBIR program to incorporate those small innovative firms in the R&D of IT systems. Understanding the extent to which the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems to advance open systems initiatives, as well as participant experiences, firm characteristics, and small innovative businesses' opportunities to participate in the SBIR program will help better align the stated goals of the SBIR program with the open systems initiatives of the DoD.

C. RESEARCH OBJECTIVES

The research conducted for this thesis encompassed several objectives. The first objective was to thoroughly examine existing literature on the SBIR program, small business participation in DoD contracting, and DoD open systems initiatives. This provided an understanding of the environment faced by small IT businesses in DoD contracting. The second objective was to determine how well the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems to advance open systems initiatives. This focused primarily on analyzing request-for-proposal contracting language from a sample of SBIR solicitation topics in order to determine how effectively the DoD has incorporated OSA principles when soliciting IT R&D from small businesses through the SBIR program.

The third objective was to research and analyze IT firms participating in the SBIR program that have received SBIR funding to provide a product or service to the DoD that supports the IT R&D challenges of the DoD and advances open systems initiatives. This focused primarily on attempting to better understand participant experiences by interviewing principal investigators employed by small SBIR firms to work on SBIR-specific projects, and attempting to better understand SBIR firm characteristics by developing exploratory case studies that reveal various details of IT SBIR firms, including an analysis of available financial information to better understand how the SBIR program is used as a source of revenue among participating small IT businesses. A thorough understanding of participating

small IT businesses can provide the DoD acquisition community with demographic information that can be subsequently used to align the SBIR program with DoD open systems initiatives. In addition, this research will help DoD acquisition professionals identify what types of companies are most likely to participate in IT-related SBIR contracts, what leads them to propose SBIR projects, and what characteristics are most likely to lead to success for an IT SBIR company in technology transition.

Finally, the opportunity to interview principal investigators employed by SBIR firms allowed me the ability to ask more than their perceptions of open systems initiatives and instead explore the SBIR program in more depth and add to the existing literature as it pertains to SBIR program performance, specifically as it relates to small IT firms. Interviews conducted in this research provided an opportunity to better understand who these small firms are that participate in the program and why; their perceptions of the proposal process; how well the DoD SBIR program communicates requirements through solicitations, specifically as they relate to information technology; whether the SBIR program quantifiably contributed to company growth; how successful the program has been meeting congressional objectives (i.e., stimulating technological innovation); how successful the participants have been in obtaining phase III funding and why; future plans to participate; and additional comments these SBIR participants felt compelled to add to this research and communicate to the DoD.

D. RESEARCH QUESTIONS

- Does the DoD leverage the SBIR program to incorporate small, innovative IT firms in DoD R&D?
- Does the DoD leverage the SBIR program to further advance open systems architecture (OSA) initiatives?
- What are the experiences of small businesses in the IT sector that were awarded SBIR contracts?
- What are the characteristics of small businesses in the IT sector that were awarded SBIR contracts?

E. METHODOLOGY

In this thesis, I analyzed SBIR solicitation topic and award information from fiscal year (FY) 2006–FY2010, which was the last fiscal year in which all solicitation information

was made publicly available. During this period, the 12 DoD components participating in the SBIR program published a total of 4,494 topics. From those SBIR topics, a total of 9,739 proposals received phase I award funding, while 5,104 received phase II award funding (DoD, n.d.).

Due to the size of the raw data set, I selected a randomized sample of 25 topics from each of the 15 SBIR solicitations that occurred during this period. This sample provided me with a confidence level of 95% and a confidence interval of 4.85. I then conducted an analysis on the randomized request for proposals released as SBIR solicitation topics to determine the extent to which the DoD incorporates open system initiatives in the DoD SBIR program. The metrics I used to analyze SBIR topic solicitation data were based on key words and phrases that best describe the nature of open system initiatives and the extent to which SBIR solicitation topics advance open systems initiatives, where appropriate.

To research SBIR participant experiences to better understand the capabilities and perceptions of innovative small businesses who participate in the SBIR program, I conducted a series of interviews of principal investigators employed by small businesses who had received phase I or phase II SBIR awards. Additional goals of the interviews were to gain insight into the experiences of participating firms; to identify the types and characteristics of companies most likely to participate in information systems technology (IST) SBIR R&D; to discover what leads them to propose SBIR projects (or dissuades them from doing so); and to learn what characteristics might lead to success for an SBIR company in technology transition, commercialization, or continued federal contracting.

Finally, to research SBIR participant characteristics, I performed an analysis of participating SBIR firms using a case study methodology to answer the following research question: What are the characteristics of small businesses in the IT sector that were awarded SBIR contracts? An additional goal of the case studies was to gain insight into the extent to which participating firms use the SBIR program as a source of revenue to fund R&D initiatives within their organization. Firms used for case study analysis were a convenient sample of SBIR firms that were awarded phase I or phase II funding to support IST SBIR solicitation topics and were chosen from the original randomized population.

F. SCOPE

In this research, I review existing literature on the SBIR program, small business participation in DoD contracting, and open systems initiatives in both the private sector and the DoD. Empirical research focuses explicitly on analyzing OSA initiatives in the SBIR program and on the experiences and characteristics of small IT firms participating in the program, rather than on a holistic evaluation of the SBIR program that incorporates small businesses from the myriad industries involved in SBIR contracting.

G. THESIS ORGANIZATION

I organized this thesis to provide a sequential flow of information focused on information systems technology initiatives in the DoD SBIR program. The chapters are organized to present the reader with adequate background information on requisite topics as they pertain to small business participation in the defense acquisition system. In the following chapter (Chapter II), I describe the history, purpose, and scope of the SBIR program, particularly as it pertains to DoD acquisition. In the latter portion of Chapter II, I provide a detailed literature review of prior attempts by the NRC, GAO, and RAND to analyze the performance of the SBIR program and demonstrate the lack of existing research focused on analyzing the extent to which the DoD uses the SBIR program to advance open systems initiatives. In Chapter III, I provide an additional literature review on small business innovation and small business competition to provide an understanding of small business participation in defense acquisition. Additionally, in the chapter, I provide a thorough review of open systems initiatives in both industry and the DoD and how those initiatives pertain to small business participation. In Chapter IV, I present an analysis of an FY2006–FY2010 SBIR solicitation topic sample to attempt to answer the following research question: Does the DoD leverage the SBIR program to incorporate small, innovative IT firms in DoD R&D? The data presented primarily builds off prior research conducted by Held, Edison, Pfleeger, Anton, and Clancy (2006) in an effort to validate or refute previous findings. In the latter portion of Chapter IV, I analyze statement of objectives (SOO) contracting language presented in the SBIR solicitation request for proposals to determine how well the request-for-proposal language outlined in the SBIR solicitation is aligned with the DoD's objective

of advancing OSA initiatives within the DoD acquisition process. In Chapter V of this research, I focus on exploring and analyzing SBIR IT firms in an effort to better understand participant experiences and the characteristics of small IT businesses that participate in the SBIR program to meet the IT R&D challenges faced by the DoD. In Chapter V, I also present 14 case studies of SBIR IT firms that have received funding for IST- or OSA-related R&D projects. With the case studies, I attempt to provide insight into the nature, characteristics, and demographics of SBIR IT firms. Additionally, the case studies present publicly available financial data from federal contracting databases to gain insight into the extent to which participating firms use the SBIR program as a source of revenue to fund R&D initiatives within their organizations.

II. SBIR LITERATURE REVIEW

A. BACKGROUND OF THE SBIR PROGRAM

The Small Business Innovation Research (SBIR) program was created pursuant to the Small Business Innovation Development (SBID) Act of 1982 (§ 881) in an effort to overcome a perceived market failure in R&D funding among small businesses. In passing the SBID Act, Congress noted,

> (1) technological innovation creates jobs, increases productivity, competition, and economic growth, and is a valuable counterforce to inflation and the United States balance-of-payments deficit; (2) while small business is the principle source of significant innovations in the Nation, the vast majority of federally funded research and development is conducted by large businesses, universities, and Government laboratories; and (3) small businesses are among the most cost-effective performers of research and development and are particularly capable of developing research and development results into new products. (SBID Act, 1982)

The law mandated that all federal agencies with an annual extramural budget for RDT&E in excess of $100 million, including the DoD, create an SBIR program and set aside 1.25% of that R&D budget for funding small business research awards. That mandated set-aside percentage has grown over numerous legislative reauthorizations of the program and is currently set at 2.6% of the federal agency extramural R&D budget. SBIR funds are subsequently allocated to qualifying small businesses in the form of contracts to pursue early stage R&D to meet agency objectives. In FY2010, the DoD, which represents over half of all federally funded SBIR dollars, invested a total of $1.2 billion in this program. The SBID Act (1982) outlined four broad congressional goals for the SBIR program:

- stimulate technological innovation;
- use small businesses to meet federal R&D needs;
- foster and encourage participation by minority and disadvantaged persons in technological innovation; and
- increase the private-sector commercialization of innovations derived from federal R&D. (SBID Act, 1982)

Currently, there are 11 federal agencies participating in the SBIR program that provide nearly $2 billion in SBIR awards annually. Table 1 lists all federal agencies

currently participating in the SBIR program. Unless otherwise noted, through this research I seek to specifically analyze the DoD SBIR program, and all references in this thesis to the SBIR program refer to the DoD SBIR program.

Table 1. Federal Agencies Participating in the SBIR Program

SBIR Participating Agencies
Department of Agriculture
Department of Commerce
Department of Defense
Department of Education
Department of Energy
Department of Health and Human Services
Department of Homeland Security
Department of Transportation
Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation

In 2000, Congress, despite a lack of thorough analysis of the effectiveness of the SBIR program, reauthorized the SBIR program until September 2008. Specifically, the Small Business Reauthorization Act of 2000 determined that (1) the SBIR program is highly successful in involving small businesses in federally funded R&D; (2) the program extended R&D capabilities of small businesses to federal agencies; (3) SBIR research has produced innovations "of critical importance" in a variety of high-technology fields; (4) the program promotes development of new products and services in the nation's high-technology industries; and (5) continuation of the program will stimulate small business growth, foster innovation, create jobs, and increase U.S. competiveness in international markets. In addition, the act established reporting requirements for participating agencies to record and maintain a centralized public database that recorded all small business concerns that received a phase I and phase II SBIR award for use in subsequent evaluation of the SBIR program. Subsequently, the Small Business Administration (SBA) developed and implemented the publicly available TECH-Net database to record information on small businesses and SBIR or Small Business Technology Transfer (STTR) awards. The Small Business Reauthorization Act (2000) also tasked the NRC to conduct a comprehensive study of how

the SBIR program has stimulated technological innovation and has used small businesses to meet federal R&D requirements, including economic rate of return, noneconomic benefits, and analysis of participation by various government agencies. The council was also tasked to make recommendations for improving the program. Finally, the Small Business Reauthorization Act (2000) created the Federal and State Technology Transfer (FAST) program to strengthen the technological competitiveness of small business concerns in the states. In December 2011, the president signed the SBIR/STTR Reauthorization Act of 2011 (§ 5001) as a section in the National Defense Authorization Act to extend the SBIR program to 2017. The reauthorization also increased the percent of extramural R&D budget requirements to 2.6% for FY2012 and requires a 0.1% increase each fiscal year until reaching 3.2% in 2017. Additionally, the act increased authorized phase I and phase II award amounts, as well as expanded eligibility criteria for small businesses entering the SBIR program.

B. THE DOD SBIR PROGRAM

The DoD has decentralized the administration of the DoD SBIR program to the Services and defense agencies to tailor the program to meet their particular R&D strategies. As a result, all topic generation, budgeting, and research emphasis are managed individually by Service components and defense agencies. Table 2 lists the 12 DoD components that currently participate in the DoD SBIR program. At the Office of the Secretary of Defense (OSD) level, the Office of Small Business Programs (OSBP) manages SBIR policy and centralizes solicitations for the entire DoD SBIR program to report to the SBA for inclusion into the TECH-Net database.

Table 2. DoD Components Participating in the SBIR Program

DoD SBIR Participating Components
Army
Navy
Air Force
Defense Advanced Research Projects Agency (DARPA)
Defense Threat Reduction Agency (DTRA)
Missile Defense Agency (MDA)
Special Operations Command (SOCOM)
Chemical and Biological Defense (CBD) Program
Office of the Secretary of Defense (OSD)
Defense Logistics Agency (DLA)
Defense Microelectronics Activity (DMEA)
National Geospatial-Intelligence Agency (NGA)

The stated objectives of the DoD SBIR program are closely aligned with congressional goals outlined in the SBID Act of 1982:

> The objectives of the DOD SBIR Program include stimulating technological innovation in *DOD's Critical Technology Areas*, strengthening the role of small business in meeting DOD research and development needs, fostering and encouraging participation by minority and disadvantaged persons in technological innovation, and increasing the commercial application of DOD-supported research and development results. (SBIR Program Office, 2012)

Unique to the DoD SBIR program objectives is that the DoD has identified critical technology areas to concentrate the R&D efforts of small firms participating in the SBIR program. Table 3 is a summary of the critical technology areas published by the DoD SBIR program office in the most recent topic solicitation instructions.

Table 3. DoD's Critical Technology Areas

1	**Air Platforms**—Fixed-Wing Vehicles; Rotary Wing Vehicles; Integrated High Performance Turbine Engine Technology/Versatile Affordable Advanced Turbine Engines; Aircraft Power; High-Speed Propulsion.
2	**Chemical/Biological Defense**—Pretreatments; Diagnostics; Therapeutics; Emerging Threats and Special Projects; CB Modeling and Simulation/Battlespace Management; CB Detection; CB Protection; CB Decontamination; CB Supporting Science and Technology.
3	**Information Systems Technology**—Knowledge and Information Management; Information Security; Communications and Networking; Modeling and Simulation Technology; Computing and Software Technology.
4	**Ground and Sea Vehicles**—Ground Vehicles; Surface Ship Combatants; Submarines.
5	**Materials/Processes**—Materials and Processes for Survivability, Life Extension, and Affordability; Manufacturing Technology; Civil Engineering; Environmental Quality.
6	**Biomedical**—Infectious Diseases of Military Importance; Combat Casualty Care; Military Operational Medicine; Medical Radiological Defense.
7	**Sensors, Electronics, and Electronic Warfare**—Radar Sensors; Electro-Optical Sensors; Acoustic Sensors; Automatic Target Recognition; Integrated Platform Electronics; RF Components; Electro-Optical Technology; Microelectronics; Electronic Materials; Electronics Integration Technology; EW RF; EW EO/IR; EW Integrated Technologies.
8	**Space Platforms**—Space and Launch Vehicles; Space Propulsion
9	**Human Systems**—System Interfaces and Cognitive Processing; Protection, Sustainment, and Physical Performance; Personnel, Training and Leader Development.
10	**Weapons**—Countermine/Mines; Guidance and Control; Guns; Missiles; Ordinance; Undersea Weapons; Weapon Lethality/Vulnerability; Lasers; High-Power Microwave.
11	**Nuclear Technology**—Warfighter Consequences Management Technology; Systems Effects and Survivability Technology; Test and Simulation Technology; Lethality and Effects; Threat Reduction and Detection Technology.
12	**Battlespace Environments**—Terrestrial Environments; Ocean Battlespace Environments; Lower Atmosphere Environments; Space/Upper Atmosphere Environments.

Note. The information in this table came from the SBIR Program Office (2012).

This research concentrates on analyzing small innovative IT businesses that provide, or have the potential to provide, products and services to support DoD requirements in the Information Systems Technology (IST) critical technology area. Although this research primarily focuses on SBIR solicitation topics, awards, and participating firms supporting the IST critical technology area, SBIR solicitation topics that include DoD open systems initiatives might not be inclusive of the IST critical technology area alone. Therefore, consideration will be made to include SBIR solicitation topics from other critical technology

areas where they demonstrate characteristics that advance open system initiatives in DoD IT acquisition.

1. Three-Phase SBIR Program

Congress requires that participating federal agencies structure their SBIR programs in three separate phases, each with specific objectives and funding limits. The DoD meets this requirement by publishing three topic solicitations annually on the DoD SBIR website, which the OSBP administers. These topic solicitations, which individual DoD components generate, include areas of R&D designed to stimulate technological innovation in the DoD's critical technology areas. Small businesses wishing to participate in the DoD SBIR program compete to win contracts to conduct the R&D identified in the solicitation and, if successful, follow a three-phase process, ultimately leading to product commercialization or integration into larger DoD acquisition programs.

a. Phase I

The objective of phase I is to establish the technical merit, feasibility, and commercial potential of the proposed R&D efforts and to determine the quality of the performance of the small business awardee prior to providing further federal support in Phase II (SBIR, n.d.). Currently, phase I awards are limited to $150,000; however, the most recent DoD SBIR solicitation instructions indicate that DoD phase I awards typically range from $70,000 to $150,000 over a period of six to nine months (SBIR Program Office, 2012). During phase I, small businesses submit proposals in response to specific DoD SBIR solicitation topics. The measure of success for phase I awards is determined by an evaluation of the extent to which phase II funding has the potential to yield a product or process of continuing support to the DoD and the private sector (SBIR Program Office, 2012). However, because the DoD acquires numerous products that do not lend themselves to commercialization, evaluating DoD SBIR proposals and projects is not limited to the extent to which a product might be commercialized for private-sector use.

b. Phase II

The objective of phase II awards is to continue the R&D efforts initiated in phase I and produce a well-defined prototype. Phase II awards are limited to $1 million; however, the DoD typically offers awards that range from $500,000 to $1 million over a period not to exceed 24 months. During phase II, SBIR contracts are evaluated on the ability of the firm to produce a well-defined deliverable prototype capable of attracting private equity investment or of being integrated into larger DoD acquisition programs.

c. Phase III

The objective of phase III is for small businesses to pursue commercialization objectives resulting from phase I/II R&D activities (SBIR, n.d.). Phase III is essentially any work that follows from phase II, although by law no SBIR funds are allowed to be dedicated to phase III financing. During phase III, firms are expected to obtain private funding, or other non-SBIR federal funding, to further develop and commercialize their SBIR technology into the commercial marketplace or transition their SBIR technology into DoD programs. For the DoD SBIR program in particular, it is quite often DoD contractors or program offices who invest in the new technology (Edison, 2010). The DoD SBIR program office defines "commercialization" in the following way:

> [Commercialization is] the process of developing marketable products or services and delivering products or services for sale (whether by the originating party or by others) to Government or commercial markets. For Phase III Awards, the term "commercialization" means the process of developing products, processes, technologies, or services; and the production and delivery of products, processes, technologies, or services for sale (whether by the originating party or by others) to or use by the Federal Government or commercial markets. (SBIR Program Office, 2012)

Limited information exists to track phase III commercialization efforts by participating SBIR firms. Congress has mandated that SBIR program administrators develop metrics to track program effectiveness. In response, the DoD has created a metric called the Commercialization Achievement Index (CAI), but because the information is self-reported and not adequately maintained, it is generally considered insufficient as an indicator of potential phase III success by an SBIR firm, or as a measure of SBIR program effectiveness

(Held et al., 2006, pp. 25–28). Because my research attempts to better understand the experiences of small innovative IT businesses that participate in the SBIR program, I asked these SBIR participants, during interviews that are further described in Chapter V of this research, to describe their phase III commercialization activity and the factors that contribute to success.

C. SBIR PERFORMANCE LITERATURE REVIEW

Several attempts have been made to evaluate the effectiveness of the SBIR program in achieving its stated goals outlined by the Small Business Innovation Development Act of 1982. The goals of the SBIR program are (1) to stimulate technical innovation, (2) to use small business to meet federal R&D needs, (3) to foster and encourage participation by minority and disadvantaged persons in technological innovation, and (4) to increase private-sector commercialization innovations from federal R&D. Of the available literature, the reports of the NRC, GAO, and RAND provide the most comprehensive attempts to evaluate SBIR effectiveness but lack quantifiable results due to the ambiguity of the SBIR goals and the inherent problems in measuring effectiveness of the SBIR program goals. Furthermore, there has been little research that focuses specifically on information systems technology initiatives within the SBIR program, and even less research has been conducted that attempts to evaluate how well the program has incorporated OSA principles into SBIR R&D efforts to maximize innovation and reduce program life-cycle costs. In this literature review, I examine existing literature of past attempts to evaluate holistically the effectiveness of the SBIR program, as well as highlight and discuss relevant information pertaining to small businesses in the IT sector that participate in DoD contracting and the DoD SBIR program.

1. National Research Council SBIR Reports

The NRC has been commissioned by the federal government on several occasions to evaluate the effectiveness of the SBIR program. In 2000, the NRC published its first research effort, *The Small Business Innovation Research Program: An Assessment of the Department of Defense Fast Track Initiative* (Wessner, 2000), which aimed at analyzing and evaluating the SBIR program through a survey and case study methodology. The report contained 10 academic articles that primarily aimed at estimating the effectiveness of the

DoD's SBIR Fast Track Initiative, but fell short of evaluating firm participation in specific industries (e.g., the IT industry). The Fast Track Initiative is an existing program for SBIR projects to attract matching investments from outside investors on projects that have been identified as most likely to be developed into viable new products that the DoD and/or others will purchase (SBIR Program Office, 2012). Wessner (2000) concluded that the DoD SBIR program effectively stimulates entrepreneurial behavior and R&D efforts by providing public venture capital funding where such funding would not be available from private venture capital investors due to the inherent high risks in the projects these firms undertake; the result, Wessner (2000) argued, is that the SBIR program effectively increases net social benefit. However, none of the research conducted in this article attempts to evaluate specific industry participation within the SBIR program and, due to the infancy of the idea, fails to evaluate the effectiveness of the SBIR program in terms of advancing the open architecture initiatives within the DoD.

The second research effort by the NRC, which spanned from 2003–2007, resulted in the publication of seven reports, including a report on the planned research methodology, an overall assessment of the SBIR program, as well as separate reports on the assessment of the SBIR program for the DoD, Department of Energy, NASA, National Institute of Health, and National Science Foundation (Edison, 2010). The research was based on the results of two surveys conducted by the NRC, and the findings were based on benchmarking methodologies developed by the NRC to evaluate the program. The report that assesses the implementation of the SBIR program within the DoD found the following results:

- The DoD is, in general, meeting the legislative and mission-related objectives of the SBIR program and the SBIR program is contributing to enhanced capabilities for the DoD.
- The DoD SBIR program has provided substantial benefits for small business participants in terms of market access, funding, and recognition.
- The program supports a diversity of small businesses who contribute to the vitality of the defense industrial base, while providing greater competition and new opportunities for DoD program managers.
- The DoD SBIR program has generated significant intellectual capital and has contributed to new scientific and technical knowledge while generating numerous publications and patents. (NRC, 2009)

The NRC report (2009) also provided demographic information on SBIR topics, awards, and participating firms within the DoD SBIR program, but did not analyze any specific critical technology area, nor did the report narrow the scope of research to IT-specific topics, or to small, innovative IT firms participating in the SBIR program. The report suggested that the SBIR program is meeting program objectives and provided various recommendations to policy-makers for improving the administration of the SBIR program in respect to the program's stated objectives.

2. Government Accountability Office SBIR Reports

The available GAO reports offer insights into the administrative functioning of the SBIR program by drawing on information made available through case studies and participant surveys; however, like the NRC reports, the GAO reports attempted to assess the effectiveness of the SBIR program holistically rather than focusing specifically on information systems technology initiatives within the SBIR program. In addition, the available GAO reports do not seek to evaluate the SBIR program specifically within the DoD, rather the research focuses on evaluating program performance across all 11 participating federal agencies.

Five specific GAO reports produced primary research. Two GAO reports contained an analysis of surveys conducted in 1987, 1992, and 1996 that provide insight into the functioning and effects of the SBIR program. Three GAO reports contained case studies that were published in 1986, 1987, and 1995 and were designed to analyze federal agency compliance with government mandates (Edison, 2010). The survey results revealed phase III trends of the SBIR program as well as demographic information, including that SBIR award recipients are relatively young firms, are relatively small firms (60% of participating firms had fewer than 25 employees) and view the SBIR program as a significant benefit to increase employment and fund R&D (GAO, 1992). The second survey results reported by the GAO attempted to measure the effectiveness of the SBIR program by evaluating the commercialization rates (i.e., phase III activity) of participating small businesses. The report found that 35% of projects resulted in commercial sales and 47% received additional development funding (GAO, 1998, p. 6).

Aside from assessing the effectiveness of the SBIR program, the available GAO reports have focused on participating agencies' administration of the SBIR program by addressing concerns related to (1) duplicate funding to similar, or even identical, research projects by more than one agency; (2) inconsistent interpretations of extramural research budgets by participating agencies; (3) geographical concentration of awards in a small number of states; and (4) lack of clarification on the emphasis that agencies should give to a company's commercialization record when assessing proposals (GAO, 2005, p. 1).

Although the GAO reports generally consider the SBIR program successful in achieving the program's stated goals, methods for how to assess program performance remain an unresolved issue and the reports do not provide conclusive evidence regarding the effectiveness of the program. This observation stems from the lack of clarity on how much emphasis program evaluation should place on commercialization versus other goals (GAO, 2005, p. 1). Furthermore, as discussed previously, no attempts have been made to specifically analyze the participation of innovative small IT firms in the SBIR program, or their impact in advancing open system architecture within the DoD.

3. RAND SBIR Reports

Research on the SBIR program conducted by RAND is more specific to the DoD than research conducted by the NRC or the GAO. In 2002, RAND was commissioned by the Office of Small and Disadvantaged Business Utilization (OSDBU) to study the effectiveness of the SBIR program within the DoD. RAND subsequently published two reports: *Evaluation and Recommendations for Improvement of the Department of Defense Small Business Innovation Research (SBIR) Program* (Held et al., 2006) and *Estimating the Cost of Administering the Department of Defense Small Business Innovation Research (SBIR) Program* (Seong, Horn, & Held, 2008). An additional report published in 2008, *Enhancing Small Business Opportunities in the DoD*, partially focused on the SBIR program (Moore et al., 2008).

Held et al. (2006) used multiple research methods to evaluate the DoD's implementation of the SBIR program, including data analysis, interviews of DoD SBIR managers and program participants, and case studies of participating small businesses. The

research focused primarily on analyzing the implementation of the SBIR program within the participating DoD agencies and the extent to which the program advances the stated goals of the SBID Act (1982), and on evaluating the demographic information of small businesses participating in the SBIR program through mini case studies. In addition, RAND's research provided recommendations for improved administrative management of the SBIR program within the DoD. The research provided various qualitative observations of the SBIR program, including that members of the defense acquisition workforce often view the SBIR program as a tax burden more than an R&D resource to be leveraged (Held et al., 2006, pp. 58, 74). The report elaborated that SBIR funding is used to "supplement" organic efforts or to fund high-risk technology that would otherwise be unfunded, and that these supplementation efforts "seemed to be a lower priority" than other primary acquisition efforts (Held et al., 2006, p. 58). In addition, the authors observed that there are few resources and high-level management efforts dedicated to extracting value from the SBIR program (Held et al., 2006, p. 103).

Another observation in the report (Held et al., 2006) that is particularly relevant to my research is an analysis of SBIR topic funding as compared to total DoD R&D funding, a ratio that can be used to infer the level at which the DoD uses the SBIR program to fund IT projects within the organization. Although Held et al. (2006) did not specifically address nor analyze the extent to which the SBIR program incorporates small businesses to advance IT R&D in the DoD, additional findings published in the report suggest that information systems technology as a defense critical technology area is under-represented as compared to all information systems technology funding available for DoD R&D. Figure 1 highlights a disparity reported in the RAND research (albeit shared with several other technology areas) between SBIR funding for IST R&D compared to total IST funding available within the DoD. The context of the data in this report was used to demonstrate that SBIR topic generation generally correlates with broad DoD priorities; however, I have specifically included it in this literature review to demonstrate that the existing literature suggests IT R&D funding in the SBIR program may be moderately underfunded as compared to broader DoD priorities.

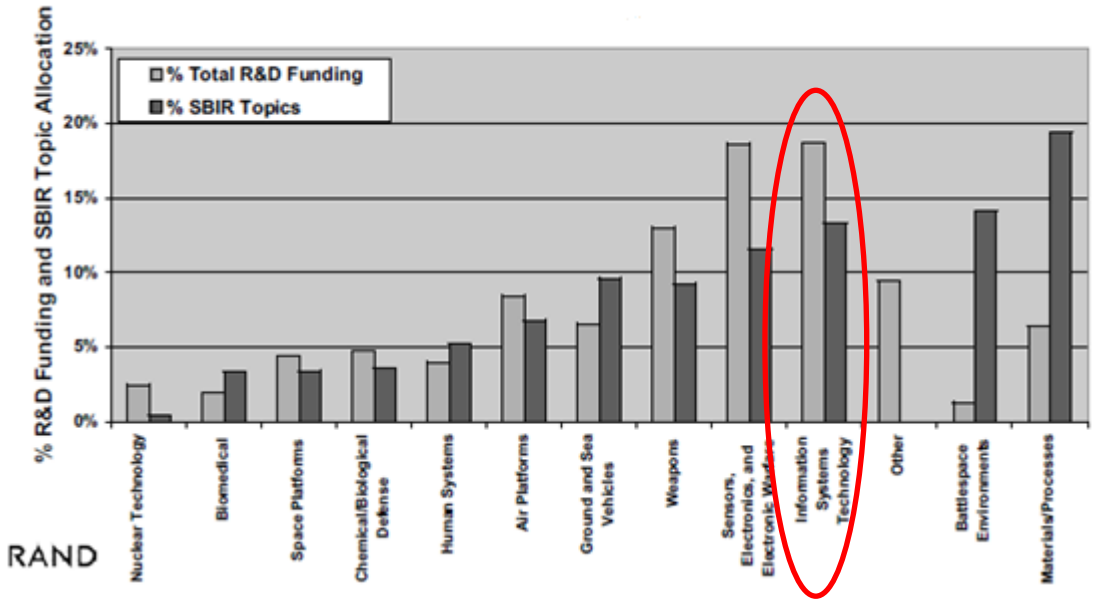

Figure 1. SBIR Defense Technology Area Comparison
(Held et al., 2006, p. 51)

In response to concerns regarding the administrative costs of managing the SBIR program within the DoD, RAND published a 2008 report (Seong et al., 2008) to estimate the management overhead required for administering the DoD SBIR program. In the report, researchers compared SBIR administration costs to the costs of managing research grants, venture capital funds, and standard defense contracts. The researchers found that the DoD SBIR program requires approximately 6% of the value of the total DoD SBIR budget to cover program administration costs (Seong et al., 2008, p. 13). Although this analysis offered insight into how the program is administered and into the overhead costs associated with DoD SBIR management, it did not assess program effectiveness, nor did the researchers address any specific technology sector (e.g., information systems technology).

Another 2008 RAND report (Moore et al., 2008) examined impediments to small business owners in contracting or subcontracting with the DoD and contains valuable insights into the nature of small business contracting within the DoD, as well as observations on small business participation in the DoD SBIR program. The authors generalized four impediments to transitioning DoD SBIR technologies into DoD programs of record: technology maturity, lack of adequate funding, timing, and acquisition culture (Moore et al., 2008, p. 47). Again,

although this research neither analyzes participation of small, innovative IT firms within the DoD SBIR program nor addresses the extent to which the DoD SBIR program advances R&D of DoD open system initiatives specifically, inferences can be made on the available data to better understand the nature of small IT firms in the DoD SBIR program. In the following section, I have included a thorough review of Moore et al.'s 2008 RAND report in an attempt to better understand the nature of small businesses in DoD IT acquisition and to address that deficiency in the existing literature.

a. 2008 RAND Report on Small Businesses in DoD Acquisition

The SBA estimates that small businesses account for 51% of non-farm private gross-domestic product in the U.S. economy (Moore et al., 2008, p. 8). Although many industries have a much smaller population of small businesses as compared to this aggregated estimate, Moore et al. (2008) presented data that demonstrates that small businesses in the professional, scientific, and technical (PS&T) services industry accounted for 58.1% of the overall industry but accounted for only 7.3% of DoD purchases in 2007, down from 27% in 2003 (p. 10). This observation highlights a declining trend in DoD contracting with small IT businesses and suggests that small innovative high-tech businesses in the PS&T services industry, which include many SBIR firms reviewed in this research, are generally underrepresented in DoD contracting. Moore et al. (2008) suggested that if DoD procurement from small businesses in these industries were to match industry averages, then DoD procurement from small businesses in these industries would nearly triple, from 12.0% to 33.0% (Moore et al., 2008, p. 8).

Other observations of the authors of the 2008 RAND report (Moore et al., 2008) include the difficulties that DoD contractors have in assessing small business capabilities. One DoD contracting official told the RAND researchers that "urgent contracts or short appropriation terms can lead purchasers to large firms rather than taking the time to investigate the capabilities of smaller ones" (Moore et al., 2008, p. 10). A similar observation was made in a 2011 Naval Postgraduate School thesis titled *Risk, Uncertainty and Open Architecture in the DoD Acquisition System* (Cole, 2011) in which the researcher noted that DoD program managers frequently contract primarily with large defense

contractors to avoid the cost and schedule risks associated with contracting small businesses to conduct similar work (p. 37). In addition, industry consolidation occurs when larger firms purchase smaller firms, which reduces the pool of small businesses within a given industry, and, subsequently, reduces small business options for DoD contracting. Industry consolidation particularly affects the IT industry of the PS&T services sector because the IT industry is maturing, and it has become increasingly difficult for firms to find growth (Pimentel, 2010). As a result, large firms frequently acquire small innovative IT businesses as a means to enter new markets, pursue growth in their existing markets, and control profit and costs.

The authors of the 2008 RAND report (Moore et al., 2008) also observed that DoD spending with small businesses varies significantly by industry and that small businesses that provide products and services directly to local commands and bases (e.g., military construction and family housing) receive a disproportionate amount of contracting dollars as compared to small businesses in other industries (Moore et al., 2008, p. 12). The causal factor is that local providers can tailor their product or service to the unique operating needs of local purchasing officers. Contracting for janitorial services or IT help desk support, for example, is much more efficient when conducted by a local purchasing officer seeking to support the needs of a military installation. Figure 2 illustrates the use of small businesses in five categories of goods, identified by RAND researchers, in which the DoD makes purchases.

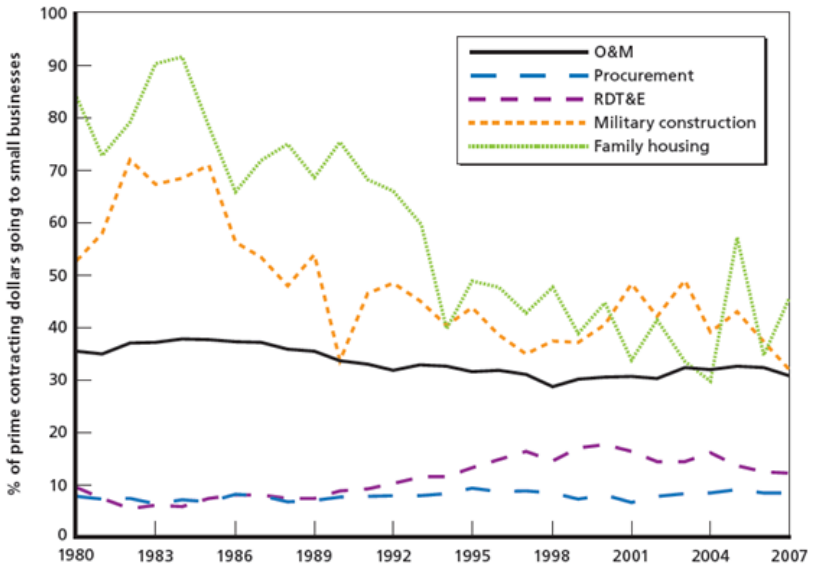

Figure 2. Use of Small Businesses as Prime Contractors by Budget Category, FY1980–FY2007
(Moore et al., 2009, p. 16)

b. 2008 RAND Report Suggests Issues Exist With SBIR Contracting

Similar to prior research, the 2008 RAND report (Moore et al., 2008) found several impediments to SBIR technology transition: technology maturity, lack of adequate funding, timing, and acquisition culture (p. 47). These impediments inhibit the transition of technology from the SBIR program into acquisition programs, as well as into a commercialized product or service in the commercial marketplace. Discussed in detail, these impediments are as follows:

- Technology maturity: SBIR R&D initiatives tend to focus on early stage technology that is not mature enough for commercialization or transition to an acquisition program.
- Lack of adequate funding: Required follow-on funding beyond a phase II SBIR project to support further development and system integration is typically scarce. In the SBIR literature, this gap between phase II and phase III is typically referred to as "the valley of death."
- Timing: Synchronizing SBIR projects and acquisition program schedules is difficult. Major acquisition programs that require specific technologies might not have the flexibility to "wait" for small business R&D efforts through the SBIR program.

- Acquisition culture: There is a culture within the DoD acquisition community that tends to view the SBIR program as a tax on its program rather than as an opportunity. The reason for this perception is not entirely clear, but the research suggests that it may be because, by law, funds that are allocated to SBIR R&D projects come primarily from program manager resources, rather than from external funding sources. (Moore et al., 2009, p. 47)

Another observation is that the SBIR program focuses on basic and applied research, which often leads to immature technology at the end of phase II. Subsequently, small businesses are less equipped to manage the longer term technology development due to cash flow constraints and difficulties obtaining phase III funds.

Moore et al. (2008) suggested several areas for additional research to best understand all the impediments associated with SBIR technology transition and how to overcome them. Of particular relevance to this research are the following recommendations:

> First, more research is needed on the development and history of SBIR projects. This might include tracking SBIR projects from proposal through Phase II development, Phase III transition and ultimate commercialization (or its lack).
>
> Second, more research is needed on SBIR companies. This might include identifying the types of companies most likely to participate in SBIRs, what leads them to propose SBIR projects (or dissuades them from doing so), and what characteristics are most likely to lead to success for a SBIR company in technology transition. (Moore et al., 2008)

My research seeks to explore these research questions in more depth to obtain a better understanding of participant experiences and SBIR firm characteristics, specifically as they relate to small, innovative, high-tech businesses in the IT sector that have the capability to provide products and services to support DoD acquisition of information systems that incorporate an OSA approach to advance OSA initiatives throughout the DoD.

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III. INNOVATION, COMPETITION, AND OPEN SYSTEM FRAMEWORKS

In this chapter, I review existing literature and discuss the nature of innovation in small businesses, how small businesses contribute to increased competition in the defense acquisition system, as well as thoroughly review open system frameworks in industry and the DoD. The purpose of this discussion is to provide context to the assumptions made that small businesses have innovative potential, to discuss existing DoD policy concerning competition and explain how competition facilitates open systems initiatives, and to provide the reader with a comprehensive review of open system frameworks in both industry (e.g., SOA) and in the DoD (i.e., MOSA, NOA, OSA). The language used to describe open system frameworks is subsequently used in the analysis of SBIR topic solicitations in Chapter IV to determine how well the DoD leverages the SBIR program to advance open systems initiatives, and how well the DoD has communicated open system requirements to small businesses participating in the program.

A. SMALL BUSINESS CONCERNS AND INNOVATION

In this section, I review innovation proxies and data sources used to measure the innovation output of a firm, as well as current literature on the innovativeness of small businesses. I ultimately suggest that small businesses are a source of tremendous innovative potential that can be leveraged using the SBIR program to solve DoD IST challenges and advance OSA initiatives within the DoD.

Innovation is defined as something new or improved that has marketable potential including (1) the development of new technologies, (2) the refinement of existing technologies, or (3) the development of new applications for existing technologies (Held et al., 2006, p. 20). The innovative potential of small businesses has long since been recognized in government as well as in the business management literature. Much research has been conducted on the role of small businesses in the U.S. economy and the unique innovative potential of small businesses, although measuring innovativeness has been a subject of controversy throughout the literature. Patent production is often used in business

management literature as a proxy for innovation and the innovative potential of small businesses because the data are readily accessible and can be used as a metric to measure the intellectual property of a firm. Intellectual property is governed by legal definitions, and an analysis of a firm's patent filings can be used to measure innovative potential because patent filings are generally used with the intent to convert knowledge to property for commercial benefit. However, while analyzing the accessible data on patent production provides some insight of the innovative potential of a firm, it is rarely considered an unequivocal proxy for measuring the innovation potential of a firm because the methods and means by which firms procure patents vary among firms and industries. In empirical research conducted by Isom and Jarcyzk (2009) on small business innovation, the researchers found that the number of patents owned by small businesses is not necessarily a good indicator of a firm's value, which is closely correlated with innovative potential. One explanation for this observation is that patent production alone is often necessary to protect existing products or technologies in order to maintain the firm's market position and is not necessarily indicative of a firm's ability to develop and introduce groundbreaking new technologies—innovative breakthroughs.

Other metrics available to use to analyze the innovative potential of small IT businesses participating in the SBIR program include technical peer-reviewed publications, patent citations, evidence of additional R&D funding (i.e., outside SBIR contracts), commercial sales, and federal sales (Gansler, 2004, pp. 17–18). Any attempt to adequately estimate the innovative potential of small businesses participating in the SBIR program requires analyzing multiple data sources.

Small businesses led by creative entrepreneurs have consistently introduced innovative and radical breakthroughs that have resulted in critical contributions to the U.S. economy. In keeping with the aforementioned definition, these breakthroughs create something new and marketable; thus, they are innovations. Frequently, these innovations have been transferred—through merger or sale—to larger firms that have the preponderance of R&D funding to develop, market, and incrementally refine the technology into a consumer product available for mass production. This division of labor, referred to by William Baumol (2005) as the "David–Goliath partnership," characterizes the market mechanism that has

historically assigned radical invention and innovation to small businesses and incremental (albeit often substantial) product improvement to larger well-established firms with sufficient R&D funding to further develop the technology (Baumol, 2005). Compared to small businesses, larger firms tend to be less innovative and focus on incremental product improvement due to their large bureaucratic management structure and the natural conservative tendency that seeks financial reward through clear and measurable results in a market that tends to avoid speculation. Small entrepreneurial businesses, on the other hand, tend to be more innovative and have a disproportionate share of radical innovative breakthroughs due to "(1) the superstar reward structure; (2) the psychic rewards to innovative activity; and (3) the scarcity and cost disadvantage of large firm competition in the arena of breakthrough innovation" (Baumol, 2005).

In a study sponsored by the SBA's Office of Advocacy (SBA, 2003) which examined technical change and innovation of small businesses through patenting, the authors found that small firm patents are twice as likely as large firm patents to be among the 1% most cited patents, which indicates a measure of importance of the referenced patents and demonstrates that the innovation behind the firm's patent created value. In addition, the authors found the following results:

- small patenting firms produce 13–14 times more patents per employee as large patenting firms;
- there are a large number of small firm innovators in the IT sector;
- small firm innovation is twice as closely linked to scientific research as large firm innovation on average, and so substantially more high tech or leading edge; and
- small firms produce more highly cited patents than larger firms. "That is, small firm patents are on average more technically important than large firm patents." (SBA, 2003, p. 2)

DoD OSA initiatives seek to introduce an open business model that includes innovative small businesses in the acquisition and contracting process in an effort to leverage this innovative potential and reduce dependency on large well-established defense contractors that tend to develop stove-piped closed systems.

Small businesses have been recognized consistently by lawmakers for their innovative potential and contribution to R&D of cutting-edge technologies that advance the

warfighting capabilities of the DoD and contribute to significant growth of the U.S. economy. For example, in a statement during a hearing before the Subcommittee on Technology and Innovation, the ranking member, U.S. Representative (D-Ore) David Wu, commented, "Small businesses are on the innovation frontline, developing new technologies that will lead to new products and services in the market, and more importantly, create high-wage, private-sector jobs and spur economic growth" (*The Role of Small Business*, 2011).

The DoD has consistently recognized the innovative potential of small businesses and attempts to leverage that innovation through the continued support of the SBIR and STTR programs, as well as a variety of other initiatives, including the Defense Acquisition Challenge, the Rapid Reaction Fund, the Quick Reaction Fund, the Open Business Cell, and the Defense Venture Catalyst Initiative (*Small Business' Role and Opportunities*, 2010). In a statement before the Subcommittee on Terrorism, Unconventional Threats and Capabilities in 2010, the ranking member, the Honorable Jeff Miller, commented on the innovative potential of small businesses and the impact these small businesses can have on DoD acquisition:

> I believe DOD can find many solutions by turning to the small business community. Small business men and women are constantly developing innovative solutions to the myriad of challenges that exist in today's world, and they do so precisely while operating efficiently and effectively. They are truly an invaluable source of talent and technology creation increasingly important to the department's operations. (*Small Business' Role and Opportunities*, 2010)

He added, "By leveraging the expertise, creativity and passion that exists among small business owners and their companies, the department will find improved efficiencies often without significant disruption or impact to current DOD functions" (*Small Business' Role and Opportunities*, 2010). In the same testimony, the Honorable Zachary Lemnios, Assistant Secretary of Defense for Research and Engineering, commented that "the small business community is an engine of innovation. It attracts entrepreneurial talent and the agility to rapidly form new teams with the speed of the commercial marketplace" (*Small Business' Role and Opportunities*, 2010).

Although the quantifiable measurement of innovativeness is a topic left to debate, the existing literature does suggest that small businesses possess unique attributes that contribute to innovative potential, particularly in the area of research. What is not in question is that U.S. policy-makers have consistently supported the notion that small businesses are, in fact, an engine for innovation and economic strength, and have, likewise, continued to provide targeted funding through various programs to stimulate small business innovation. For the defense acquisition workforce (DAW), small businesses provide an opportunity to leverage that innovation while also promoting an open business model where competition serves to reduce program life-cycle cost. The SBIR program is one such program that has been continuously supported and provides the means for the DAW to incorporate small innovative firms to meet the IST R&D challenges of the DoD, as well as to advance OSA initiatives within the DoD.

B. SMALL BUSINESS CONCERNS AND COMPETITION

The DoD OSBP is administered by the USD(AT&L) in order to advise the Secretary of Defense on all matters related to small business participation in the DoD acquisition process. The OSBP is responsible for developing small business policy and providing oversight to ensure compliance by all military departments and defense agencies for statutory laws governing contracting processes with small or disadvantaged businesses. These responsibilities include compliance with the following programs and requirements:

- the 8(a) program for small disadvantaged businesses;
- women-owned small businesses;
- Service-Disabled Veteran-Owned Small Business/Veteran-Owned Small Business (SDVOSB/VOSB); and
- the Historically Underutilized Business Zones (HUBZone) Program.

In 2011, the OSBP released its *Strategic Plan 2011* (USD[AT&L], 2011), which highlighted the open business model concept by stressing the importance of increased competition as a means to increase innovation and reduce overall program costs within the DoD. Specifically, the *Strategic Plan 2011* states,

> Increase competition. As a public organization, the DoD is committed to responsibly spending each taxpayer dollar and using competition to acquire

> affordable and cost-effective systems. The strategic value of small business is its critical role in the creation and sustainment of a competitive defense industrial base. Large prime contractors rely on small businesses not only for their products and services, but the competitive characteristics that often elude large companies such as agility, flexibility, innovation, and responsiveness. The President's introductory memo to the 2010 National Security Strategy states, "Simply put, we must see American innovation as the foundation of American power." This is a testimony to the conclusion of academia and industry that innovation is the key to our country's global competitiveness over the next century. Small businesses are the primary source of American innovation, making the OSBP's primary strategic goal to "Create Maximum Opportunities for Small Businesses in DoD Acquisitions" aligned perfectly with the mandate for increased competition. (USD[AT&L], 2011, p. 8)

The governing regulatory document for defense acquisition, DoDD 5000.01, *The Defense Acquisition System* (USD[AT&L], 2007), requires the participation of small businesses in the acquisition process as a means to increase competition to reduce costs as well as to leverage the innovative potential of small businesses. Specific instruction outlined in DoDD 5000.01 states,

> Acquisition strategies shall be structured to facilitate small business participation throughout a program's life cycle through direct participation or, where such participation is not available, through fostering teaming with small business concerns. (USD[AT&L], 2007).

Furthermore, in describing the Technology Development Phase of the Defense Acquisition Management System, Department of Defense Instruction (DoDI) 5000.02, *Operation of the Defense Acquisition System* (USD[AT&L], 2008) instructs program managers to maximize the use of small businesses in technology R&D efforts: "During Technology Development and succeeding acquisition phases, the PM shall give small business the maximum practical opportunity to participate" (p. 17). Additional guidance published in DoDI 5000.02 (USD[AT&L], 2008) instructs program managers to "consider the use of technologies developed under the Small Business Innovation Research (SBIR) program" and "give favorable consideration to SBIR technologies" (p. 14).

In 2009, President Obama signed the Weapon Systems Acquisition Reform Act, which among other acquisition reform initiatives, emphasized the importance of competition throughout the life cycle of major defense acquisition programs in acquisition strategy. The

act requires that every major defense acquisition program include "measures to ensure competition, or the option of competition, at both the prime contract level and the subcontract level . . . throughout the lifecycle of such program as a means to improve contractor performance" (WSARA Act, 2009, § 202). Additionally, relevant to IT system acquisition, the act (2009) states explicitly that the measures to ensure competition may include the "use of modular, open architectures to enable competition for upgrades" (WSARA Act, 2009, § 202).

In a 2010 memorandum for acquisition professionals titled *Better Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending*, the USD(AT&L) issued specific guidance directing, among other things, increased use of small businesses in the DoD acquisition process as a means to increase vendor competition, to lower overall costs, and to promote an open systems approach. The memorandum highlights the importance of competition in program acquisition processes as a means to reduce excessive cost overruns caused by vendor lock-in, which creates a situation where acquisition choices are limited and an organization becomes dependent on a single manufacturer or supplier for a product or service (DoD OSA Data Rights Team, 2011). The 2010 memorandum states,

> Real competition is the single most powerful tool available to the Department to drive productivity. Real competition is to be distinguished from a series of directive buys or other contrived two-source situations which do not harness the full energy of competition. (USD[AT&L], 2010, p. 9)

This "real competition" referenced in the memorandum is specifically aimed at eliminating or reducing the trend within the DAS where program contracts are fulfilled by a single vendor who subsequently develops closed-system proprietary products—often referred to as stove-piped systems—that create a dependency on a single firm for maintenance, upgrade, and additional program support. In the DoD's ecosystem of IST programs and platforms, the stove-piped systems developed as a result of vendor lock-in significantly increase overall program costs by providing one vendor with monopoly power due to the lack of compatibility between different hardware, software, operating systems, or file formats. Increased costs to the DoD when using closed-system proprietary information systems stem from (1) the inconvenience and expense of converting data to other formats and converting to

more efficient, secure, and inexpensive application programs; (2) a lack of a competitive market that provides bargaining ability to reduce prices and improve service; (3) vulnerability to forced upgrades from single vendor contractors; and (4) the corruption or loss of critical data while attempting to convert it (The Linux Information Project, 2006).

To stimulate competition within the DAS and prevent excessive program costs caused by vendor lock-in, the 2010 memorandum directs the DoD acquisition community to "increase the dynamic small business role in defense marketplace competition" and recognizes that

> small businesses have repeatedly demonstrated their contribution to leading the nation in innovation and driving the economy by their example of hiring over 65 percent of all new jobs and holding more patents than all the nation's universities and large corporations combined.
>
> Our defense industry must leverage that innovation and opportunity into our competitions, as small business representation on programs has demonstrated lower costs to the government. (USD[AT&L], 2010, p. 10)

The specific direction implemented by the memorandum requires that component acquisition executives (CAEs) emphasize small business utilization through weighting factors in past performance and fee construct in all competitive and non-competitive procurement actions (USD[AT&L], 2010, p. 10). This instruction emphasizes the importance that the USD(AT&L) places on small business' contribution to program acquisition and seeks to leverage small business capabilities, increase market research and DoD outreach to small businesses, and remove barriers to small business participation in the defense acquisition processes.

Competition is widely accepted as an acquisition best strategy to enhance the performance of contractors and lower program life-cycle costs. Increasing competition also facilitates incorporating small innovative businesses into the defense acquisition system as prime or subcontractors. Although existing DoD policy and federal legislation directs the use of small businesses in defense contracting, the Weapon Systems Acquisition Reform Act of 2009 (§ 202) directs the use of OSA for IT acquisition to enhance contractor performance and innovation, and to lower program life-cycle cost. In the following section, I describe open system frameworks in industry and the DoD to further illustrate how these initiatives

can leverage small innovative IT businesses participating in the SBIR program to improve DoD IT acquisition.

C. OPEN SYSTEM FRAMEWORKS

In this section, I review existing literature and provide definitions and discussion on open system frameworks that exist in private industry as well as within the DoD. Research conducted by a Tiger Team for the Navy SBIR program (2008) identified that incorporating OSA principles into DoD acquisition facilitates SBIR technology transition (pp. 25–27). An open system is defined as a system that employs modular design, uses widely supported and consensus-based standards for its key interfaces, and has been subjected to successful validation tests to ensure the openness of its key interfaces (Open Systems Joint Task Force [OSJTF], n.d.-b). In industry, the most common open systems initiative is SOA, while DoD open systems initiatives primarily include the MOSA, NOA, and OSA for developing and fielding IT system components and platforms. The acceptance of open systems initiatives across the DoD represents a major new SBIR access opportunity. Although these independent approaches share many commonalities, in this section I review the definition and application of each model to provide a framework for the analysis of SBIR solicitation topics and awards, and to determine the extent to which they advance these open system initiatives.

1. Service-Oriented Architecture

Implementing an open systems framework for designing network architecture is not a concept unique to the DoD. In industry application, SOA seeks to enhance the "openness" of system design and encourages competition through an open business model—a characteristic that SOA shares with DoD open architecture initiatives such MOSA, NOA, and OSA. In this discussion, I review industry application of SOA as a framework for which an open business model can encourage participation by small businesses to maintain a program's technical superiority and stimulate competition to reduce program life-cycle costs.

The concept of SOA has received an increasing amount of attention in the commercial sector and private industry over the past several years as firms increasingly leverage IT systems to enhance business management and provide an interface for customer

interaction. In the private sector, incorporating SOA concepts into IT system development and life-cycle maintenance has demonstrated quantifiable benefits in reducing costs and enhancing IT department staff efficiency, as well as many qualitative benefits that include increased business staff efficiency, enhanced decision-making support, reduced duplication of IT services, faster time to market, and improved IT system scalability and flexibility (Wolff, 2011). The military does not have a unique definition of SOA, nor is the term *service-oriented architecture* discussed in the various DoD DAS instructions or publications; however, many of the underlying concepts of SOA are closely correlated to the DoD's open system initiatives.

SOA is derived from the concept that IT systems can be decomposed to particular services that provide business functionality and information, and that those services can be discovered and shared across a network. A definition of a service is "an implementation of a well-defined piece of business functionality, with a published interface that is discoverable and can be used by service consumers when building different applications and business processes" (O'Brien, Bass, & Merson, 2005).

In *Service-Oriented Architecture: Concepts, Technology, and Design*, Thomas Erl (2005a) attempted to formalize a definition of SOA:

> Contemporary SOA represents an open, agile, extensible, federated, composable architecture comprised of autonomous, QoS-capable, vendor diverse, interoperable, discoverable, and potentially reusable services, implemented as Web services.
>
> SOA can establish an abstraction of business logic and technology, resulting in a loose coupling between these domains.
>
> SOA is an evolution of past platforms, preserving successful characteristics of traditional architectures, and bringing with it distinct principles that foster service-orientation in support of a service-oriented enterprise.
>
> SOA is ideally standardized throughout an enterprise, but achieving this state requires a planned transition and the support of a still evolving technology set. (p. 54)

Erl (2005a) provided a supplementary definition, applicable to both primitive and contemporary SOA initiatives, that is more concise:

> SOA is a form of technology architecture that adheres to the principles of service-orientation. When realized through the Web services technology platform, SOA establishes the potential to support and promote these principles throughout the business process and automation domains of an enterprise. (p. 54)

SOA is based on the concept that the underlying logic required to solve complex problems or define unique business processes can be better constructed, carried out, and managed if it is decomposed into a collection of smaller, related pieces and that these "services" are loosely coupled, discoverable throughout a network, and focused on providing core business processes or services. An alternative definition, provided in *Service Oriented Architecture for Dummies* (Hurwitz, Bloor, Kaufman, & Halper, 2009), is as follows: "A service oriented architecture (SOA) is an architecture for building business applications as a set of loosely coupled black-box components orchestrated to deliver a well-defined level of service by linking together business processes" (p. 5). SOA is based on a common set of principles that include the following: services are reusable, services share a formal contract, services are loosely coupled, services abstract underlying logic, services are composable, services are autonomous, services are stateless, services are discoverable, and services are modular (Erl, 2005b). To thoroughly understand the implementation of SOA in industry and draw comparisons with similar efforts by the DoD, a review of these key underlying principles is provided here.

- *Services are reusable*. Although immediate reuse opportunities might not necessarily be present during system design, SOA services are designed to support potential reuse. By applying standards that allow reuse, the chances of accommodating future system requirements and additions with less development effort are increased. SOA reusability requires that underlying logic is divided into services with the intention of promoting reuse (Erl, 2005a).
- *Services share a formal contract*. In order for services to interact, they do not need to share anything but a formal contract that defines the terms of information exchange and any supplemental service description information. Service contracts provide rules and characteristics of that particular service and its operations in formalized logic to ensure discoverability and information exchange.
- *Services are loosely coupled. Loosely coupled* refers to how two components interact within a service-oriented architecture. Services are designed to interact on a loosely coupled basis and avoid forming tightly coupled

connections that result from business-process interdependencies. The emphasis is on simplicity: one component passes data to another component and makes a request, the second component carries out the request, and, if necessary, passes data back to the first component (Hurwitz et al., 2009, p. 5).

- *Services abstract underlying logic.* Only the service's unique description is visible, or available, to the outside world. The underlying logic is irrelevant and invisible to service requestors.
- *Services are composable*. Groups of services can be assembled to form composite services; essentially, services may compose other services. This possibility allows logic to be represented at different levels of granularity and promotes reusability and the creation of abstraction layers (O'Brien et al., 2005).
- *Services are autonomous.* Services have control over the logic they encapsulate, and the logic that is governed by a service resides within an explicit boundary within that service. Autonomy requires that the individual services remain as independent and self-contained as possible with regards to the unique control they maintain over their underlying logic (Erl, 2005a).
- *Services are stateless*. Services should not manage state information because doing so can impede their ability to remain loosely coupled. Services should be designed to maximize statelessness even if that means deferring state management elsewhere (O'Brien et al., 2005).
- *Services are discoverable.* Services should allow their descriptions to be discovered and understood by humans and service requestors that may be able to make use of their underlying logic. Because each service provides a unique and reusable piece of processing logic, SOA implementation requires the use of service registries or directories to manage service descriptions, which are outwardly descriptive so they can be found and accessed by available discovery mechanisms (Wolff, 2011).

Two key components that underlie the principles of SOA are web services to support the sharing of information and open-source software standards to store and share data. Using open-source software, such as extensible markup language (XML), facilitates retrieval of that data from any IT system and promotes sharing of data between systems. Other technologies incorporated in SOA include web-services description language (WSDL), which allows an IT system to publish its interface on a network, and the simple object access protocol (SOAP) that allows active communication between two disparate IT systems.

Incorporating the principles and concepts of SOA into IT systems reduces dependency on proprietary stove-piped systems, facilitates the sharing of information between system components, and removes business process and underlying logic

interdependencies that inhibit system flexibility and prevent future alterations or modifications to system components as requirements change. SOA promotes organizational agility by leveraging service business representation, service abstraction, and the loose coupling between business and application logic with the use of service layers. As an organization changes—internal reorganization, corporate merger, and so forth—the fundamental principles of SOA, including loose coupling, open standards, and discoverability, ensure that the organization's business logic and application technology infrastructure will be capable of accommodating change: "Organizational agility is perhaps the most significant benefit that can be realized with contemporary SOA" (Erl, 2005a). Figure 3 illustrates how the implementation of SOA can allow for this business process adaptability and flexibility, and how SOA can eliminate tightly integrated business processes and the underlying logic common in traditional enterprise resource planning (ERP) models and system engineering design.

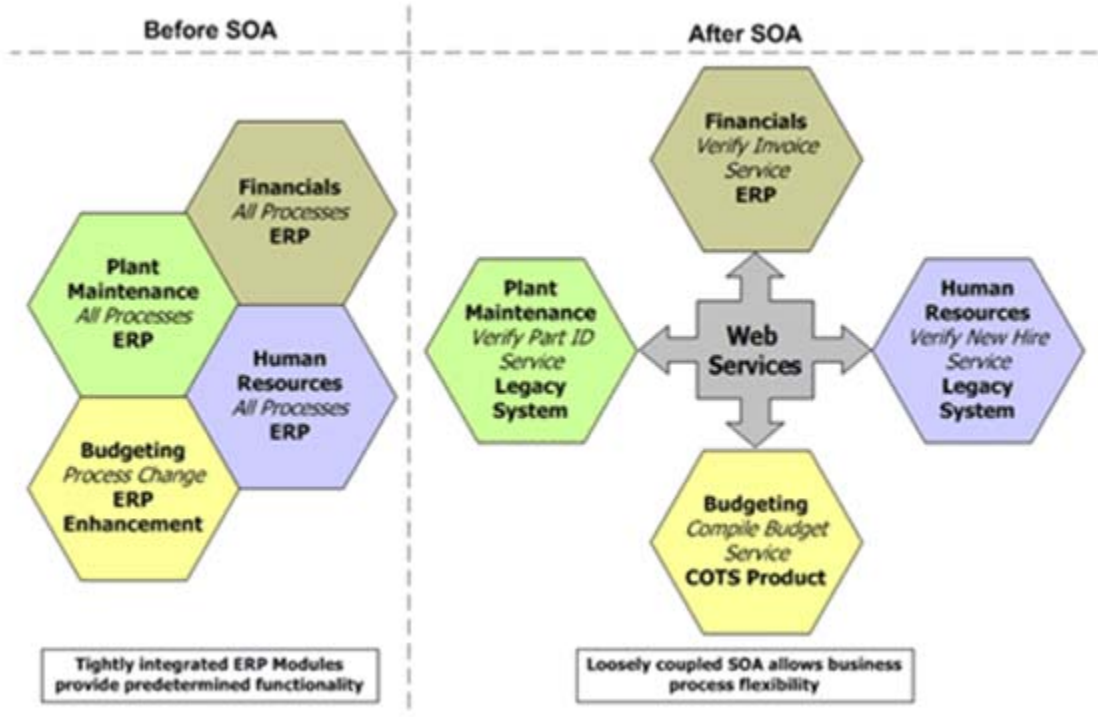

Figure 3. Before and After Service-Oriented Architecture
(Wolff, 2011)

2. Modular Open Systems Approach

The DoD introduced an MOSA into the DAS in 2003 with the publication of DoDD 5000.01 (USD[AT&L], 2007) as a way of implementing open architecture and an OSA process in the DoD: "Acquisition programs shall be managed through the application of a system engineering approach that optimizes total system performance and minimizes total ownership costs. A modular, open systems approach shall be employed, where feasible" (USD[AT&L], 2007, p. 9).

In 2004, the USD(AT&L) established the OSJTF to champion the establishment of MOSA within the DoD and ensure implementation by all DoD acquisition programs. The original mission statement of the OSJTF was as follows:

- make MOSA an integral part of the acquisition process;
- provide expert assistance in applying MOSA;
- ensure application of MOSA by all acquisition programs; and
- collaborate with industry to ensure a viable open standards base. (OSJFT, n.d.-a)

Further guidance was provided in the 2008 publication of DoDI 5000.02, *Operation of the Defense Acquisition System* (USD[AT&L], 2008), which made the concept of a MOSA mandatory in DoD acquisition: "Program managers shall employ MOSA to design for affordable change, enable evolutionary acquisition, and rapidly field affordable systems that are interoperable in the joint battle space" (USD[AT&L], 2008).

MOSA is a business and technical strategy for developing a new system or modernizing an existing one. A MOSA approach to DoD acquisition emphasizes evolutionary acquisition and spiral software development by using widely supported commercial interface standards in developing systems using modular design concepts (OSJTF, 2004, p. 6). Designing systems, including DoD IT systems, using MOSA principles ensures that design strategies are based on widely supported open standards, which increases the likelihood that future additions or changes to the system can be integrated in a cost-effective manner. To effectively design a system for affordable potential future changes requires that the system be developed to include modularity. By incorporating MOSA

strategy in developing new systems or modernizing an existing system, the DoD seeks to achieve the following objectives:

- Adapt to evolving requirements and threats;
- Promote transition from science and technology into acquisition and deployment;
- Facilitate systems integration and leverage commercial investment;
- Reduce the development cycle time and total life-cycle cost;
- Ensure that the system will be fully interoperable with all the systems it must interface with, without major modification of existing components;
- Enhance commonality and reuse of components among systems;
- Enhance access to cutting-edge technologies and products from multiple suppliers;
- Mitigate the risks associated with technology obsolescence;
- Mitigate the risk of a single source of supply over the life of a system;
- Enhance life-cycle supportability; and
- Increase competition. (OSJTF, 2004, p. 4)

Although these specific objectives for incorporating MOSA in DoD acquisition do not provide specific instruction directing or encouraging the use of small businesses in the acquisition process, several MOSA objectives correlate closely with the benefits of incorporating small business participation in DoD contracting. As such, promoting participation of small businesses in the DoD acquisition process through available small business R&D programs and initiatives directly supports several of the aforementioned MOSA objectives including the following: promote transition from science and technology into acquisition and deployment, leverage commercial investment, enhance access to cutting-edge technologies and products from multiple suppliers, mitigate risks associated with technology obsolescence, mitigate the risk of a single source of supply over the life of a system, and increase competition.

To successfully achieve these objectives, MOSA depends on the adherence to five major principles: establishing a MOSA-enabling environment, employing modular design, designating key interfaces, using open standards for key interfaces, and certifying

conformance (OSJTF, 2004, p. 6). Figure 4 identifies the principles alongside associated benefits.

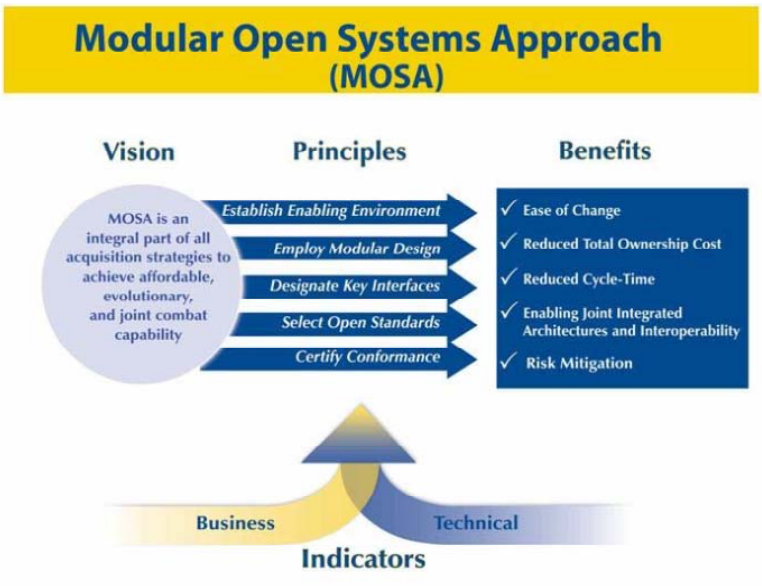

Figure 4. MOSA Principles
(OSJTF, 2004)

The OSJTF produced a program manager's guide (OSJTF, 2004) that formed baseline guidance and procedures for implementing open architecture initiatives within the DoD acquisition system. As of 2011, the OSJTF was no longer in operation, having transferred responsibilities to the Office of the Undersecretary of Defense for Systems Engineering; however, the terminology and principles originally developed by the OSJTF continue to define the open systems approach of the DoD's open system initiatives.

3. Naval Open Architecture

Although the DoD MOSA initiative was primarily developed to facilitate a broad open systems approach to weapon system development, including the development of sub-systems and component software, the NOA initiative focuses on incorporating an open systems approach for the development and acquisition of DoD information systems as a way to reduce the rising cost of naval warfare systems and platforms while continuing to increase the capability delivery on shortened demand timelines (DoD OSA Data Rights Team, 2011). The OSJTF (n.d.-b) has defined open architecture as "an architecture that employs open standards for key interfaces within a system." Another definition, provided by the DoD

Open Systems Architecture Data Rights Team (2011), is as follows: "An open architecture is defined as a technical architecture that adopts open standards supporting a modular, loosely coupled and highly cohesive system structure that includes publishing of key interfaces within the system and full design disclosure" (p. 2).

The Department of the Navy (DoN) has been the primary proponent of open architecture since establishing the Program Executive Office (PEO) for Integrated Warfare Systems (PEO–IWS) in 2002. In 2007, PEO–IWS published the *Naval Open Architecture Contract Guidebook* (DoN, PEO–IWS, 2007), which outlines NOA principles and contract language for program managers who are incorporating NOA principles into National Security System acquisition programs. The document outlines the background and definition of NOA:

> Naval Open Architecture (NOA) is the confluence of business and technical practices yielding modular, interoperable systems that adhere to open standards with published interfaces. This approach significantly increases opportunities for innovation and competition, enables re-use of components, facilitates rapid technology insertion, and reduces maintenance constraints. NOA delivers increased warfighting capabilities in a shorter time at reduced cost. (DoN, PEO–IWS, 2007, p. 2)

In 2005, the Deputy Chief of Naval Operations (OPNAV [Warfare Requirements and Programs, N6/N7]) published the *Requirement for Open Architecture (OA) Implementation* to establish the requirement to implement OA principles across the naval enterprise in an effort to integrate disparate systems and technologies, reduce program costs, and reduce program acquisition cycle time to keep pace with the rapid evolution of commercial and military technology (OPNAV [Warfare Requirements and Programs, N6/N7], 2005). The following section describes those principles of NOA as originally outlined with consideration into how small businesses can be incorporated into defense acquisition to advance NOA.

The following is a review of the principles of the NOA initiative as directed by the OPNAV (2005), as well as considerations for including small businesses in the acquisition process to achieve those principles and meet the stated goals for integrating disparate systems, reducing program costs, and reducing acquisition cycle time:

(1) Modular Design and Design Disclosure. Modular design and design disclosure permits evolutionary design, technology insertion, competitive innovation, and alternative competitive approaches from multiple qualified sources.

The traditional stove-piped acquisition process develops systems through dedicated contracts with single vendors, who are in turn responsible for the development and integration of each individual sub-component of the system. Decoupling sub-components in a modular design while identifying and disclosing key interfaces allows for the contribution of multiple vendors to an open system. Incorporating small business participation in the R&D of modular system components and leveraging the innovative potential of small businesses as prime contractors or subcontractors can potentially incorporate cutting-edge commercial technologies while reducing overall program costs in DoD acquisition and program life-cycle management.

(2) Reusable Application Software. This principle directs the use of reusable application software that is selected through open competition of best-of-breed candidates, reviewed by subject-matter expert peers and based on data-driven analyses and experimentation to meet operational requirements. Design disclosure must be made available for evolutionary improvement to all qualified sources.

Software development and maintenance accounts for an increasingly greater percent of total ownership costs for DoD programs, and leveraging innovative small businesses in a competitive contracting process to develop reusable software could provide significant cost savings in program acquisition development costs.

(3) Interoperable Joint Warfighting Applications and Secure Information Exchange. This principle addresses the use of common services, common warfighting applications, and information assurance as intrinsic design elements.

Secure information exchange is a fundamental characteristic of open architecture. The use of open-source code and standardized application interfaces in developing software applications, as well as implementation of a service-oriented approach to software and architecture design enables the “openness” of network architecture. Small business participation does not necessarily enhance information exchange between applications; however, including small businesses in application design has the potential to reduce the traditional proprietary approach to DoD system acquisition while significantly

expanding the pool of available contractors to participate in DoD-related acquisition programs.

(4) Life-Cycle Affordability. This principle includes system design, development, delivery, and support, while mitigating COTS obsolescence by exploiting the Rapid Capability Insertion Process/Advanced Processor Build (RCIP/ARB) methodology.

RCIP reduces program life-cycle costs and reduces hardware and software obsolescence through continuous, reduced-cost upgrades that leverage COTS hardware and software technology. APB is a disciplined process to develop new functionality and software algorithms from the laboratory to the Fleet in under two years (Cole, 2011, p. 15).

Innovative small businesses in the information systems technology sector produce a variety of COTS hardware and software in rapid iterations, which could be applied and inserted into DoD systems. Leveraging existing commercial technologies, including those developed by small businesses, can provide the most current technologies at lower cost, as opposed to the traditional reliance on single large defense contracting firms that develop proprietary stove-piped systems tailored for unique DoD application.

(5) Encouraging Competition. This principle seeks to encourage competition and collaboration through the development of alternative solutions and sources.

Encouraging competition by adopting an open business model is one of the core characteristics of NOA. Open competition among viable competitors leverages the collaborative innovation of a number of firms and reduces overall program costs compared to the traditional single-vendor approach. Encouraging small business participation in an open business model allows one organization that might have a unique software capability to collaborate on a program with another vendor that specializes in hardware; the result is that both firms contribute their unique product or service at a lower cost than a single-vendor approach. In addition, competition within the contract request for proposal and awarding process uses the market mechanism to lower proposal costs, which in turn reduces overall cost to the DoD.

4. DoD Open Systems Architecture

The DoD's approach for designing new systems and modernizing existing systems has evolved from the original principles outlined by the OSJTF MOSA, principles that concentrated primarily on weapon system platform technology development, to an OSA that applies MOSA principles and NOA implementation strategies to the national security system or systems that integrate national security systems with weapon platforms. OSA is based on the guiding principles outlined in DoDD 5000.01 (USD[AT&L], 2007), which instructs that "acquisition programs shall be managed through the application of a system engineering approach that optimizes total system performance and minimizes total ownership costs. A modular, open systems approach shall be employed, where feasible." Subsequent instruction outlined in DoDI 5000.02 (USD[AT&L], 2008) reinforced a modular open system approach to DAS acquisition strategies, and the OSJTF was chartered by the USD(AT&L). Currently, the OSJTF has transferred responsibility for the oversight of open systems to the Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD[SE]). Although the framework under which MOSA was originally designed remains largely unchanged, and is considered "the DOD preferred approach for implementation of open systems," OSA applies MOSA principles and NOA implementation strategies to acquisition programs that design new systems or modernize existing ones (ODASD[SE], 2012).

In December 2011, the DoD OSA Data Rights Team published a draft version of the *DoD Open Systems Architecture Contract Guidebook for Program Managers* to coordinate DAS efforts to include OSA characteristics in system design, modernization, and acquisition. The document highlights the following:

> The key enabler for open architecture is the adoption of an open business model which requires doing business in a transparent way that leverages the collaborative innovation of numerous participants across the enterprise permitting shared risk, maximized asset reuse and reduced total ownership costs. The combination of open architecture and an open business model permits the acquisition of Open Systems Architectures that yield modular, interoperable systems allowing components to be added, modified, replaced, removed and/or supported by different vendors throughout the life cycle in order to drive opportunities for enhanced competition and innovation. (DoD OSA Data Rights Team, 2011)

Similar to earlier MOSA and NOA initiatives, OSA is composed of five fundamental principles to obtain "openness" of a system:

- modular designs that are based on standards with loose coupling and high cohesion in order to allow for the independent acquisition of system components;
- enterprise investment strategies that are based on collaboration and trust, and that maximize reuse of proven system designs and reduce overall costs;
- aggressive transformation of program life-cycle sustainment strategies for software intensive systems through proven technology insertion and product upgrade techniques;
- lower development risk through transparency of system designs, continuous design disclosure, and government, academia, and industry peer-review processes; and
- strategic use of data rights to ensure a level and competitive playing field and access to alternative solutions and sources across the program life cycle. (DoD OSA Data Rights Team, 2011)

OSA is fundamentally rooted in an open business model approach to system design and acquisition that encourages industry competition and third-party participation in system development and modernization. Achieving these five OSA principles ensures that a third-party—including innovative small businesses—can add, modify, replace, remove, or provide support for a component of a system and maximize acquisition choice and flexibility. OSA facilitates collaboration within and across military departments and industry by allowing program managers and PEOs to pursue common architectures or capabilities across platforms. In addition, OSA encourages the use of COTS technology in DoD systems, and it "increases competition among system developers through the use of open standards and standard, published interfaces" (DoD OSA Data Rights Team, 2011, p. 4). Table 4 demonstrates the business and technical elements of OSA that must be included as foundational elements within a program.

Table 4. Business and Technical Practices of OSA
(DoD OSA Data Rights Team, 2011)

Business Practices of OSA	Technical Practices of OSA
• Seek data rights in technical data and computer software sufficient for competition throughout the life cycle as an objective;	• Modular architectures with open standards and published interfaces;
• Continuous competition throughout the life cycle;	• Separation of hardware and software through middleware[4];
• Increased capability to the warfighter on a faster development timeline;	• Maximized reuse of assets to limit unique development;
• Reduced life cycle costs;	• Full Design disclosure[5] ; and,
• Shared risks with other programs;	• Limited use of well-defined proprietary solutions.
• Minimized duplication for technology development investments, shared life cycle costs; and	
• Collaboration through peer reviews.	

Current DAS acquisition strategies seek to implement OSA in system design and acquisition through an open business model that encourages vendor competition, eliminates stove-piped programs that result from vendor lock-in, incorporates the newest technologies in system design, and lowers program life-cycle costs. The OSA approach should encourage both the acquisition community to seek out innovative small businesses for DoD acquisition projects and the small business community to proactively seek prime-contracting or sub-contracting opportunities for DoD projects.

The wide acceptance of open systems initiatives in DoD acquisition represents a major new SBIR access opportunity. From this perspective, the SBIR program is an integral and significant source of innovative technologies and new products that are ready for application and integration into complex DoD systems (Navy SBIR Program, 2008, p. 26). However, SBIR technology insertion is strongly dependent on proactive management processes and planning activities, and requires that the defense acquisition community proactively communicates that intent to small businesses participating in the program. In the following chapter, I review IST initiatives in the DoD SBIR program and analyze how well the DoD has used the SBIR program to advance open system initiatives in DoD IT acquisition.

IV. INFORMATION SYSTEMS TECHNOLOGY INITIATIVES IN THE DOD SBIR PROGRAM

The first objective of this research is to explore the extent to which the DoD leverages the SBIR program to incorporate small, innovative IT firms in DoD R&D. Additionally, in this research I focus on analyzing the extent to which the SBIR program is used to advance open system architecture initiatives within defense contracting to reduce reliance on proprietary "stove-piped" IT systems and promote an open business model that leverages the innovative potential of small businesses and encourages competition to reduce program life-cycle cost. In this chapter, I first review secondary research and analyze a sample population of SBIR solicitation topics and related awards in the *IST critical technology area* in an effort to answer my first research question: Does the DoD leverage the SBIR program to incorporate small, innovative IT firms in DoD R&D efforts?

Secondly, as the DoD shifts to an OSA, an opportunity is presented to increase innovation and expand competition to many suppliers including small businesses for separate components of complex DoD systems. However, this requires that the DoD proactively communicate this intent by requiring small businesses to incorporate open system architecture principles in technology development and product design. In this chapter, I present a thorough analysis of the population sample that was used to examine the extent to which the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems to advance OSA initiatives based on contracting guidelines published by the Department of the Navy and the DoD that outline suggested language to be used in requests for proposals (RFP) for defense contracting.

A. SAMPLE DATA COLLECTION

At the time this research was conducted, the DoD OSBP SBIR office made publicly available all topic solicitation and award data through FY2010. Most research that has been conducted on the SBIR program tends to use a single solicitation period or fiscal year to develop a sample population; this research, however, analyzed topic and award data over a five-year period from FY2006–FY2010. This approach to analyzing topics and awards in the

SBIR program reduces sampling biases that might result from using only one solicitation as a dataset for analysis. Table 5 provides a summary of the total SBIR budget, the number of topics, the number of proposals, the number of phase I awards, and the number of phase II awards during the FY2006–FY2010 time period used in this analysis.

Table 5. Summary of SBIR Data During FY2006–FY2010

SBIR Budget	# Topics	# Ph I proposals	# Ph I awards	# Ph II awards
$5,898,574,726	4,494	63,173	9,739	5,104

Note: The information in this table came from the *DoD SBIR Annual Report Summary* (DoD, n.d.)

Due to the size of the raw data set and time and resource constraints, a randomized sample of 25 topics was chosen from each of the 15 SBIR solicitations that occurred during this period, resulting in a total sample size of 375. This data was collected from past SBIR solicitation documentation that is available on the DoD's OSBP SBIR website. Although this research predominately focuses on analyzing the IST critical technology area within the SBIR program (where I expect most open system-related awards to be categorized), topics from all critical technology areas were included in the sample to ensure topic solicitations from other critical technology areas that might promote an open systems approach were included in the sample population. DoD guidance for an open system approach to system acquisition is focused primarily on national security systems (NSSs), which may include SBIR topics not categorized as IST. Examples might include SBIR topics soliciting for the R&D of weapon systems, sensors, and other platforms considered "open" by using open standards and published key interfaces to integrate components of the system or facilitate information sharing across an enterprise network. For example, past successful implementations of a modular open system approach include the Acoustic Rapid COTS Insertion/Advanced Processing Build (A-RCI/APB) conducted by the U.S. Navy, the Virginia Class Non-Propulsion Electronic Systems (NPES), and the E-2 Hawkeye aircraft upgrade, neither of which would necessarily be classified as an *information systems technology* critical technology area as defined by the DoD SBIR topic solicitation. A randomized sample of SBIR topics was chosen that included 375 topics from the 12 participating agencies and provided results to reflect the target population of 4,494 with a

confidence level of 95% and a confidence interval of 4.85. Appendix A contains the complete list of all SBIR topics used to generate a sample for this research.

The DoD SBIR solicitations each contain addendum documentation from each of the participating DoD components that provide solicitation topics and component-specific instructions. Although some formatting differences of solicitation topics do exist between components, each solicitation contains similar information including title, technology areas, acquisition program (component dependent), objective, description, phase I description, phase II description, and phase III description and private-sector commercialization potential description.

B. OBSERVATIONS AND ANALYSIS OF SBIR SOLICITATION SAMPLE

SBIR solicitations are categorized by the topic's critical technology area as determined by the component SBIR program manager. Solicitation topics are frequently categorized by multiple technology areas that generally range from one to four or more categories. In an effort to extend the work of Held et al. (2006), who conducted a similar analysis based on 2004 solicitation data, this research uses the FY2006–FY2010 SBIR sample to replicate the 2006 study and reevaluate how SBIR priorities compare with broader DoD RDT&E priorities, and in particular the IST topic area priorities. The 375 topics in this sample were mapped to the 12 critical technology areas listed in the topic solicitation. Held et al. (2006) used the percentage of R&D funding described in the topic solicitation, which was obtained from the defense technology area plan (DTAP), as an indicator of the DoD's technology prioritization and to compare with the percentages of SBIR topics included in each technology area, which I replicated using the FY2006–FY2010 sample. The findings of the 2006 research were that "in general, SBIR topic allocation aligned well with the overall defense R&D budget allocations" (Held et al., 2006, p. 51). Using the 2006 study as a framework, this research mapped the FY2006–FY2010 sample to associated critical technology areas outlined in the solicitation. This analysis supports the findings of the 2006 report; that is, SBIR topic allocation continues to be generally aligned with the defense R&D budget allocations. SBIR topic generation appears to be relatively stable between the two

studies with only minor differences, which supports the broad observation that topic generation in the SBIR program correlates with the DoD RDT&E budget (see Figure 5).

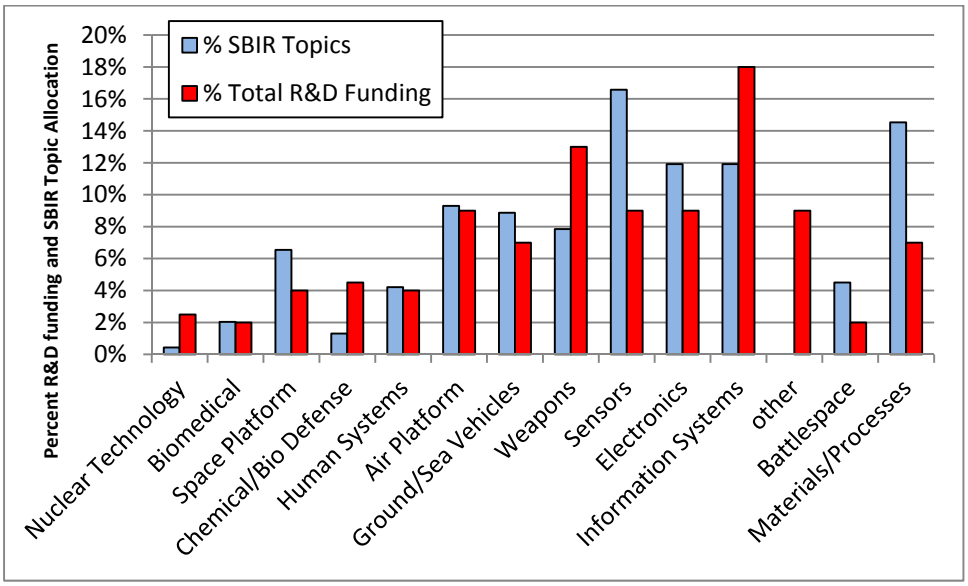

Figure 5. SBIR Topic Allocation and DoD R&D Funding

On average, SBIR topics categorized as IST account for approximately 12% of the sample used in this research. That is, the DoD focuses approximately 12% of SBIR solicitation resources and effort on the R&D of information technology systems. No current federal budgeting documents outline the RDT&E budget specifically for information systems technology platforms; however, by using data originally collected in the 2006 RAND study, which estimates that the DoD RDT&E budget allocates approximately 18% funding to information systems technology projects, this analysis suggests that the SBIR program continues to moderately underfund information systems technology programs. However, given the limits of using potentially dated information from the DTAP, a more thorough analysis may be required to adequately evaluate current trends in DoD information systems technology R&D initiatives. Additionally, although this analysis suggests that the SBIR program moderately underfunds IST projects in general, SBIR topics that are not categorized as IST do occasionally require software development, which could contribute to underestimating the percent of IST-related SBIR topics.

C. OPEN SYSTEMS ARCHITECTURE INITIATIVES IN THE DOD SBIR PROGRAM

The second objective of this research is to examine the extent to which the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems that advance OSA initiatives. This analysis was conducted by examining all 375 published SBIR topics contained in the sample population to determine how well the request-for-proposal language outlined in the SBIR solicitation is aligned with the DoD's objective of advancing OSA initiatives within the DoD acquisition process. The metrics used to assess the SBIR requests for proposal were based on contracting language explicitly outlined in the *Naval Open Architecture Contract Guidebook* (DoN, PEO–IWS, 2007) and the *DoD Open Systems Architecture Contract Guidebook* (DoD OSA Data Rights Team, 2011), both of which are resources available to the DAW on the Defense Acquisition University (DAU) Acquisition Community Connection website at https://acc.dau.mil/oa. Because SBIR-funded research frequently involves basic research that is not necessarily appropriate for OSA, a further analysis of the sample was conducted in order to determine which topics were directly associated with NSS, or could be integrated with larger NSS platforms to ensure an adequate comparison could be made.

1. DoD Request for Proposal Language Guidance

Early attempts to insert OSA principles into the defense acquisition process were led primarily by the OSJTF, which published the *Program Manager's Guide: A Modular Open Systems Approach to Acquisiton* in 2004. The document was prepared to provide program managers, system engineers, contracting officers, and the entire program team the tools to implement MOSA in defense acquisition programs. The primary objectives of the document were to define MOSA, explain why MOSA is important, explain how MOSA should be planned and implemented, and explain how MOSA initiatives will be assessed and adjuticated (OSJTF, 2004, p. 1). Although the document adequately explained MOSA principles to the defense acquisition workforce, it did not explicitly provide instruction on how to construct contracting language to incorporate open system principles into requests for proposal and defense contracts.

In 2007, the U.S. Navy Program Executive Officer, Integrated Warfare Systems (DoN, PEO–IWS, 2007) published the *Naval Open Architecture Contract Guidebook* for program managers as part of the ongoing effort to enhance open architecture initiatives within the Department of the Navy. The document expanded earlier efforts by the OSJTF by providing guidance and example contracting language for program managers and contracting officers and their supporting organizations to assist them in incorporating open architecture principles into their programs and contracts (DoN, PEO–IWS, 2007, p. 1). Although the document provides detailed guidance for incorporating open architecture principles throughout the defense acquisition process, it specifically includes recommended contracting language to be used in the statement of work (SOW) and statement of objectives (SOO) portion of the request-for-proposal solicitation. Additionally, the *Naval Open Architecture Contract Guidebook* (DoN, PEO–IWS, 2007) includes both a long and short NOA Checklist in the appendices that are designed to be used by program managers, contracting officers, and supporting organizations to validate a system's programmatics in order to ensure the benefits of an open system are achieved (DoN, PEO–IWS, 2007, pp. 3-1–4-4).

As MOSA initiatives within the DoD expanded from primarily weapon system procurement to OSA initiatives designed to incorporate NSSs, the DoD OSA Data Rights Team distributed the *DoD Open Systems Architecture Contract Guidebook* in 2011. This document largely replicates the earlier *Naval Open Architecture Contract Guidebook* with few modifications. The purpose of this document is to provide program managers, contracting officers, and their supporting organizations with DoD-wide guidance and recommended language for incorporating OSA principles into NSS acquisition programs. Similar to the Navy's earlier guidance, this document provides detailed guidance and recommended contract language to be used in the request-for-proposal solicitation. Additionally, the document also published OSA checklists in the appendices, which are designed to be used by program managers, contracting officers, and supporting organizations to validate a system to ensure the benefits of OSA are achieved (DoD OSA Data Rights Team, 2011, pp. 83–91). Among other requirements, these checklists require competition and collaboration in the defense acquisition process and recommend program managers and

contracting officers consider technologies developed under the SBIR program to encourage participation by qualified small businesses (DoD OSA Data Rights Team, 2011, p. 89).

To further clarify what types of acquisition programs should incorporate open system architecture principles, both contracting guidebooks defined national security system as follows:

> The term "NSS" refers to any telecommunications or information system operated by the Government, the function, operation, or use of which (1) involves intelligence activities; (2) involves cryptologic activities related to national security; (3) involves command and control of military forces; (4) involves equipment that is an integral part of a weapon or weapon system; or (5) is critical to the direct fulfillment of military or intelligence missions, but excluding any system that is to be used for administrative and business application purposes (including payroll, finance, logistics, and personnel management applications). (DoD OSA Data Rights Team, 2011, p. 5)

This was the primary definition of NSS used in this analysis to determine which SBIR solicitation topics were directly associated with NSS, or could be integrated with larger NSS platforms.

2. Analysis of Open Systems Architecture Initiatives in the SBIR Program

The aforementioned contract guidebooks provide explicit guidance and recommended language for request-for-proposal documents released by program managers who are incorporating OSA principles into NSS-related acquisition programs. Under the SBIR program, these requests for proposal are released as SBIR solicitations three times a year as described in Chapter II of this research. Both contract guidebooks provide system architecture approach characteristics to be utilized when incorporating OSA principles into defense acquisition programs. Table 6 provides a summary of these characteristics and their relevant definitions and formed the basis for the analysis of SBIR topic request-for-proposal solicitations in this research. Although many of the characteristics were retrieved from guidance published in the contract guidebooks, it should be noted that additional useful characteristics were added to expand this analysis and ensure relevant SBIR topics would be adequately identified (an example is the inclusion of "service-oriented architecture," which is not directly addressed by the contract guidebooks but nonetheless indicates that an SBIR topic seeks "openness" in system design).

The 31 OSA characteristics identified were used to analyze the 375 SBIR topic solicitations included in the sample. Keyword searches were used to identify potential SBIR topic RFP contracting language that either explicitly directed the use of open system architecture principles within the SBIR RFP language, or implied that system design should incorporate an "open" design in system development and engineering. Of the 375 SBIR topics identified for this analysis, only 22 (approximately 6%) included relevant language that solicited small businesses for R&D of IT systems that advance OSA initiatives through the SBIR program.

Table 6. Open Systems Architecture Approach Characteristics

	Characteristics	Definition		Characteristics	Definition
1	Modular Open System Approach (MOSA)	MOSA is a business and technical strategy for developing a new system or modernizing and existing one. A MOSA approach to DoD acquisition emphasizes evolutionary acquisition and spiral software development by using widely supported commercial interface standards in developing systems using modular design concepts (OSJTF, 2004, p.6).	17	Published / Open interface	Modules should contain components that are self-contained elements with well defined, open and published interfaces implemented using open standards to facilitate the exchange of information between disparate systems and encourage competition by avoiding proprietary interfaces that result in vendor lock.
2	Open Architecture (OA)	A technical architecture that adopts open standards that support a modular, loosely coupled and highly cohesive system structure that includes publishing of key interfaces within the system and full design disclosure (DoD OSA Data Rights Team, 2011, p.2). Both the DoD OSA guidebook and the Naval OA guidebook explicitly direct that the contractor shall develop and maintain an open architecture that "incorporates appropriate considerations for reconfigurability, portability, maintainability, technology insertion, vendor independence, resuability, scalability, interoperability, upgradeability, and long-term supportability" (ibid, p.14).	18	Spiral development	"A risk-driven process model generator for guiding multi-stakeholder concurrent engineering of software-intesnsive systems. Its distinguishing features include a cyclic approach for incrementally growing a system's degree of definition and implementation, and a set of anchor point milestones for ensuring feasibility of the incremental definitions and implementations" (Hanson et al, 2000, p.9) Fundamental aspect of modular open systems approach: A MOSA approach to DoD acquisition emphasizes evolutionary acquisition and spiral software development by using widely supported commercial interface standards in developing systems using modular design concepts (OSJTF, 2004, p.6).
3	Service Oriented Architecture (SOA)	A form of technology architecture that adheres to the principles of service-orientation. When realized through the Web services technology platform, SOA establishes the potential to support and promote these principles throughout the business process and automation domains of an enterprise (Erl, 2005a, p.54).	19	Interoperability	"The ability of systems, units, or forces to provide data, information, materiel, and services to and accept the same from other systems, units, or forces and to use the data, information, materiel, and services so exchanged to enable them to operate effectively together. Information Technology (IT) and National Security System (NSS) interoperability includes both the technical exchange of information and the operational effectiveness of that exchanged information as required for mission accomplishment (DoD OSA Data Rights Team, 2011, p.107).
4	Modular, Open Design	"A design (organization) where functionality is partitioned into discrete, cohesive, and self-contained units with well-defined, open and published interfaces that permit substitution of such units with similar components or products from alternate sources with minimum impact on existing units (DoD OSA Data Rights Team, 2011, p. 109). Modular, Open Design is specifically addressed by the suggested contract language in both the DoD and the Navy guidelines: "The contractor shall develop an architecture that is layered and modular and uses standards-based COTS/NDI hardware, operating systems, and middleware that all utilize either non-proprietary or non-vendor unique key module or component interfaces" (DoD OSA Data Rights Team, 2011, p.2).	20	Information Exchange	Term used to describe the extent to which information can be shared and exchanged among systems or throughout an enterprise network. Used throughout open framework literature, and included within the NOA and OSA contracting guidebooks as a fundamental component of open architecture.
5	Module Coupling	Refers to a measure of the relative interdependence among modules. The OSA guidebook states explicitly that the "design approach shall result in modules that have minimal dependencies on other modules (loose coupling), as evidenced by simple, well-defined interfaces and by the absence of implicit data sharing. The purpose is to ensure that any changes to one module will not necessitate extensive changes to other modules, and hence facilitate module replacement and system enhancement" (DoD OSA Data Rights Team, 2011, pp.14-15).	21	Software reuse	Term used to describe the degree to which a software module can be used in more than one computing program or software systems, and therefore save resources. Addressed in both NOA and OSA guidebook: "the contractor shall re-use pre-existing or common items unless a determination is made to not re-use" (DoD OSA Data Rights Team, 2011, p.15).
6	Module Cohesion	Refers to a measure of the relative functional strength of a module and addressed explicitly in both guidebooks. The OSA guidebook states: the "design shall result in modules that are characterized by the singular assignment of identifiable, and discrete functionality (high cohesion). The pupose is to ensure that any changes to system behavioral requirements can be accomplished by changing a minimum number of modules within the system" (ibid, p.15).	22	Discoverability	Term used to describe an underlying principle of service oriented architecture where service registries or directories are used to manage service descriptions to allow services to be found and accessed by discovery mechanisms; facilitates the sharing of data and information between components or across and enterprise network.
7	Open System	A term used to describe a non-proprietary technical architecture design that is based on publicly known standard interfaces that support interoperability among components or disparate systems. "Open systems" is a concept that is fundamentally rooted in SOA, MOSA, NOA, and OSA.	23	Web Services	Term used to describe standard display and exchange of information. Specifically addressed in both the NOA and OSA guidebook that directs contracting languange that includes the use of commercial standards including "web services for remote system calls" (DoD OSA Data Rights Team, 2011, pp.18-19).
8	Open Source	"Computer software for which the source code and certain other rights normally reserved for copyright holders are provided under a software license that meets the Open Source Definition or that is in the public domain. This permits users to use, change, and improve the software, and to redistribute it in modified or unmodified forms" (DoD OSA Data Rights Team, 2011, p. 110).	24	Layered system design	"'Layered' means a system in which components are grouped, i.e., layered, in a hierarchical arrangement, such that lower layers provide functions and services that support the functions and services of higher layers (DoD OSA Data Rights Team, 2011, p. 107). Specifically addressed in both NOA and OSA guidebooks: the "design approach shall result in a layered system design, maximizing software independence from the hardware, thereby facilitating technology refresh" (ibid, p. 15).
9	Open standard(s)	"Widely accepted and supported standards set by recognized standards organizations or the marketplace. These standards support interoperability, portability, and scalability and are equally available to the general public at no cost or with a moderate license fee" (DoD OSA Data Rights Team, 2011, p. 110). The OSA guidebook contains recommended language requiring the contractor to use open standards in system design.	25	Enhanced portability	"'Portability' is the software codebase feature to be able to reuse the existing code instead of creating new code when moving software from an environment to another" (DoD OSA Data Rights Team, 2011, p. 111). Specifically addressed in both NOA and OSA guidebooks: the "layered design shall also isolate the application software layers from the infrastructure software to enhance portability and to facilitate technology refresh" (ibid, p. 15).
10	XML	Extensible Markup Language: Standard used to transport and store data between systems and components; commonly used in open systems and explicilty discussed in both the NOA and OSA contracting guidebook.	26	Non-proprietary / vendor lock	A fundamental concept of open systems architecture is to reduce proprietary software/hardware that results in 'vendor lock.' "Vendor lock-in' or just 'lock-in', is the situation in which customers are dependent on a single manufacturer or supplier for some product (i.e., a good or service), or products, and cannot move to another vendor without substantial costs and/or inconvenience. This dependency is typically a result of standards that are controlled by the vendor (i.e., manufacturer or supplier). It can grant the vendor some extent of monopoly power and can thus be much more profitable than would be the absence of such dependency" (DoD OSA Data Rights Team, 2011, p. 115).
11	XMI	Extensible Markup Language Metadata Interchange: Standard used to to exchange metadata information using XML. Specifically directed in both the NOA and OSA guidebook: "...document and model how it will use tools that are capable of exporting model information in a standard format (e.g. XMI)" (ibid, p.16).	27	Application Programming Interaces	"a set of routines, protocols, and tools for building software applications. A good API makes it easier to develop a program by providing all the building blocks. A programmer then puts the blocks together" (DoD OSA Data Rights Team, 2011, p. 103).
12	UML	Unified Modeling Language: Standard used for software modeling and recommended by both NOA and OSA contracting guidebooks.	28	Software Independence	Term used to describe the decoupling of software from hardware platforms. Specifically addressed in the NOA and OSA guidebook: "The contractor's design approach shall result in a layered system design, maximizing software independence from the hardware, thereby facilitating technology refresh" (ibid, p. 15).
13	WSDL	Web-services description language: XML based standard used to describe functionality that is offered by a service. XML is a fundamental standard used in Service Oriented Architecture to allow messages to be fully self-contained; it facilitates standardized messaging to eliminate the need for service logic to share dependencies and supports loose coupling (Erl, 2005a, p.43).	29	Technology Insertion	"increasing a system's or product's Warfighting operational capability by integrating new capabilities or upgrading the system's current capabilities with up-to-date and more capable COTS or custom technologies" (DoD OSA Data Rights Team, 2011, p. 115). Specifically addressed in the NOA and OSA guidebook: "The contractor's architectural approach shall support the rapid and affordable insertion and refreshment of technology through modular design, the use of open standards and open interfaces" (DoD OSA Data Rights Team, 2011, p. 16)
14	SOAP	Simple Object Access Protocol: XML based standard protocol for exchanging structured information between web services. SOAP is a fundamental standard used in Service Oriented Architecture to allow messages to be fully self-contained; it facilitates standardized messaging to eliminate the need for service logic to share dependencies and supports loose coupling (Erl, 2005a, p.43).	30	Life-cycle sustainability	Refers to the degree to which a program is capable of obtaining efficient life-cycle sustainability with regards to technology insertion, maintenance, and continued support. Life-cycle sustainability is a fundamental principle of open systems architecture approach to system design.
15	Commercial standards	Specifically addressed in the NOA and OSA guidebook as a system architecture approach characteristic, commerical standards are "standards developed by international or national industry standards bodies that have been widely apopted by industry" (DoD OSA Data Rights Team, 2011, p.18).	31	Open business practice	Promotes an open business model to enhance competition in federal acquisition to enhance innovation and reduce program life-cycle cost. Specifically addressed in both NOA and OSA contracting guidelines: "the contractor shall demonstrate that the modularity of the system design promotes the identification of multiple sources of supply and/or repair, and supports flexible business strategies that enhance subcontractor competition" (ibid, p. 17).
16	Commercial off-the-shelf (COTS)	An item that is (a) a commercial item, (b) is sold in substantial quantities in the commercial marketplace, and (c) is offered to the government, without modification, in the same form in which it is sold in the commercial marketplace" (DoD OSA Data Rights Team, 2011, p.105). Both NOA and DoD OSA seek to maximize the use of COTS in system architecture design, and state specifically that "the contractor shall develop an architecture that...uses standards based COTS/NDI hardware, operating systems, and middleware that all utilize either non-proprietary or non-vendor-unique key module or component interfaces" (ibid, p.14).			

A more thorough analysis of the SBIR topics was subsequently conducted in order to determine the extent to which the SBIR topic RFP language satisfied existing DoD OSA initiatives. RFP language contained in the SBIR topic was assigned an ordinal rank (high, medium, and low), dependent on the level of detail in the SBIR RFP that directs OSA principles in the R&D effort. Table 7 provides the metrics used to assign ordinal ranks to OSA-related SBIR solicitation topics. This more thorough analysis revealed that four SBIR topics that had a high level of OSA principles incorporated into the SBIR RFP language, six topics that were categorized as "medium," and 11 topics that were categorized as "low," in that they required the use of open standards to promote system interoperability, or contained other contracting language that would tend to guide the R&D effort toward the design of a system that promoted OSA principles.

Table 7. Ordinal Rank of Open Systems Architecture SBIR Solicitation Topics

Open System Architecture Rank	Metric
High	SBIR topic solicitation contains statement of work (SOW) languange that explicitly directs research and development of a system or component that incorporates open system architecture and an open systems approach to system design. Topic solicitation closely follows contracting language guidelines as outlined in the NOA and OSA contracting guidebook to ensure the fundamental principles of open systems architecture is incorporated into system design
Medium	SBIR topic solicitation contains some statement of work (SOW) language that directs research and development of a system or component that incorporates open system architecture and/or and open systems approach to system design. Topic solicitation makes casual reference to contracting language guidelines as outlined in the NOA and OSA contracting guidebook (i.e. requires the use of XML as an open standard).
Low	SBIR topic solicitation contains few OSA related references or implicitly contains statement of work (SOW) language that would serve to guide contractors toward research and development of a system or component that incorporates the fundamental principles of open system architecture.

Eleven SBIR topics were categorized as either "high" or "medium," indicating that the SBIR topics included RFP language that specifically directed that system design requires the use of OSA principles to facilitate data interoperability and system application interaction. Interestingly, several SBIR topics specifically address the requirement to incorporate SOA principles into system design, which indicates the DoD SBIR program's recognition of SOA principles despite the agency's lack of a definition of SOA or an explicit requirement that SOA principles be incorporated into DAS contracting language. Other SBIR topics that explicitly directed the use of OSA principles did so by explicitly stating the requirement in the request for proposal. Examples include SBIR topics published by the Navy (N08-058; N07-131; N06-179), the Air Force (AF073-025), and the Army (A10-064). Finally, other SBIR topics that were considered to contain strong language in the requests for proposal indicating the requirement for an OSA design did so by reiterating OSA characteristics throughout the RFP to make it apparent that proposals must address system

"openness" to ensure data interoperability and system application interaction, as well as technology insertion into larger existing DoD platforms.

The remaining 11 SBIR topics identified in this analysis were assigned an ordinal rank of "low" because while request-for-proposal language did suggest the use of OSA principles in system design, the language contained few explicit references to OSA and rather implied, through the general construct of the RFP, that the R&D effort should incorporate "openness" in system design. Although the topics did not explicitly address OSA, they did include characteristics that would guide contractors in developing a system based on OSA; examples include requirements that applications be integrated with a variety of data types, software reuse, open source software, a modular approach to system design, system integration, interoperability with existing DoD systems, and knowledge sharing. SOA was also prevalent among a number of these SBIR topics, further indicating the DoD SBIR program's recognition of SOA principles. Appendix B presents the complete analysis and summary of SBIR topics that were identified as containing OSA principles in the SBIR request-for-proposal language.

3. National Security Systems

The DoD SBIR program funds a broad variety of early stage basic and applied R&D efforts designed to support the broader technology development goals of the DAS. Technology developed under the SBIR program includes products and services that range from innovative patient litter systems for transporting patients in military vehicles, to Airborne IT networking systems that leverage OSA concepts to enhance network routing and data interoperability. Naturally, any SBIR topic that seeks to leverage OSA does so only when such principles are appropriate for the project. Therefore, any thorough analysis of SBIR topic RFPs to examine the extent to which the DoD uses the SBIR program to advance OSA initiatives must address the inconsistency in topics. The DoD's objective is to incorporate OSA principles primarily into NSSs; as such the purpose of both the Navy and DoD contracting guidebooks is to provide recommended language of contracts and solicitations issued by the DoD and service components for NSS or larger "systems of systems" (DoD OSA Data Rights Team, 2011, p. 5). Therefore, a careful analysis of the 375

topics contained in the SBIR solicitation sample was conducted in order to determine which SBIR topics were directly applicable to, or could be integrated with, contracts for NSSs. The metric used for this analysis was based on the definition of NSS outlined in both documents:

> The term "NSS" refers to any telecommunications or information system operated by the Government, the function, operation, or use of which (1) involves intelligence activities; (2) involves cryptologic activities related to national security; (3) involves command and control of military forces; (4) involves equipment that is an integral part of a weapon or weapon system; or (5) is critical to the direct fulfillment of military or intelligence missions, but excluding any system that is to be used for administrative and business application purposes (including payroll, finance, logistics, and personnel management applications). (DoD OSA Data Rights Team, 2011, p. 5)

This analysis resulted in 96 SBIR solicitation topics from the sample, or approximately 26% of SBIR solicitation topics, that were associated with NSS (i.e., the SBIR topic RFP solicits small businesses for R&D of a product that is directly classified as NSS or could be integrated with existing NSS platforms). That is, 26% of SBIR topics solicit small business participation in the R&D of information systems technologies that support NSSs, which is specifically where the DoD seeks to incorporate OSA principles. These SBIR topics are annotated in Appendix A using an asterisk next to the topic number. The analysis reveals that for the population of NSS-related SBIR topics, only 23% had incorporated elements of OSA characteristics into the SBIR topic RFP language during the time period used in this research. Furthermore, of the SBIR topics in this sample that were associated with NSSs, the DoD awarded $101.7 million in phase I and phase II contracts, but only 17% ($17.4 million) of that funding was awarded to the 23% of OSA-associated topics identified in Appendix B. The demonstrated under-representation of OSA in NSS-associated SBIR topic solicitations, as well as the disproportionately lower phase I and II award funding for OSA-related SBIR R&D projects, illustrates that the DoD SBIR program does not thoroughly incorporate and embrace OSA initiatives within the SBIR program, which can inhibit system interoperability and integration when attempting to insert SBIR technologies into larger DoD platforms.

To analyze the extent to which the DoD incorporates OSA characteristics into SBIR RFP language over time, I mapped NSS-related solicitation topics to the fiscal year that they

were released to determine the percent of topics that address OSA characteristics. This time series analysis of SBIR topic RFP language containing OSA characteristics revealed incremental improvement within the DoD SBIR program to incorporate OSA characteristics into SBIR RFPs, suggesting increased importance over time is being placed on clarifying SBIR solicitations to ensure OSA principles are included in the firm's R&D efforts (see Figure 6). Indeed, by FY2010, 32% of SBIR topic RFPs contained language that directed the use of OSA characteristics when appropriate, up from 11% in FY2006. This is likely the result of a gradual adoption of OSA principles in the DAS as well as the dissemination of guidance that encourages OSA characteristics be included in system design and engineering. Although the MOSA initiative had been thoroughly articulated prior to the first fiscal year used in this sample, documentation that provided specific instructions for developing RFPs that incorporate OSA characteristics had not been disseminated until the Navy released the *Naval Open Architecture Contract Guidebook* in 2007, which may contribute to the upward trend illustrated in Figure 6. However, despite DoD policy and guidance supporting OSA initiatives, this analysis suggests there is room for improvement—specifically, that the DoD components participating in the SBIR program should proactively incorporate OSA characteristics in SBIR topic RFPs to encourage R&D of NSSs that leverage an OSA design approach.

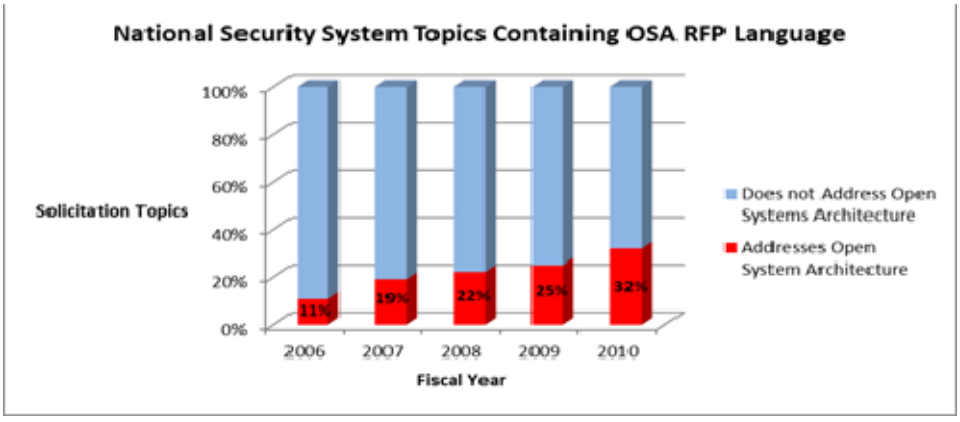

Figure 6. National Security System Topics Containing Open Systems Architecture Request for Proposal Language

SBIR solicitation topics that explicitly or implicitly directed the use of OSA principles in system design were predominately drafted by the U.S. Navy. Of the SBIR

topics drafted by the Navy that were related to NSS, nearly half (40%) contained OSA principles in the RFP. This result reflects the Navy's early adoption and pioneering of open architecture as a means to develop modular, interoperable systems that adhere to open standards with published interfaces. As the pioneer of open architecture, the U.S. Navy first drafted the *Naval Open Architecture Contract Guidebook* in 2007 as a guide for program managers and contracting officers to incorporate open architecture principles in contracts for NSSs, before a similar document was published by the DoD OSA Data Rights Team (2011). Nonetheless, this analysis suggests that the principles of open architecture—which run congruent to the DoD's OSA—have been more widely accepted within the Navy than within other components of the DoD, particularly within the administration of each component's SBIR program. Figure 7 breaks down the 22 identified SBIR topics by component to illustrate.

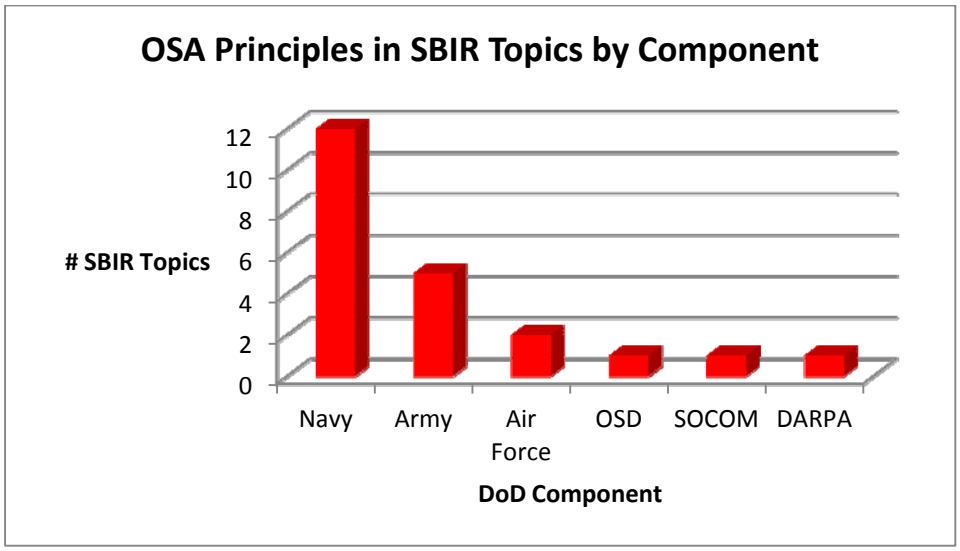

Figure 7. Open System Architecture Principles in SBIR Topics by Component

V. SMALL BUSINESS PARTICIPATION IN THE DOD SBIR PROGRAM

In addition to analyzing the extent to which the DoD leverages the SBIR program to incorporate small, innovative IT firms in DoD R&D and the extent to which those efforts advance OSA initiatives, this research seeks to understand the nature of the innovative high-tech small businesses who participate in the SBIR program to meet the IT-specific R&D challenges faced by the DoD. In this chapter, I first present data gathered from a series of interviews with SBIR program participants who were awarded either phase I or phase II SBIR contracts for R&D efforts related to IST, including those associated with OSA. The purpose for conducting the SBIR participant interviews was to answer the following research question: What are the experiences of small businesses in the IT sector which were awarded SBIR contracts? Next, I randomly selected 14 firms for a more thorough review of participating firm characteristics using a case study methodology in order to answer the following research question: What are the characteristics of small businesses in the IT sector which were awarded SBIR contracts? Companies that were selected for the case studies were chosen because they were awarded SBIR contracts specifically for IST projects associated with OSA, or they possessed the capability to advance OSA initiatives in meeting the IT R&D challenges of the DoD.

A. INTERVIEW ANALYSIS OF SMALL BUSINESS EXPERIENCE IN THE SBIR PROGRAM

To better understand the experiences of small IT companies participating in the SBIR program, I conducted phone interviews with SBIR participants from June 2012 to August 2012. The interview response rate was approximately 32%—nine interviews were conducted from a population of 28 companies that were solicited. All firms that were solicited had received phase I or phase II SBIR awards specifically related to IST research, and many were directly associated with OSA initiatives. The interviewees were mostly principal investigators (PIs) who were primarily responsible for drafting the SBIR proposal and conducting the research, but also included one co-founder of a company that is no longer in business, and one co-founder and current president of a successful software development

firm. To maintain confidentiality of the interviewees involved in this research, responses will remain anonymous; all data collected as a result of the interviews in the research is used to better understand and generalize the experiences of small IT companies participating in the SBIR program.

This research has predominately focused on the idea that the SBIR program is an attractive vehicle to incorporate small IT companies into defense acquisition programs and to advance OSA initiatives within the DoD. Therefore, the original intent of the interview questions was to assess participant perceptions of DoD OSA initiatives and whether the DoD SBIR program has effectively communicated those initiatives. However, these interviews also provided an opportunity to better understand who these small firms are that participate in the program and why; their perceptions of the proposal process; how well the DoD SBIR program communicates requirements through solicitations, specifically as they relate to information technology; whether the SBIR program quantifiably contributed to company growth; how successful the program has been meeting congressional objectives; how successful the participants have been in obtaining phase III funding and why; future plans to participate; and recommendations for improving the program or additional comments these SBIR participants felt compelled to add to this research, and communicate to the DoD.

1. SBIR Program Participation

To better understand what led an individual or a company to submit an SBIR proposal, the I asked following question: What led you (or your company) to participate in the SBIR program? Some of the interviewees were PIs that did not have a thorough understanding of how the company initially got involved in the program and simply continued submitting SBIR proposals for the company once hired; other interviewees—particularly the co-founders that were interviewed—were very aware and/or involved in the initial entry into the SBIR program. Findings from this portion of the interviews include the following: participants enter the program to augment funding as well as to align R&D efforts with identified customers; the SBIR program is an effective mechanism for the DoD to communicate R&D requirements directly to small firms to achieve maximum participation; most successful firms continuously participate in the program; the SBIR program has

provided external funding that successfully supported high-tech startup firms and their continued participation has been a result of a perception that private external funding *would not* adequately support the R&D efforts; the higher risk involved in the SBIR program inevitably results in awarded firms that are no longer in business and, therefore, not able to transition technologies or commercialize, but the risk taken by the federal government in administering this program provides a unique opportunity for even the smallest company to pursue an idea, develop innovative technology, and enter an otherwise inaccessible market in the hopes of achieving further growth.

Naturally, augmenting R&D funding through the SBIR program was a common reason provided for submitting SBIR proposals. Additionally, one of the primary reasons for participating in the SBIR program, cited by numerous interviewees, was that the SBIR program *aligns* the R&D efforts of small companies with potential customers. Those potential customers are either the DoD directly through potential phase III contracts for technology transition into another defense program, or the defense industry that subsequently subcontracts the smaller company to provide a specific technology that is required. Participating in the SBIR program ensures that R&D efforts of small companies have an identified user who specifically needs that capability; in a sense, the SBIR program is frequently used as a "guide" to steer R&D projects that have potential customers in mind. One interviewee stated that his firm "uses the SBIR program as a springboard for technologies to develop and commercialize them and get them into the hands of the customer." Another interviewee explained that his firm was involved in high-tech "niche technology" R&D that is aligned with some of the interests of the federal government; his firm seeks to develop new technologies that are marketable to both the private and public sector, and he periodically reviews SBIR solicitations for technology RFPs that align with the core competencies of the firm and identify potential customers. Another interviewee stated that "we have core competency areas that we focus on and we seek to apply those technologies in a certain way," and added that his firm looks for topics that align with technologies they have researched before (personal communication, 2012). The information provided in the interviews highlights how the SBIR program is an effective mechanism for

the DoD to communicate organizational R&D requirements to small companies in the private sector through the solicitation and award funding processes.

Most of those interviewed for this research have been involved in multiple SBIR proposals. Additionally, their firms have participated in the program for multiple years; one interviewee described it as "participation in the (SBIR) program has been a tradition within the company" (personal communication, 2012). Those who were aware or involved in the company's entrance into the SBIR program stated that the program was involved in the company's original business strategy by providing initial funding and specific R&D work with identified customers for the start-up company. One principal investigator explained that "our first project was funded by SBIR" and that the company's founder watched another company use the SBIR program, was involved in that project, and decided later to apply for an (unrelated) SBIR award, which he subsequently won, allowing him to start a company (personal communication, 2012). This anecdotal description of the company's history resulted in the significant growth of a R&D group now comprised of four companies that specialize in various sensing technologies.

Another interviewee, who was a co-founder and is currently the president of a very successful software development firm, described his experience entering the SBIR program: "We started in 1988, so we've been participating in the program for a long time. I think I found out about it from a client who was doing an SBIR" (personal communication, 2012). The interviewee stated that he was originally doing software consulting and that he found out about the program through word-of-mouth; the interviewee described his entrance into the SBIR program as "two people looking for work." Furthermore, the interviewee stated that his continued participation in the SBIR program is influenced from his observation that the SBIR program provides funding where the private sector would not: "I don't think that I've worked on an SBIR that the private sector would fund," explained this software development firm chief executive. This observation supports Wessner's (2000) conclusion—discussed in Chapter II of this research—that the DoD SBIR program effectively stimulates entrepreneurial behavior and R&D efforts by providing public venture capital funding where such funding would not be available from private venture capital investors due to the inherent high risks in the projects these firms undertake.

Although the interviews conducted for this research support the notion that the SBIR program is successfully used by small innovative startups as a source of funding and direction for supporting an identified customer base, not all small startup firms that win SBIR awards are successful. The co-founder of one such firm that received both phase I and phase II SBIR funding to advance innovative biometrics technologies to potentially reach customers was interviewed for this research. The interviewee applied for an SBIR phase I award as a source of funding to further research and develop biometric technology. When asked what led him to apply for SBIR funding, the interviewee stated that he saw the SBIR program as a source of external funding, and he felt the SBIR program "is clearly one that you have an opportunity of winning." He was attracted to the SBIR program because of the program's focus on the technical proposal and the merit of the research effort, rather than focusing on the proven capability of the firm (i.e., past experience, outside funding, revenue prospects), which is common for private venture capital funding. The interviewee stated that one benefit of the SBIR program is that it is "proposal focused," rather than firm focused (personal communication, 2012). This observation suggests that by focusing primarily on technical feasibility of proposals and less on past performance and profitability, as is the case in private external funding, the SBIR program provides a unique opportunity for even the smallest company to pursue an idea, develop innovative technology, and enter an otherwise inaccessible market in the hopes of achieving further growth. According to the interviewee, the business' failure was unrelated to the viability of the SBIR technology. Another unrelated example of an SBIR-awarded firm that is no longer in business is that of Traverse Technologies, which is discussed in more detail in the case study portion of this research.

2. Integrating SBIR Funds Into Existing R&D Efforts

To better understand the extent to which SBIR funding is used to support existing R&D efforts within a firm or, conversely, to begin research of a new technology, the following question was asked: Did your SBIR research support existing projects within your firm? The interviews revealed that participating firms submit SBIR proposals that support the firm's "core technologies," and that typically half of the time the SBIR funds are used to advance or modify an existing product or technology, while the other half of the time the

funds are used as a resource to create new projects, explore new product areas, and research and develop new technologies.

Of those interviewed, most responses suggest that firms—particularly more well-established firms that have a number of concurrent projects—use SBIR-funded research about 50% of the time to support existing technology R&D within the firm and tailor the technology for DoD application, while the other 50% of the time SBIR funds are used as a resource to research and develop new technologies and products. In answering this question, one interviewee stated that "it has been a mix actually; some projects are the logical continuation of a larger project" while others are "brand new technologies in an area that we theoretically understand well, but have no existing framework to build on; so, we build it from the ground up in the SBIR program" (personal communication, 2012). Another answer to the question was "yes and no," and the interviewee pointed out that all SBIR-funded R&D is new, but the underlying goal is to integrate the result into a larger product/platform. SBIR research is "always new research, but is tangential to something that we've already done so that it can be integrated into existing products" (personal communication, 2012). Another interviewee explained that his innovative IT firm uses the SBIR program as one mechanism among many for funding R&D projects. His firm receives a lot of funding through outside sources, is not necessarily dependent on the program, and typically uses SBIR funding to tie into the long-range goals of the firm: "There's always something we're working towards, which is facilitated by SBIR funding," he commented (personal communication, 2012). The co-founder and president of one software development firm explained that approximately 50% of SBIR grants supplement existing projects within the firm and added that sometimes his firm will do an SBIR-funded project that opens whole new areas of research for the firm, which provides a means to expand the firm's organic R&D projects and expertise.

To effectively participate in the DoD SBIR program, successful firms submit proposals based on their "core technologies," while balancing the requirements outlined by the DoD and the long-term goals of the organization. One interviewee described this solicitation and proposal process as a "compromise" between the R&D efforts of the DoD and the specific defense-related technologies it pursues, and the existing R&D technologies of the small businesses that often seek to commercialize a technology to the private sector.

When submitting an SBIR proposal, the interviewee described the process where they look at all the available solicitations in an effort to find the topics that are aligned to the research objectives of the firm. Oftentimes, the SBIR topic "requires something that is slightly different or tangential than what we're interested in." In response, the interviewee described how he (the firm) would propose something that adequately accounts for the SBIR topic solicitation but stays within the scope of the firm's existing research (personal communication, 2012). This process allows SBIR funding to assist and further advance the existing R&D projects of the small firms that participate.

3. Industry Perceptions of the SBIR Proposal Process

To better understand industry perceptions of the SBIR proposal process, the amount of effort and resources required by small companies to submit a proposal, and how well proposal requirements are explained in the DoD's SBIR request-for-proposal solicitation, the following questions were asked: Did you find the SBIR proposal process overly cumbersome? Did you experience any problems during the proposal process? Interviewees generally agreed that the DoD SBIR proposal process was not overly cumbersome, that the amount of time and resources spent preparing an SBIR proposal was commensurate with federal contracting in general, that the SBIR program is perceived as highly competitive, and that problems do occur when different DoD components release different rules in the SBIR solicitation instructions.

All participants who were interviewed for this research generally agreed that the DoD SBIR proposal process was not overly cumbersome, and they did not experience any significant problems submitting their SBIR proposal. Furthermore, most agreed that in their experiences contracting with the federal government, SBIR proposal expectations were fair in that they adequately addressed submission requirements, were not overly complex, and generally correlated to expectations of federal contracting requirements. One principal investigator commented, "I wouldn't call it any more cumbersome than any other government contracting process" (personal communication, 2012). Another principal investigator who had submitted a number of SBIR proposals commented that the proposal process was not overly cumbersome and stated that "no proposal is easy; the (SBIR proposal)

took a fair amount of resources to put together, but it felt about right." Another principal investigator stated the proposal process was "not overly cumbersome to us, but I can see how it might be daunting to someone just starting out in the (SBIR) program." One principal investigator described the proposal process as a "team effort" among subject-matter experts (SMEs) within the firm. The interviewee was responsible for writing the bulk of SBIR proposals for his firm, but to be successful he explained how he frequently required additional SMEs to help review the proposal for accuracy, and to ensure it says what he wants it to say. Often, he knows what the proposals should say to be the most competitive, but often relies on other members of the "group" to contribute and review the proposal. Often, several people will work on SBIR proposals including frequently relying on "outside" support such as university labs (personal communication, 2012). Although he described the process as time consuming and requiring a fair amount of resources to put together, the interviewee felt that the process was adequate to maintain competition in the SBIR program, and was commensurate with expectations of federal contracting in general.

Another subject that several of the interviewees discussed was their perceptions of the competitiveness of the SBIR program. Interviewees who addressed program competitiveness in their responses all agreed that the SBIR program is *very* competitive, which allows the DoD to award SBIR contracts to fund a select number of projects at the best value. One principal investigator explained how SBIR contracting "can be an extremely competitive program." He explained that SBIR competitors are on the "top of their game" and submit very competitive proposals during topic solicitation. Additionally, the PI commented on his observations that DoD SBIR reviewers are "exceptionally intelligent people" who know exactly what they want. The interviewee provided an example of this competitiveness in the SBIR program by describing a phase I award he had won from the Navy. The proposal "wasn't unambitious," promising phase I basic research as well as software simulation. He successfully demonstrated both the research and the simulation; however, a competing firm brought both a working software simulation model *and* a hardware prototype, which exceeded what was required by the solicitation as well as what his firm was able to provide the DoD under the contract. His observation was to highlight how competitive the SBIR

program really is: “when you have companies going all out like that, that is true competition” (personal communication, 2012).

Finally, while interviewees agreed that the SBIR proposal process was not overly cumbersome, many expressed frustration that the solicitation guidance and requirements varies among organizations and even among components within the DoD. One PI expressed his frustration with the lack of standardization of SBIR proposal requirements among components within the DoD: “trying to comply with all these different rules is cumbersome” (personal communication, 2012). Another PI of a larger participating firm explained that one thing that can make the SBIR proposal process cumbersome is that there are often two sets of requirements: (1) an SBIR requirement document that is published that applies to all components, and (2) unique requirements imposed by the specific DoD component. Each component can impose requirements in addition to the “blanket DOD proposal requirements, so you have to be aware that there are two sets of documents and sometimes new firms can miss this.” An example the interviewee used is that although the blanket DoD proposal guidelines limit proposals to 25 pages, the Army further restricts the proposals to 20 pages (personal communication, 2012). Finally, another principal investigator expressed concern when contracting personnel required additional paperwork from the company on top of the SOW. He mentioned how the DoD contracting office has the ability to add additional requirements, but now gives additional funds. As an example, one U.S. Army contract added 20 additional deliverables that required considerable time and resources to research and write. He felt that was counterproductive because it detracted from technology development, but mentioned that in his experience it is a trend that is getting worse (personal communication, 2012).

4. Defining IT Requirements in SBIR Solicitation Requests for Proposal

To better understand how well the DoD communicates the information technology requirements of specific R&D projects on the SBIR RFP, I asked the question: Did the SBIR solicitation adequately define the IT requirements of the project? Interviewees generally agreed that IT requirements were adequately defined in the SBIR RFP, that IT requirements in SBIR solicitation RFPs vary from vague capability requirements that leave things open to

interpretation to specifically defined system requirements, and that the SBIR program is improving in adequately defining IT requirements in SBIR RFPs.

Most interviewees generally agreed that IT requirements were adequately defined in the SBIR solicitation RFP; of the nine interviewed, only one commented that in his experience IT requirements were not adequately defined and two stated that only sometimes were IT requirements adequately defined. One interviewee stated that because he was employed by a high-tech IT firm, the IT requirements outlined in SBIR solicitation RFPs were "relatively modest" and he was not concerned about how IT requirements were defined (personal communication, 2012).

All interviewees commented on the observation that IT requirements in SBIR solicitation RFPs vary from vague capability requirements that leave things open to interpretation to specifically defined system requirements, but mostly agreed that both approaches were acceptable depending on the needs of the DoD. One PI pointed out that, although he understood that some RFPs contain vague capability requirements to solicit for a broad R&D effort, he felt that when there is a known customer and specific technology that needs to be developed, "it would be nice to get more information on the request for proposal" (personal communication, 2012). Another PI expressed some frustration with those SBIR solicitation RFPs that were poorly constructed and lacked adequately defined IT requirements; he added that the most well-defined SBIR solicitation RFPs are for specific hardware or software and that in his experience what makes a stellar solicitation is clear statements outlining expected performance requirements.

Finally, the co-founder and president of one software development firm who has participated in the SBIR program since 1988 explained how he has observed the DoD continue to make progress in communicating and adequately defining IT requirements in solicitation RFPs, namely as a result of a changing environment as it pertains to IT systems. He commented that in his experience he felt that "about two-thirds of the time they do a good job" at specifically defining the IT requirements in the SBIR RFP. He believes that "trends are getting better" with respect to adequately defining IT requirements in the SBIR RFPs, and that the improved trend is a result of the changing environment: the "world is changing in a favorable way." He elaborated by stating that inadequately defined IT requirements had

been a significant issue in the SBIR program in the past as a result of legacy systems that frequently had problems integrating with other systems due to poorly developed system interfaces. "Often, legacy systems did a crappy job of developing (system) interfaces, which resulted in an integration disaster." In his opinion, the problems caused by legacy systems are decreasing, which results in a better understanding of the IT requirements for SBIR solicitation RFPs.

5. Company Growth in the SBIR Program

Existing literature on the SBIR program has tended to focus on evaluating how well the program meets congressional goals outlined in the SBA Act of 1982 as a measure of performance rather than focusing on evaluating the growth of companies that participate in the program, particularly those firms that compete for contracts in the IST critical technology area. In an effort to better understand how the SBIR program contributes to company growth as perceived by participating small businesses, beyond what could be inferred from the case study portion of the research, I asked the question: Did your SBIR phase I or II research contribute to company growth; and if so, how? Interviewees overwhelmingly agreed that the SBIR program had directly contributed to company growth. Examples of company growth that were directly resultant from SBIR funding include the creation of new jobs to work on SBIR-funded R&D, particularly during phase II; stimulating other R&D projects within the company that are not funded by SBIR; and expanding firm revenue through technology transition into both a DoD program and commercial market. In addition, these interviews and the subsequent case studies support an observation that firms that successfully transition SBIR technologies spin off new companies to further develop, manufacture, and sell those technologies on the commercial market.

All interviewees agreed that the SBIR program had contributed to company growth. When asked to provide a quantifiable measure of growth, many of those interviewed stated that SBIR projects, particularly phase II projects, directly resulted in additional employment. One PI whose firm had recently been awarded 3–4 SBIR phase II contracts stated that they had already hired additional employees for the SBIR project and "were looking to hire quite a few more people" (personal communication, 2012). Other examples of increased

employment include hiring additional project management personnel to manage multiple SBIR and non-SBIR R&D efforts of the company. The co-founder and president of one software development firm, who specifically relied on the SBIR program to augment start-up funding in 1988, felt strongly that the SBIR program has and continues to directly contribute to company growth. He stated that company growth stimulated by the program has been twofold: Half of the growth resulting from SBIR-funded research is attributed to requirements for hiring additional employees to work on SBIR-related projects. The other half of the company growth resulting from the SBIR program is the result of "other work" associated with SBIR-funded R&D projects. Often, SBIR funds and projects stimulate other projects or research within the firm that requires resources to develop and transition the technology, and that result in further growth of the company. The executive stated that company growth from the SBIR program is "about half and half" attributed to these two factors (personal communication, 2012).

The SBIR program also contributes to company growth by expanding firm revenue through technology transition. Most of those interviewed for this research, particularly those employed by larger companies, had been personally involved or were aware of SBIR-funded R&D projects within their firm that had successfully transitioned into a DoD program or were successfully commercialized and sold or licensed in the commercial marketplace. This success has contributed to company growth, provided the resources to expand, hire additional employees, and provided new products and services to customers. One PI, whose firm was founded through funding through the SBIR program, noted that his experience has been that firms eventually move out of the SBIR program and get into bigger programs and government contracts. He explained that efforts funded through the program form the foundation for new technologies and show the government and/or private investors that the firm possesses the technology, skill, and resources to develop a technology and "get a competitive edge; otherwise, it is hard without the SBIR program" (personal communication, 2012).

Finally, during these interviews, several PIs noted how the SBIR funding contributed to company growth by proving funding to develop and commercialize technologies and, subsequently, spin-off firms to further develop, market, and sell those technologies on the

commercial marketplace. One PI discussed a 2010 spin-off company that was created specifically to help further commercialize and manufacture an SBIR technology. The PI mentioned that his company is very active in the SBIR program. Even though it is still a very small company that employs approximately 120 employees, his firm has been very successful at spinning off firms to commercialize technologies developed under the SBIR program. He stated that spin-off companies currently employ over 2,000 people and have gross revenue exceeding $700 million, which serves as anecdotal evidence supporting the economic successes of the SBIR program. According to the company's website, the particular firm he worked for was founded in 1961and was one of the first firms to compete in the SBIR program. It has subsequently spun off seven firms, specifically for commercializing SBIR technologies. Forming spin-off companies to commercialize SBIR technologies while retaining core R&D capabilities with the parent company is not isolated to this one example. Another PI discussed how his firm (which was founded using SBIR funding and is now a group of four separate companies) uses a similar practice to commercialize SBIR technology. Finally, the case studies conducted for this research include Physical Optics Corporation (POC), a frequent award winner that appears to be somewhat dependent on the SBIR program as a source of R&D funding but has successfully spun off six different companies primarily for the purpose of commercializing SBIR technologies. This phenomenon, if not thoroughly understood by researchers attempting to quantify the performance of firms in the SBIR program, could result in underestimating the performance of participating firms or even the success of the SBIR program in general. Additionally, it highlights the difficulty in any academic research that might attempt to estimate the return on investment of federal funding used in the SBIR program to encourage technological innovation and stimulate small businesses within the economy.

6. Congressional Objectives to "Stimulate Technical Innovation"

One of the stated congressional objectives of the SBIR program is "to stimulate technical innovation" (SBID Act, 1982). The interviews conducted in this research provided an opportunity to contribute to existing literature and asses participant perceptions of whether and how the SBIR program stimulates technical innovation. During the interviews, the following question was asked: Did your SBIR-funded research stimulate technical innovation

by helping to obtain intellectual property or helping to advance company projects, or by any other measure that you feel is relevant? Responses indicate that SBIR program has helped to stimulate technical innovation by obtaining intellectual property, including patents and SBIR data rights; to develop technical expertise within the organization; and to support higher-risk basic research that will result in more technical innovation because the R&D efforts are specifically focused on developing an entirely new technology.

All interviewees felt that the SBIR program stimulates technical innovation within the IT industry. Most stated that research that the SBIR program funded resulted in obtaining patents for innovative new products that were later commercialized. One PI described patents for software initially developed within the SBIR program that is deployed on Coast Guard cutters and software tools that are used throughout the Department of Justice, while another described innovative modeling software used in the commercial sector. SBIR data rights were also described by some interviewees as intellectual property that resulted from the SBIR program. One PI stated, "Definitely, the term 'technology innovation' is vague, but the SBIR program has definitely done that," at his small firm. As an example, the firm has acquired data rights for various technologies they've developed under the SBIR program. Although firms cannot retain full data rights under the SBIR program, they can retain *SBIR data rights*, which this interviewee considered to be very beneficial and exceptionally strong; he considered SBIR data rights to be almost as good as intellectual property. Another topic discussed was how participation in the SBIR program has helped develop technical expertise that advances the technical portfolio and capability of a small company. One interviewee of a very small firm mentioned this as an example of *potential* intellectual property that provides the resources to transform an idea into a tangible product.

Other interviewees felt that higher risk basic research in the SBIR program will result in more technical innovation because the R&D efforts are specifically focused on developing an entirely new technology. One PI of a successful SBIR firm commented that the SBIR program stimulates technical innovation and that the basis of technical innovation in the SBIR program results from the program being "high risk, so nothing is guaranteed" (personal communication, 2012). He elaborated that, in his experience, SBIR funding is concentrated on developing high-risk technologies, which often lead to innovative new technologies that

were not previously available: “definitely the result is high innovation when you get [an SBIR award]” (personal communication, 2012). The interviewee has noticed a trend, which is that some agencies are not willing to take high risks, while others actively seek “risky” technology development through the SBIR program. As an example, he noted that the Defense Advanced Research Projects Agency (DARPA) is particularly interested in high-risk innovative technologies through the SBIR program, while the Army tends to focus on developing a specific product, which has less risk involved. “How much risk the PM can tolerate dictates how much innovation [is stimulated through the SBIR program]; risk is set by the tone of the program manager; innovation is all related to that” (personal communication, 2012). Less risky SBIR projects are closely tied to a specific product, while projects with more risk often result in an innovative prototype that might be incorporated into a product.

7. Phase III Transition of SBIR Information Technologies

In an effort to determine how successful IT firms participating in the SBIR program were at commercializing SBIR technologies, and what lessons, if any, exist for successful phase III commercialization efforts, I asked the following questions: Have you had success in obtaining phase III funding? If not, why do you think the project did not receive phase III funding? If so, what characteristics do you think are most likely to lead to phase III funding? Of the nine participants interviewed, seven (approximately 78%) reported that they had personally received phase III funding, and most indicated that they have experienced considerable success obtaining phase III funding in multiple projects. Interview responses indicated that the source of phase III funding was evenly split between transitioning technologies into DoD acquisition programs and commercializing the product for sale or lease in the commercial marketplace or obtaining private equity for continued R&D (e.g., one PI recently received a $2.5 million grant from a research institute). Interviewees provided many “best practices” to achieve phase III transition of SBIR technologies, which are described in depth in the next section.

Best practice characteristics of successful SBIR phase III funding included identifying a customer upfront; identifying transition opportunities and developing a plan for

phase III technology transition early in the project; expanding the search for potential phase III opportunities outside the DoD component that originally released the SBIR solicitation; focusing on developing the technology to meet specific customer requirements to achieve technology readiness level (TRL) 6 or 7 by the end of phase II; obtaining defense acquisition workforce point of contact information early for potential DoD program transition; and identifying potential private investors for non-DoD SBIR transition and working with them throughout the project. On the other hand, this research found that failed phase III funding efforts may result from cost-plus contracts awarded to prime contractors for program technology development that act as a disincentive for the transition of SBIR technologies into DoD programs, and that broad and vaguely defined system requirements on the SBIR solicitation RFP are less likely to result in follow-on phase III funding because the R&D project lacks a specific product and/or customer.

To further elaborate on the best practices discussed during the interviews, one PI stated that his company has been successful by focusing on developing and "pushing" a *product* with a customer in mind. He stated that successful follow-on funding is a result of focusing on customer needs and requirements rather than focusing on "a bunch of research to prove it works." The interviewee suggested that SBIR projects can be scoped down so that the team can focus on obtaining technology readiness level (TRL) 6 or 7 by the end of phase II. He elaborated that the technology needs to be targeted to the requirements of a specific customer who can take the technology out to the field; that concept "gets more people interested" (personal communication, 2012). Another PI suggested that success depends on two best practices: (1) developing a plan for phase III technology transition early in the project by finding transition programs and opportunities as early as possible and lining them up, and (2) not looking only within the agency that released the SBIR solicitation for transition opportunities (personal communication, 2012).

One PI who stated that he had been more successful commercializing products into the commercial sector than transitioning technologies into DoD programs commented that successfully obtaining phase III funding is the result of identifying potential customers early in the project, and of working with the customer throughout the project so by phase II, "you have something very close to what they want," and they are interested in the technology

upfront (personal communication, 2012). He used an example where a potential customer was interested in an SBIR-funded technology to use in a manufacturing production line. During the phase II effort, the firm was able to sell the technology to the commercial customer. "The most important thing was that there was a need for this product to help in production." He added, "The key component is interaction with customers." His experience has been that the non-DoD commercial market is more "open" and more willing to test and use the technology, while the DoD has more politics and bureaucracy and, as a result, his experience has been that it is more difficult to get his technology into DoD procurement (personal communication, 2012).

One software development executive commented that his firm has had considerable success obtaining phase III funding. He described phase III funding as having "two different phase III funding" sources: going after "unrelated commercial customers" and transitioning the technology into related DoD programs. The avenue for phase III funding "depends on the project. Some [SBIR projects] are more interesting to commercial markets," while others are very much aligned with specific DoD requirements. In terms of transitioning technology to DoD programs, the executive said the most important characteristic that leads to phase III funding is having appropriate contact information for personnel in the DoD acquisition community. Contacting the appropriate acquisition workforce personnel to establish a dialogue regarding program requirements is essential to facilitate technology transition of an SBIR-funded project. The interviewee stated that sometimes he was able to look up the contact information himself, while other times the SBIR program manager has the appropriate acquisition community contact information. When DoD RDT&E efforts are correlated with the defense acquisition in support of specific programs, there is an improved possibility that the SBIR firm will be able to transition the technology into a DoD program. The interviewee stated that, in his experience, 80% of the time the SBIR program managers do not have adequate acquisition community contact information or a specific program identified for technology transition. As a result, he has to "dig [himself]" for the contact information, and, if successful, is frequently able to transition the technology into a DoD program.

One PI who has had extensive experience in the SBIR program provided particularly illuminating information regarding phase III transition challenges. His experiences were in line with the aforementioned discussion, namely that failing to identify a point of contact and establish a relationship early, as well as failing to develop a transition plan, will result in a failed phase III effort. However, he also suggested that cost-plus contracts awarded to prime contractors to develop program-specific technologies during the technology development phase (following milestone A in the Defense Acquisition Management System) act as a disincentive for the transition of SBIR technologies into DoD programs. Asked about his successes and failures with phase III transition, he explained that after the government has funded phase II SBIR research, they have no more funding for the technology and are not allowed to use SBIR resources to continue to fund further development. Subsequently, "the government tells small firms that you need to transition to a big company that will pay to transition this technology into a larger system. My experience is that the prime contractors are not interested in doing this." The most evident reason is that the government is also funding the large prime contractors to develop similar technologies in-house. The interviewee provided an example that he was familiar with: "One example is video processing." The PI's firm has developed sophisticated software for this technology and they license it out on the open market, but the large prime contracting firms have a contract to develop the *same technology* with a *cost-plus contract*; for the prime contractor, it is more profitable to develop the technology in-house than it is to pay a license fee to a small firm that has already developed the technology. "That is one big problem; the big companies don't have a motivation to transition phase III technology from a smaller firm because it doesn't help the bottom line" (personal communication, 2012).

Finally, one PI who was unsuccessful at obtaining phase III funding, particularly in transitioning technologies into DoD programs, stated that the funding gap between phase II and phase III prevents smaller firms from advancing a technology to maturity. He commented that on several occasions he had lined up federal contracts for a technology that was developed under SBIR; however, the "government backed out for whatever reason." Furthermore, he stated that the funding gap between phase II and phase III was "a big problem" for small companies who are forced to shelf projects due to lack of funding.

8. Open Systems Architecture Initiatives in the DoD SBIR Program

This research has predominately focused on the idea that the SBIR program is an attractive vehicle to incorporate small IT companies into defense acquisition programs and to advance OSA initiatives within the DoD. However, to do so effectively, the DoD SBIR program must communicate that intent through contracting language in the SBIR solicitation RFPs, as discussed in Chapter IV, as well as by establishing dialogue with small businesses, particularly those in the IT industry, to communicate the purpose and intent of OSA initiatives in the DoD. To better understand how familiar small businesses are with OSA initiatives in the DoD, the following questions were asked: Are you familiar with OSA initiatives in the DoD? If so, do you feel that the DoD has made it apparent that they desire "open" systems for IST SBIR projects? The research found that OSA concepts have, in fact, been communicated effectively to small businesses participating in the SBIR program; of the nine individuals interviewed for this research, seven (approximately 78%) were familiar OSA initiatives in the DoD. Those who indicated that they were not aware of OSA initiatives in the DoD seemed to be familiar with industry initiatives that correlate to OSA initiatives in the DoD. One PI who didn't recall seeing OSA principles mentioned in SBIR solicitation RFPs commented that an open architecture approach "seems like such a natural logical thing that it makes perfect sense to me" (personal communication, 2012).

Many of the participants who were interviewed for this research agreed that the DoD SBIR program has effectively communicated their intent to develop systems that incorporate OSA principles in system design. In answering the question, one PI stated, "Yes, they've been beating that horse for a long time now; we all know that they're interested in open source and we all know why" (personal communication, 2012). The president of one software development company interviewed for this research was thoroughly aware of OSA initiatives in the DoD and agreed that the SBIR program was effectively incorporating OSA into IST R&D projects; he mentioned that sometimes the SBIR solicitation RFPs do not mention OSA requirements in the request for proposal, but "when you contact the SBIR PM they make it known" that an OSA approach is desired for the project. Furthermore, he stated that in his experience, SBIR solicitation RFPs mention OSA approaches about one third of

the time (personal communication, 2012), which corresponds to the findings of this research discussed previously in Chapter IV.

Although most individuals agreed that they were aware of OSA initiatives in the DoD, some felt that the DoD SBIR program could improve at communicating its intent to incorporate OSA characteristics into solicitation RFPs and contracts. Asked to elaborate, one PI commented that SBIR solicitation RFPs are "not always clear" and requirements, including OSA characteristics, are often vague. This often results in ambiguity and a lack of understanding of what system the SBIR technology is intended to be integrated with.

9. Future Participation in the SBIR Program

In order to gauge overall participant satisfaction with their experiences in the SBIR program, all interviewees were asked the question, Do you expect to submit another SBIR proposal in the future? Eight interviewees (approximately 89%) felt strongly that they expected to submit another SBIR proposal in the future. Most stated that without a doubt they would participate, while others would continue to review SBIR solicitations for projects that align to that firm's particular area of research. One PI who expected to submit another SBIR proposal in the future mentioned that the R&D group in his firm is scaling back on SBIR projects. This PI is primarily a researcher in a highly successful IT firm who enjoys participating in the SBIR program, but engineers on the development side of this company tend to dislike the SBIR program because it is focused on developing a new technology and delivering a specific product within a predetermined schedule. Additionally, the stiff competition in the SBIR program dissuades engineers in this particular innovative small company.

One co-founder of a small startup suggested that he would not submit another SBIR proposal in the near future. His firm had focused on commercializing very specific biometrics technology that he had developed and was awarded both phase I and phase II. He has made research discoveries in his line of research but felt that the SBIR program is not an appropriate funding source for continued R&D funding. He stated, "I don't think the SBIR is appropriate because I don't see [my technology] as something that the SBIR [program] will ask for because no one knows" about the advancements he has made in his field.

10. Additional Findings

Following the interviews, many participants offered additional insight and recommendations for improvement, and shared some concerns regarding the SBIR program. The most common were concerns regarding implications of the SBIR/STTR Reauthorization Act of 2011 and subsequent SBA policy directives that will negatively affect small businesses participating in the SBIR program. Implications of the SBIR/STTR Reauthorization Act of 2011 and subsequent SBA policy directives include allowing foreign-owned entities—including non-domestic businesses and foreign government agencies—access to compete in the SBIR program, as well as new policies that allow small businesses competing in the SBIR program to be majority owned by non-small business entities, which includes large corporations, multiple venture capital operating companies (VCOCs), hedge funds, and private equity firms (Shindell, 2012). Several PIs expressed concern that the Reauthorization Act and SBA policies will deter small businesses from participating in the SBIR program while creating legislative loopholes that allow federal small business set-asides and intellectual property developed under the program to go to large corporations and/or foreign investors. One PI stated that these new rules "run contrary to the purpose of the SBIR program" and suggested that they might inhibit technology development by small businesses. He added that SBIR technologies, which are essentially funded by the U.S. government, should remain "in-house," and that allowing foreign entities to compete in the program is not necessarily a good thing (personal communication, 2012). Another PI who expressed concern with the eligibility criteria for entry into the SBIR program was concerned that the changes would allow much larger companies to own subsidiaries to enter the SBIR program. He stated that he "doesn't want to compete with General Electric or a GE subsidiary in the SBIR program; that's not what the program was designed for" (personal communication, 2012).

B. CASE STUDY ANALYSIS OF SMALL BUSINESS CHARACTERISTICS IN THE SBIR PROGRAM

A major limitation to existing studies of the DoD SBIR program is that little data have been collected about the companies that win SBIR awards (Held et al., 2006, p. 109). To expand existing literature and better understand the characteristics of small IT firms

participating in the SBIR program, 14 firms that received SBIR funds for IST-related R&D contracts were randomly selected as the basis for a case study analysis. The population used to select companies was based on the FY2006–FY2010 sample population used in this research and included a diversity of firms from well-established frequent award winners to "micro" firms who have minimal participation within the SBIR program. Although resource limitations prevented gathering a sufficient number of case studies to generate statistically valid results, these case studies were developed to gather general characteristics of the program and participating firms to generate data not available through interviews in order to provide the DoD acquisition community with relevant information about the general characteristics of small IT firms actively participating in the DoD SBIR program. Information used for this review was obtained from Internet searches, company websites, DD350 individual contracting action report forms, the SBA's TECH-Net database, the DoD Office of Small Business Programs' SBIR database, and the USPTO database.

In addition to describing and generalizing participant characteristics, the case studies analyzed available financial information in order to compare the percent of revenue received through SBIR awards (in terms of funds obligated through the program) to total firm revenue for the time period FY2006–FY2010 in an attempt to draw comparisons between selected firms. Although some firms did make historical financial data available on their website, annual revenue figures were obtained from DD350 individual contracting action report forms obtained from the publicly available Federal Procurement Data System Next Generation (FPDS–NG) database. The DD350 form is a useful source of information on firms participating in the SBIR program and includes information on the contracting office and contractor; the type of business (e.g., woman owned, minority owned, HUB zone qualification, etc.); the purpose, dates, and type of contracts; the number of employees; and, particularly relevant to this research, the annual revenue of the firm, whether the contract belongs in the SBIR program, and, if so, what specific phase of the SBIR program (FPDS–NG, n.d.).

The annual revenue figures used in this research were obtained from the FPDS–NG database and reflect a three-year average of a firm's revenue, rather than a "snapshot" of the most recent revenue figure for the year in which the contract was made. This caused minor

discrepancies in comparing the percent revenue received as a result of SBIR contracts in years when the firm's revenue fluctuated significantly. However, for the purpose of this research in generalizing firm characteristics, and due to the lack of publicly disclosed financial information of privately owned firms, the revenue data provided from the FPDS–NG database was used to estimate participant annual revenue. All SBIR contracts received by the firm between 2006 and 2010 (as listed on the FPDS–NG) were summed and divided by the corresponding revenue during that time period to establish the percent of annual revenue received (in terms of funds obligated) through the SBIR program. In a few cases (e.g., Analatom in 2006–2007), the SBIR annual award amount obligated exceeded the three-year average of the firm's revenue, indicating that significant growth of the firm (or substantial SBIR contracts) caused the three-year average revenue reported in the FPDS–NG database to underrepresent the actual annual revenue of the firm during the period. The case studies provided in this research present a graphic representation of the percent of annual revenue attributed to SBIR awards compared to total revenue per year from 2006–2010, as well as aggregate totals for the entire time period. Each figure contains "SBIR awards," which represents the total amount of SBIR-related contract obligations recorded for that time period, and "other revenue," which represents the firm's activity in the commercial marketplace in both the private and public (i.e., prime or subcontracting) sector, but exclusively represents non-SBIR-related revenue and was calculated by subtracting total annual SBIR award funding from annual revenue as reported on the DD350 form maintained in the FPDS–NG database.

1. Physical Optics Corporation

The Physical Optics Corporation (POC) is based in Torrance, CA, and is classified as a woman-owned firm specializing in the development of advanced technologies in applied technology, information technology, photonic systems, electro-optics, and holography. It has received SBIR awards supporting OSA initiatives. The company is oriented toward R&D service for the DoD but maintains a variety of products for commercial sale. The company was founded in 1985 and began as "a small business innovative research and development company" (POC, 2010) that was primarily focused on holographic technology and laser optics and has since earned 92 U.S. patents. The firm's primary North American Industry

Classification System (NAICS) code is R&D in physical, engineering, and life sciences. As of May 2012, the POC reported 155 employees and a three-year average annual revenue of $28 million on DD350 forms recorded in the FPDS–NG database (however, that number may underrepresent actual revenue based on corporate news releases that suggest consolidated revenue of $45 million in 2010).

During the 2006–2010 time period used for this research, the POC has continued as a frequent award winner in the SBIR program, earning 271 phase I and phase II awards for approximately $83.5 million—the largest recipient of SBIR funds of the firms in this study. Figure 8 compares total annual revenue, while Figure 9 depicts the SBIR percent of total revenue for the POC over the 2006–2010 time period. According to the firm's website, the POC has commercialized over 100 products since its inception and spun off six different companies, demonstrating a history of growth. Five of the six spin-off firms continue to receive some R&D funding through the SBIR program; however, each firm appears to have been spun off primarily for the purpose of commercializing SBIR technologies and each is oriented toward commercial market sales. Additionally, 150 former POC employees are employed among the six POC spin-off firms. The POC continues as a successful competitor in the SBIR program. Held et al. (2006) identified the POC as a "continuing DOD-SBIR frequent award winner" (p. 128) for the period of 1994–2003 and listed it as having the second most contract actions among the 58 firms listed. The POC has proven remarkably successful in the SBIR program and appears to receive a majority of federal contracts through the program: A query of the FPDS–NG database for federal POC contracts during this time revealed that most were SBIR related, which suggests the firm is primarily oriented toward government R&D.

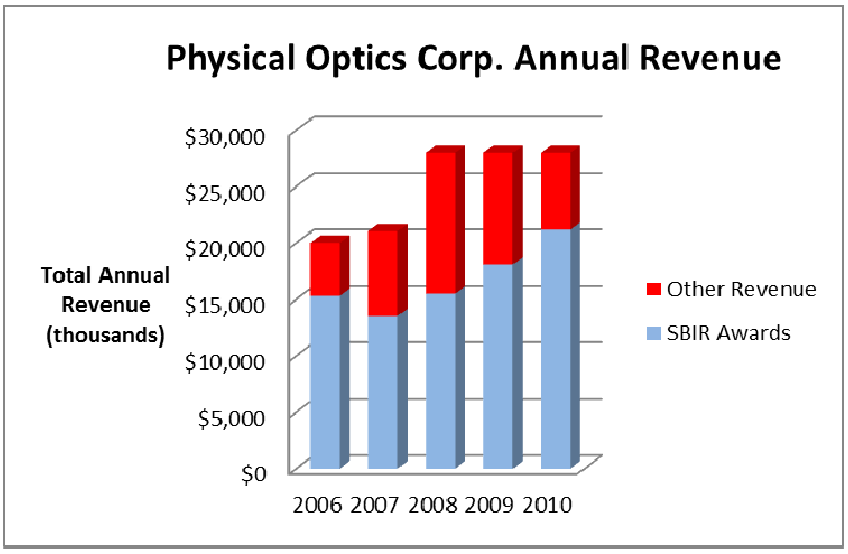

Figure 8. Physical Optics Corporation Annual Revenue

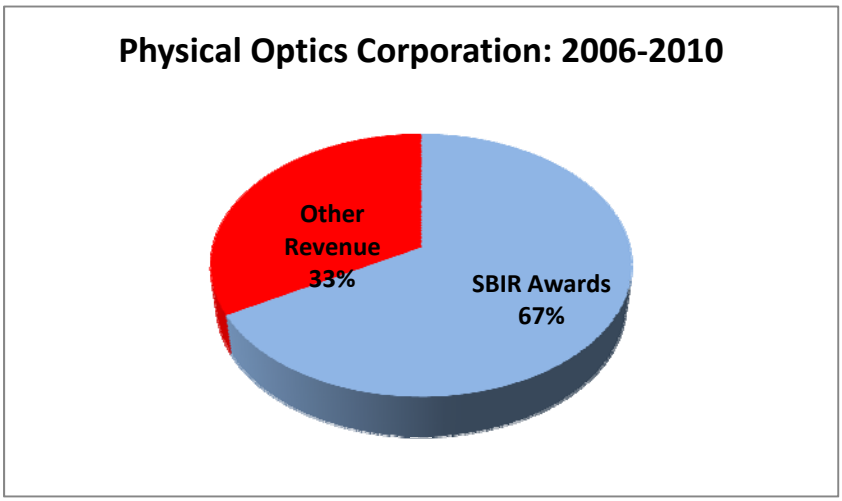

Figure 9. Physical Optics Corporation, SBIR Percent of Total Revenue

2. Orielle LLC

Orielle LLC was founded in 1999 and is headquartered in Pullman, WA, adjacent to Washington State University. It has received an award supporting OSA initiatives. Orielle is a very small firm that is a partnership between two people who conduct R&D specifically in the area of computer science. It appears that the company was at least somewhat dependent on SBIR phase I funding to support initial start-up costs. For the 2006–2010 period used for this study, Orielle was awarded just two phase I SBIR contracts in 2008 for web services and software configuration management, including the Air Force topic AF073-025 discussed in

this research as associated with OSA. Figure 10 compares total annual revenue, while Figure 11 depicts the SBIR percent of total revenue for Orielle over the 2006–2010 time period. Orielle appears somewhat dependent on the SBIR program as a source of revenue and little information is available regarding other revenue sources; because other revenue is based on a self-reported three-year revenue average, 2004 and 2005 SBIR awards most likely contributed to this figure. The last contract recorded in the FPDS–NG database for Orielle was the 2008 contract identified in this research, and there is no indication that Orielle has commercialized any products or is even still in business. Orielle has received two phase II awards (2002 and 2005); however, no evidence was found for the commercialization of any of its R&D efforts.

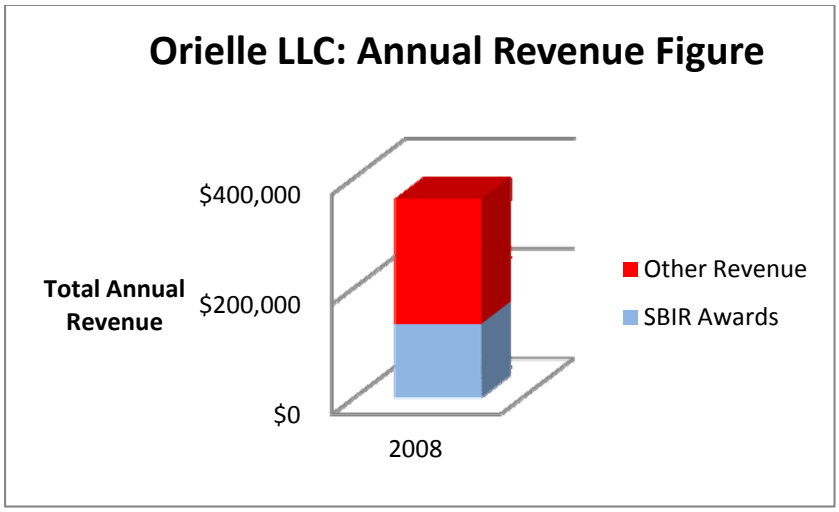

Figure 10. Orielle LLC Annual Revenue

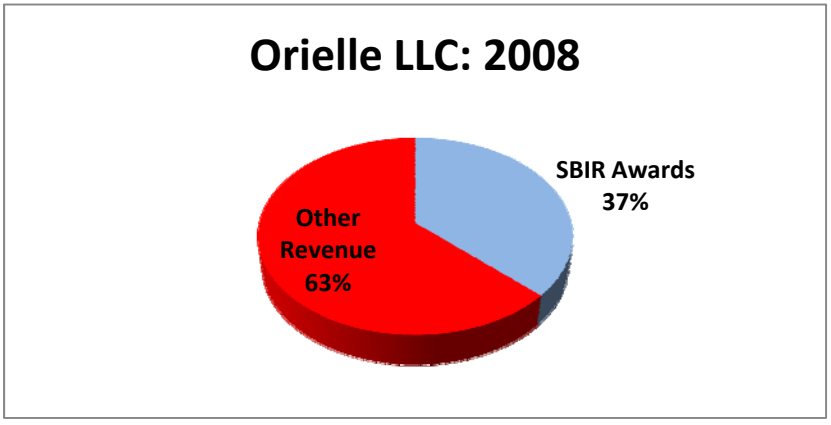

Figure 11. Orielle LLC, SBIR Percent of Total Revenue

3. Future Skies

Founded in 2001, Future Skies is a woman-owned business headquartered in Wall Township, NJ, specializing in software development, specifically custom computer programming services (NAICS code 541511; Executive Office of the President, Office of Management and Budget [OMB], 2007). From 2006–2010, Future Skies received one phase I SBIR award for R&D of a biometric data system that shares data across the DoD GIG using an SOA framework and subsequently received phase II funding for the project. This is the only SBIR activity recorded for Future Skies. Future Skies is a defense-oriented software development firm that appears to be heavily involved in subcontracting for software development on U.S. Army programs. Products include software for the C2R Planner, the PASS Client Interface, and CPOF DataBridge, which directly supports open architecture initiatives for the DoD: "The CPOF DataBridge is an open-architecture Future Skies product that leverages various data feeds to support a large user base via plug-in architecture" (Future Skies, n.d.). As of May 2012, Future Skies reported 78 employees and a three-year average annual revenue of $10 million on DD350 forms maintained in the FPDS–NG database.

Figure 12 compares total annual revenue, while figure 13 depicts the SBIR percent of total revenue for Future Skies over the 2006–2010 time period. The SBIR award represents a fraction of total revenue for this first-time award winner; most funding appears to be from subcontracted software R&D efforts supporting the U.S. Army outside of the SBIR program. Although there is no evidence that Future Skies has attempted to commercialize its lone SBIR-awarded proposal between 2006–2010, the firm advertises several products that have commercial applications, particularly for DoD subcontracting.

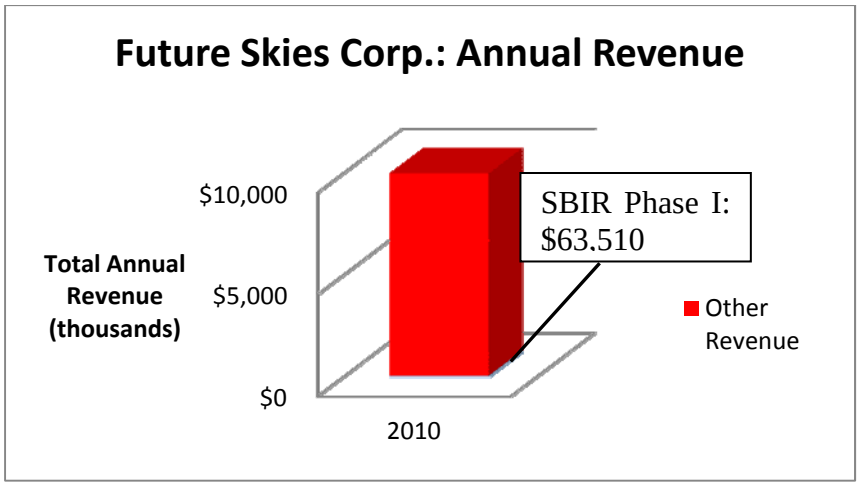

Figure 12. Future Skies Corporation Annual Revenue 2010

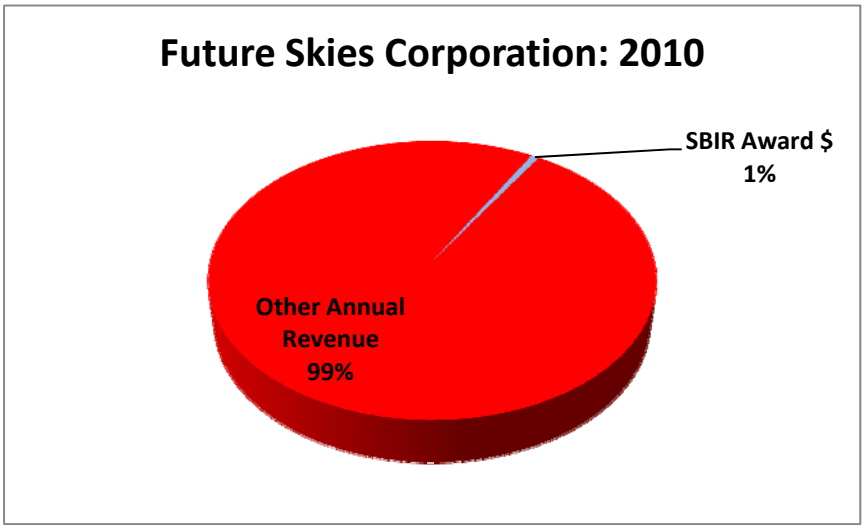

Figure 13. Future Skies Corporation, SBIR Percent of Total Revenue

4. Traverse Technologies

Traverse Technologies was a small, privately controlled computer consulting firm that was incorporated in West Newbury, MA, in 2004. Originally, Traverse Technologies worked in the design and development of Geographic Information System networks and is also an innovator in the development of open source software. Between 2006 and 2010, Traverse Technologies earned three SBIR awards, two being phase I awards and one being a phase II award supporting an OSA-related metadata tagging information system project. As of 2010, Traverse Technologies reported eight employees and a three-year average annual revenue of $800,000 on DD350 forms maintained in the FPDS–NG database. Figure 14

compares total annual revenue, while figure 15 depicts the SBIR percent of total revenue for Traverse over the 2006–2010 time period. From 2008–2010, 39% of Traverse Technologies' revenue was from SBIR awards; however, it is unclear what other sources of revenue existed for Traverse Technologies or if previous SBIR funding was used in the revenue data reported on the DD350 form. There was no evidence of phase III transition or commercialization of any product and the firm is subsequently no longer in business.

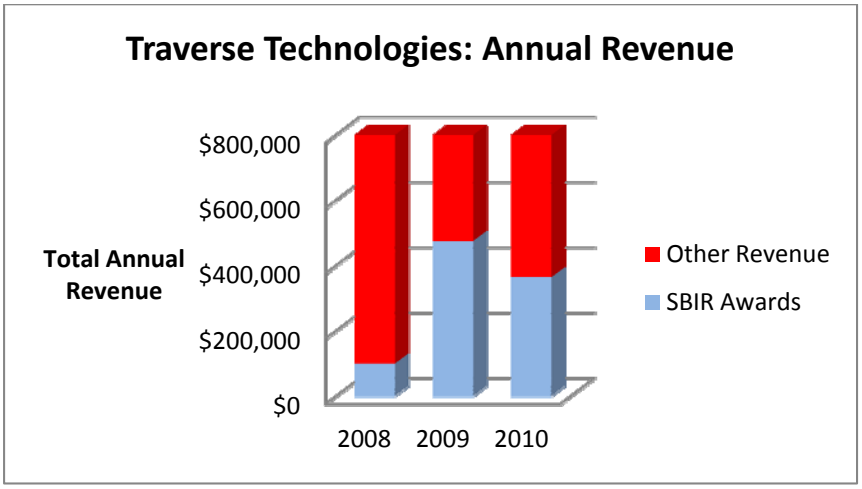

Figure 14. Traverse Technologies Annual Revenue

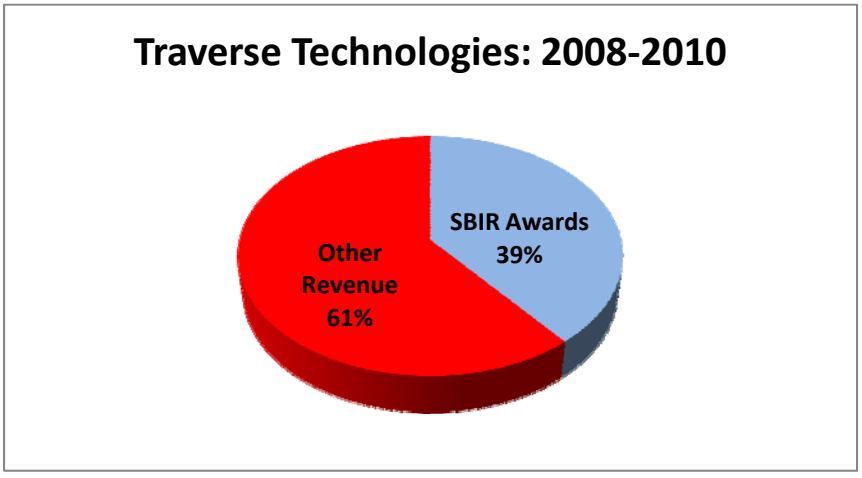

Figure 15. Traverse Technologies, SBIR Percent of Total Revenue

5. Analatom Incorporated

Analtom was founded in 1980 in the city of Sunnyvale, CA, and was an early innovator in the field of Micro-Electrical Mechanical Systems (MEMS). The use of MEMS in combination with integrated circuits has allowed Analatom Inc. to develop innovative

microsensors that the firm has elected to use in order to evaluate the health of structures, often through the detection of corrosion.

As of February 24, 2012, Analatom Inc. reported eight employees and an annual revenue of $799,229. From 2006–2010, Analatom Inc. earned four DoD SBIR Awards: Three were phase I awards, and one was a phase II award. These SBIR awards were focused on R&D efforts related to corrosion-sensing technology that can evaluate the structural health of aircraft, as well as a large OSA database to assemble and analyze large amounts of data. Figure 16 compares total annual revenue, while figure 17 depicts the SBIR percent of total revenue for Analatom over the 2006–2010 time period. Analatom does not appear to be specifically focused on DoD-related sales and reports commercial customers (and potential sales) in the aerospace, petrochemical (including Chevron), utilities, land-based vehicles (including DoD subcontracting on a U.S. Army program), civil infrastructure (including the Federal Highway Administration), civil engineering (including Caterpillar Inc.), and shipping (including Northrup Grumman) industries.

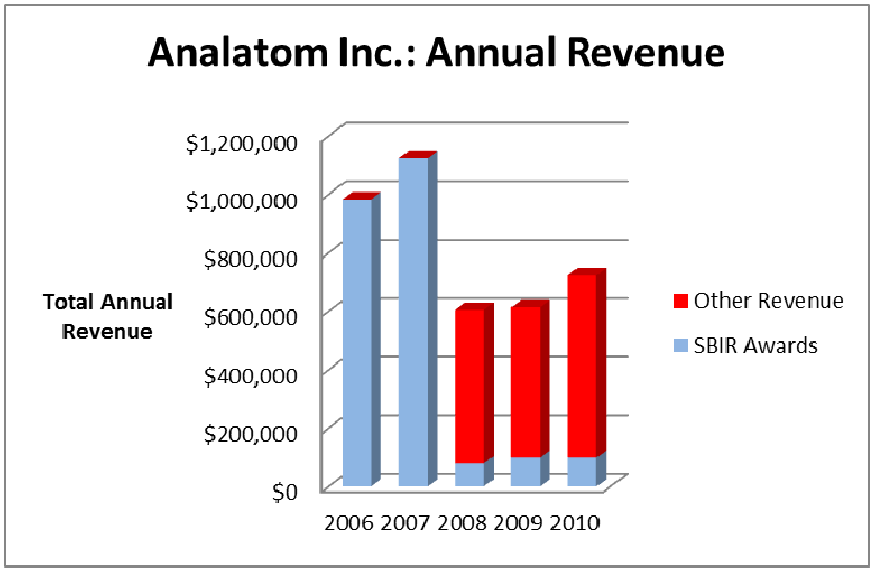

Figure 16. Analatom Inc. Annual Revenue

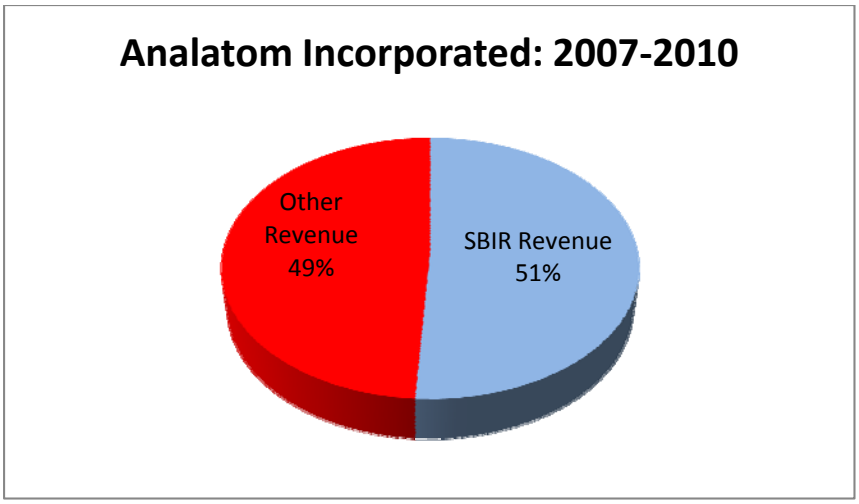

Figure 17. Analatom Inc., SBIR Percent of Total Revenue

6. Harmonia Holdings Group LLC

Harmonia Holdings Group LLC was founded in 1999 and based in Blacksburg, VA. The firm appears to be primarily defense and government focused, and provides software R&D that supports the defense industry. Harmonia is the only company identified in this research that is a woman-owned and minority-owned business located in a HUB zone. DD350 form information maintained in the FPDS–NG indicates Harmonia employs 28 people and had an annual revenue of $2.5 million as of March 2012. Harmonia's primary NAICS' code is 541511 (Executive Office of the President, OMB, 2007), corresponding to custom computer programming services. Harmonia is a developer of software technologies such as RISE™, a tool that helps convert legacy code to "modern architectures like SOA"; IMPACTA, a software tool for managing software development; Conforma, a software tool that integrates data into a common language; and several software tools.

It does not appear that Harmonia initially relied on SBIR funding; its first SBIR award was not until 2003 for developing software code using user interface markup language for application in the U.S. Navy. Figure 18 compares total annual revenue, while Figure 19 depicts the SBIR percent of total revenue for Harmonia over the 2006–2010 time period. According to the revenue data recorded on contracting DD350 forms, SBIR funding accounted for 96% of revenue. Revenue recorded in the FPDS–NG generally correlated to company profile data published by *Inc*. magazine ("Harmonia Holdings Group," 2011)

featuring Harmonia Holdings Group, which reported revenue of $3 million in 2010, up from $2.8 million in 2007. The firm's website suggests sales to several commercial clients including KocBeko, Lockheed Martin, Northrup Grumman, Raytheon, SAIC, and Schneider Electric. Harmonia also advertises successful SBIR phase III transitions, including technology insertion into the Zumwalt Class destroyer, the tactical Tomahawk Weapon Control System, a reusable mission planning library, as well as TV set-top boxes. Additionally, Harmonia's RISE^{TM} software was specifically developed out of an SBIR contract with the Missile Defense Agency (MDA07-005). The SBIR program appears to have facilitated technology development for Harmonia, allowing the firm to receive several prime contracts with the DoD and federal agencies, and the firm has been repeatedly recognized as one of the fastest growing private businesses in the country.

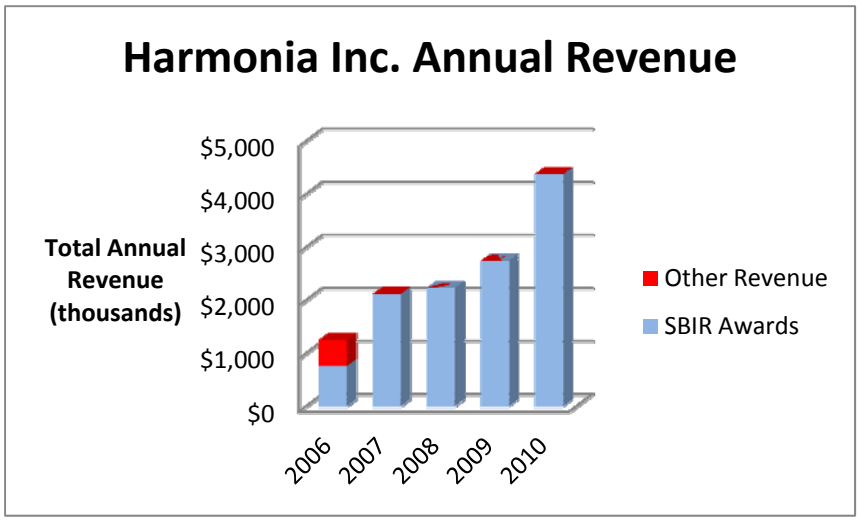

Figure 18. Harmonia Holdings Group Annual Revenue

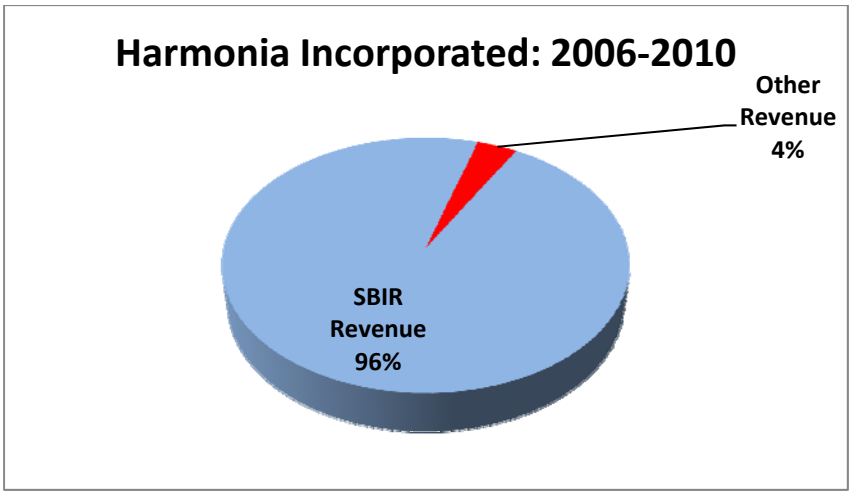

Figure 19. Harmonia Holdings Group, SBIR Percent of Total Revenue

7. Toyon Research Corporation

Toyon Research Corporation was founded in 1980 and is based in Goleta, CA, with 105 employees and annual revenue recorded in the FPDS–NG of $26.3 million as of March 2012. The firm is primarily oriented toward the defense industry and provides both technical development and defense system analysis. According to the company's website, its areas of expertise are largely in the following five areas: antennas and radio frequency systems; analysis of advanced sensor and weapons programs; homeland security; intelligence, surveillance, and reconnaissance algorithms; and missile systems.

Toyon Research Corp. has worked on over 500 contracts for over 50 government and commercial clients since its founding. DoD R&D financing may have contributed to Toyon's initial growth—in 1980 the company received a $30,000 fixed-price contract from the Department of the Air Force. Additionally, the first recorded SBIR contract listed in the SBA's TECH-Net database for Toyon was in 1986 under an Air Force SBIR contract.

Figure 20 compares total annual revenue, while Figure 21 depicts the SBIR percent of total revenue for Toyon over the 2006–2010 time period. From 2006–2010, 25% of the firm's reported revenue came from SBIR funding with almost the entirety of the contracts being with DoD agencies. The government agency awarding the most SBIR contracts to Toyon Research Corp. during the period was the Army. SBIR funding supported R&D

efforts primarily in software development (including various algorithms) and communications systems.

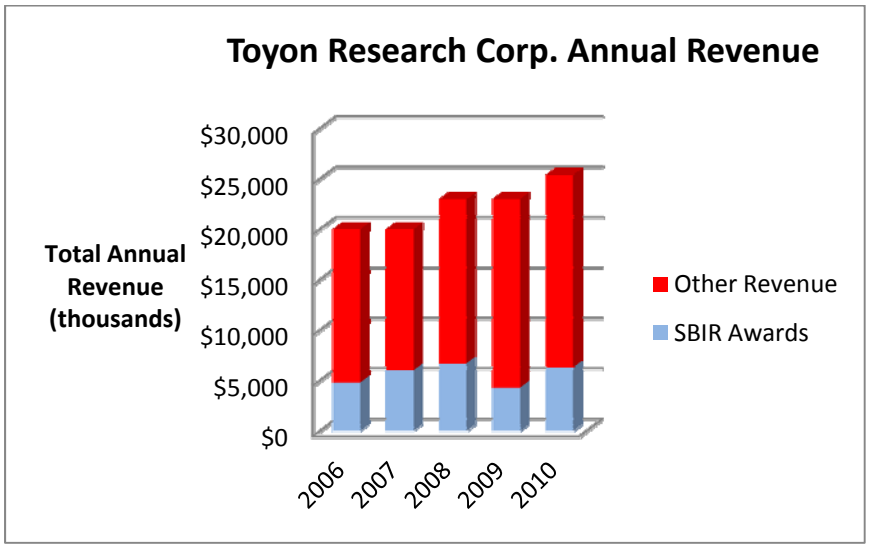

Figure 20. Toyon Research Corporation Annual Revenue

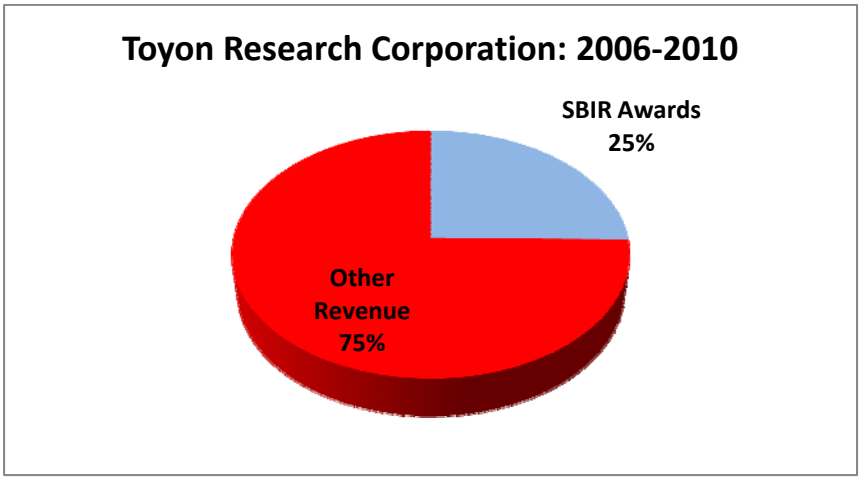

Figure 21. Toyon Research Corporation, SBIR Percent of Total Revenue

8. Infoscitex Corporation

Infoscitex is highly acclaimed, innovative firm based in Waltham, MA, that has consistently earned "increased yearly revenue" since its founding in 2000. In 2011, Inc. 500 listed Infoscitex ("Infoscitex," 2011) as one of America's fastest growing private firms. Infoscitex is oriented toward the defense industry; however, the firm also competes in the aerospace, life sciences, energy, and environment markets and provides information

technology solutions to commercial organizations such as Corning Inc. and Ortho-Clinical Diagnostics, as well as various DoD components. During the time period 2006–2010, Infoscitex bought Systran Federal Systems in 2006 and spun off IST Energy Corporation to market and sell waste-to-energy systems, both of which demonstrate company strength and indicate growth.

As of March 2012, FPDS–NG records showed that Infoscitex had 100 employees. Unique to this Infoscitex case study is that the firm publishes all audited financial statements on its website, which I used in both Figure 22 and Figure 23 in comparing SBIR contracts to total revenue instead of the three-year averages recorded in the FPDS–NG database that underreported revenue. This more accurate comparison reveals that from 2006–2010, SBIR funding accounted for 24% of total revenue (see Figure 23); however, SBIR funding declined after 2009 and remained low through 2012 despite substantial revenue growth through other sources (see Figure 22). This growth was achieved through both commercial sales and contracts (notably with the Air Force Research Laboratory) for multi-year R&D services. A PI who was interviewed for this research and is employed at Infoscitex indicated that SBIR-funded research has contributed to the company's growth and is often used to support existing projects that are not necessarily SBIR-specific projects. Furthermore, the interviewee mentioned that SBIR-funded research often leads to the development of certain technologies that are subsequently used in other products and services for both public- and private-sector use.

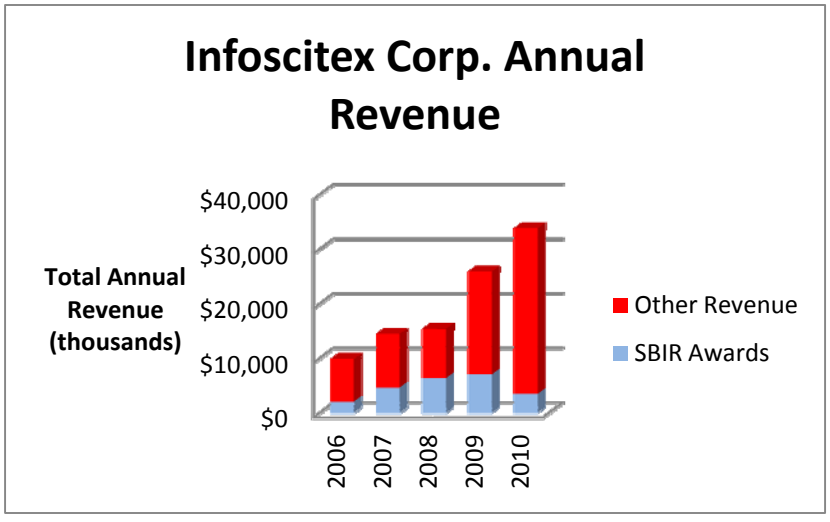

Figure 22. Infoscitex Corporation Annual Revenue (From Income Statement)

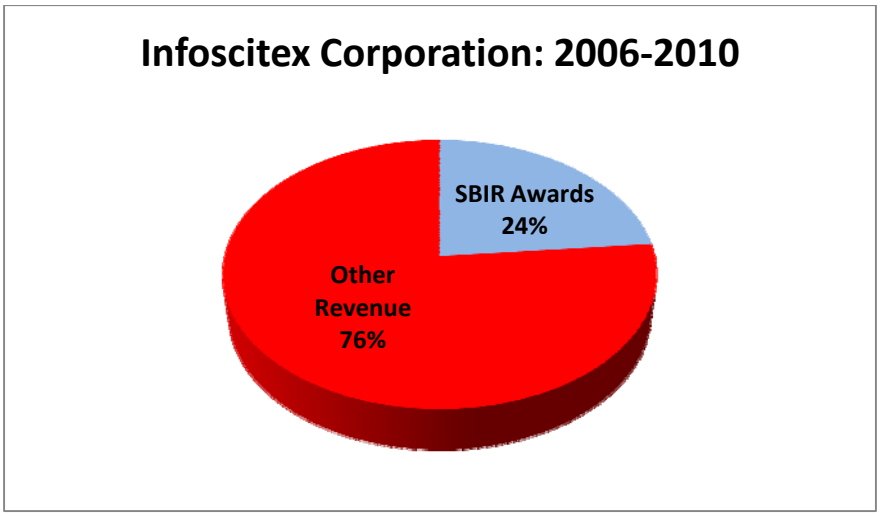

Figure 23. Infoscitex Corporation, SBIR Percent of Total Revenue

9. Reservoir Labs Inc.

Reservoir Labs Inc. was founded in 1990 and has offices in New York City, NY, and Portland, OR. Currently, the firm employs approximately 20 people and is primarily a software development firm that specializes in advanced compiler, network, and reasoning technologies, with an emphasis on mapping innovative algorithms to emerging high-performance and embedded architectures. Reservoir Labs does not appear to be heavily oriented on defense R&D contracting and supports a variety of customers. Although the firm maintains a confidential customer list, it appears that a significant portion of revenue is generated from the licensing of software technologies, including R-Stream High-Level Compiler, R-Scope, R-Check, CrossCheck, Alef, Salt & Shaker, and UltraViolet. Additionally, the firm offers professional software assessment services to various customers, including various DoD components through the SBIR program. The firm did not initially participate in the SBIR program or rely on SBIR funding for start-up costs; its first recorded SBIR wasn't awarded until 2004.

As of March 2012, Reservoir Labs Inc. reported a three-year average annual revenue of $3 million on DD350 form information recorded in FPDS–NG; however, it is unclear whether total revenue increased as DoD SBIR funding steadily increased from 2006–2010. Figure 24 compares total annual revenue, while Figure 25 depicts the SBIR percent of total revenue for Reservoir Labs over the 2006–2010 time period. Approximately 26% of

Reservoir Labs, Inc.'s, revenue from 2006–2010 could be attributed to the SBIR program (see Figure 25). An interview with a PI who is employed at Reservoir Labs Inc. stated that SBIR funding has helped the firm continue to develop existing technologies within the firm, while other SBIRs support "brand new technologies in an area that we theoretically understand well, but have no existing framework to build on. So, we build it from the ground up in the SBIR program" (personal communication, 2012). Where applicable, technologies developed under an SBIR contract are subsequently inserted into projects that support other contracted R&D efforts or into a commercialized product.

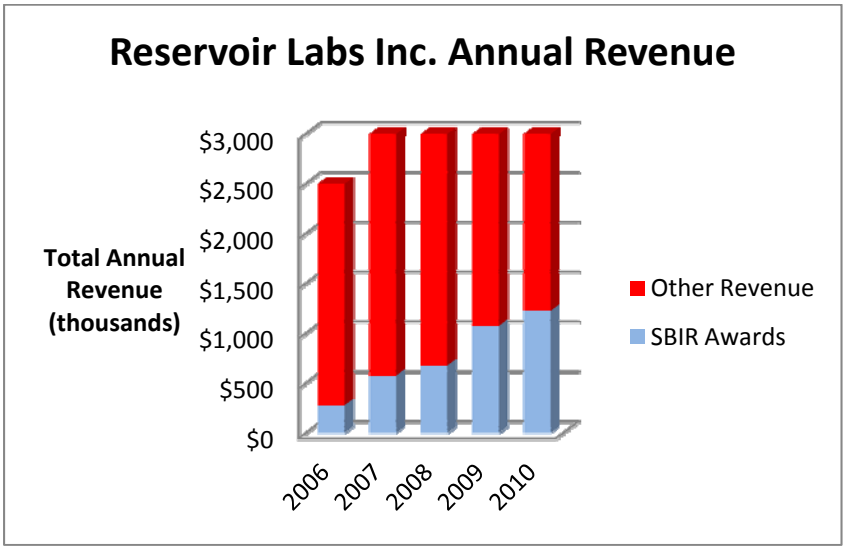

Figure 24. Reservoir Labs Inc. Annual Revenue

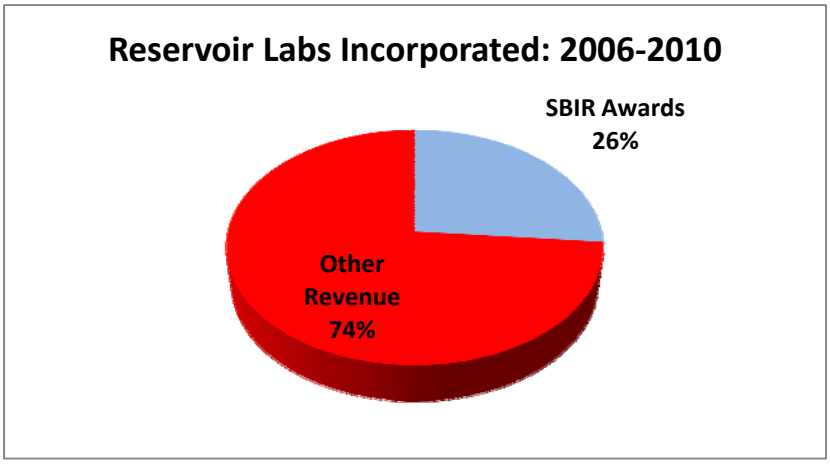

Figure 25. Reservoir Labs Inc., SBIR Percent of Total Revenue

10. Navmar Applied Sciences Corporation

Founded in 1977, Navmar Applied Sciences Corporation is a defense industry-oriented firm that provides hardware and software engineering and technical services primarily for DoD application. As of March 2012, Navmar reported a three-year average annual revenue of $35.8 million and 201 employees on DD350 forms recorded in the FPDS–NG database; however, their website indicates the firm employs over 500. Navmar is a Service-disabled veteran-owned small business, which Congress has mandated receive a percent of all federal contracts. Navmar is based in Warminster, PA, but has nine other locations throughout the country. Since its inception, much of Navmar's business revolved around improving the Navy's undersea warfare capabilities, such as the development of a small, undersea surveillance probe for the Navy in 1996. In 2002, Navmar branched into the development of unmanned aircraft systems for the Navy. Navmar also offers a range of software solutions in addition to providing systems tests, offering corrosion management methods, and possessing expertise in aerial refueling methods and air vehicle technology.

Figure 26 compares total annual revenue, while Figure 27 depicts the SBIR percent of total revenue for Navmar over the 2006–2010 time period. According to data recorded in the FDPS–NG database, between 2006 and 2010, SBIR phase I and phase II funding accounted for approximately 10% of annual revenue (see Figure 27). Figure 26 demonstrates that SBIR contracts for Navmar remain fairly constant over time, which suggests they use SBIR funding for R&D efforts that support the wide variety of products and services Navmar provides as a prime and subcontractor in the defense industry. Unique to the Navmar case is the large amount of SBIR phase III activity recorded in the FPDS–NG database, which suggests Navmar is particularly successful at transitioning technology from the SBIR program to the commercial market.

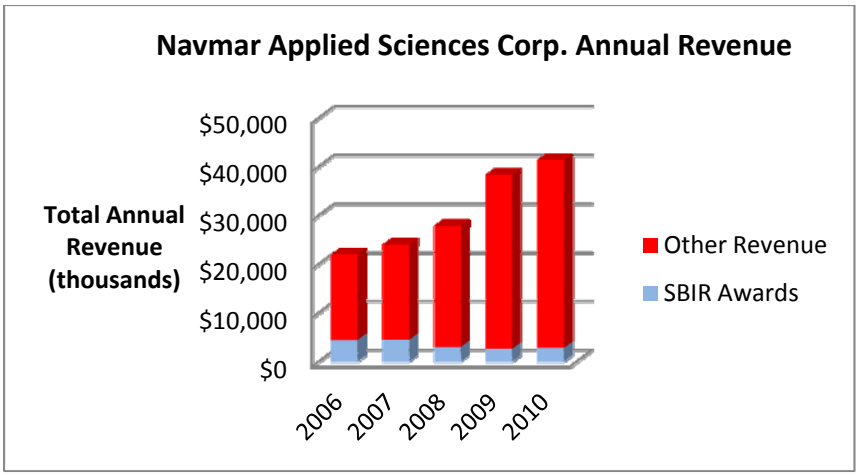

Figure 26. Navmar Applied Sciences Annual Revenue

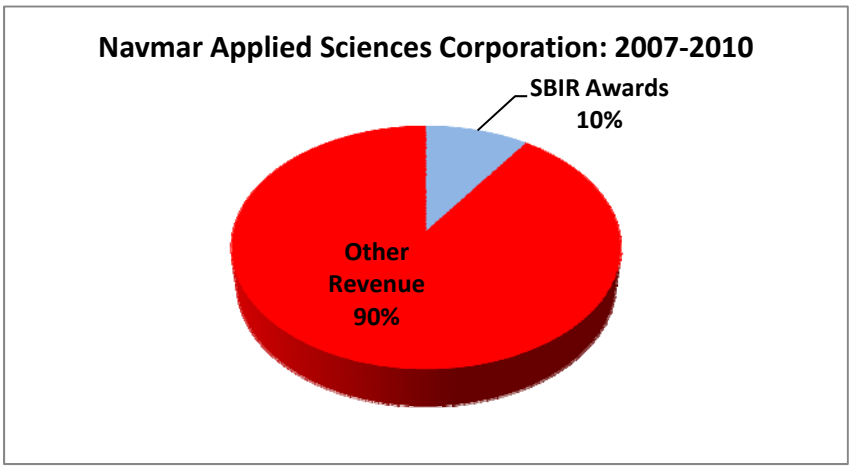

Figure 27. Navmar Applied Sciences, SBIR Percent of Total Revenue

11. Scientific Systems Company Inc.

Scientific Systems Company Inc. (SSCI) was founded in 1976 and is a minority-owned company based in Woburn, MA. According to its website, it is one of the top 20 recipients of SBIR awards in the U.S (Scientific Systems, 2012). SSCI appears to be heavily oriented toward product and service R&D for the defense industry, particularly in the area of unmanned ground, air, and underwater vehicles. According to the SBA TECH-Net database, 85% of the firm's business is in R&D, and 15% in service. In its R&D efforts, SSCI collaborates with numerous partners in industry, such as Raytheon, Boeing, Sikorsky, and in academia, including Yale, University of Southern California, and Boston University.

Figure 28 compares total annual revenue, while Figure 29 depicts the SBIR percent of total revenue for SSCI over the 2006–2010 time period. As of March 2012, SSCI reported 50 employees and a three-year average revenue of $9.1 million, which represented an 82% growth in revenue since 2006. However, according to contract data maintained in the FPDS–NG database, this revenue growth was accompanied by a 231% increase in SBIR funding, from $2.3 million in 2006 to $7.5 million in 2010 (see Figure 28). SSCI's first SBIR award occurred on September 1996, and the majority of SSCI's contracts during the 2006–2010 period analyzed were for DoD components, including the Navy, Army, and Air Force. SSCI has also received numerous SBIR awards for R&D projects supporting NASA. Held et al. (2006, p. 128) identified SSCI as a "continuing DOD-SBIR frequent award winner" for the period of 1994–2003, which suggests the firm has longstanding participation in the program. Because the firm is primarily oriented toward the defense industry, phase III commercialization of SBIR technologies for SSCI appears to be most likely in the technology transition into DoD acquisition programs as a subcontractor; one example provided on their website is the Tomahawk Cruise Missile Program.

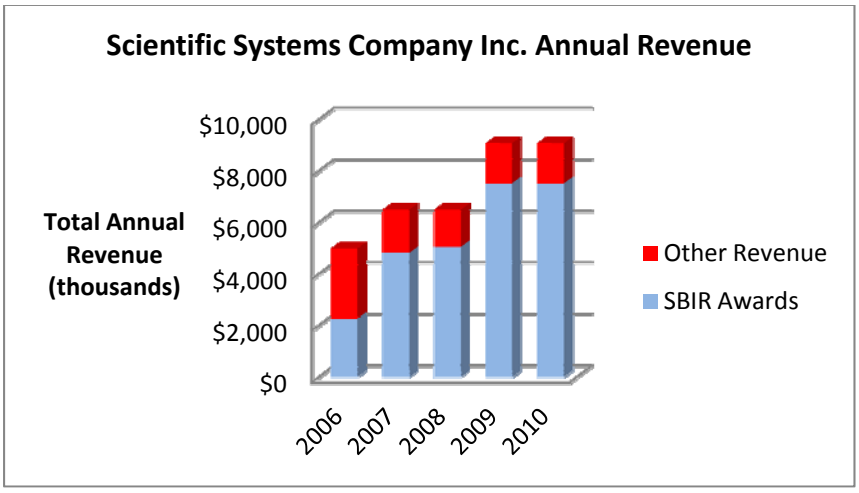

Figure 28. Scientific Systems Company Inc. Annual Revenue

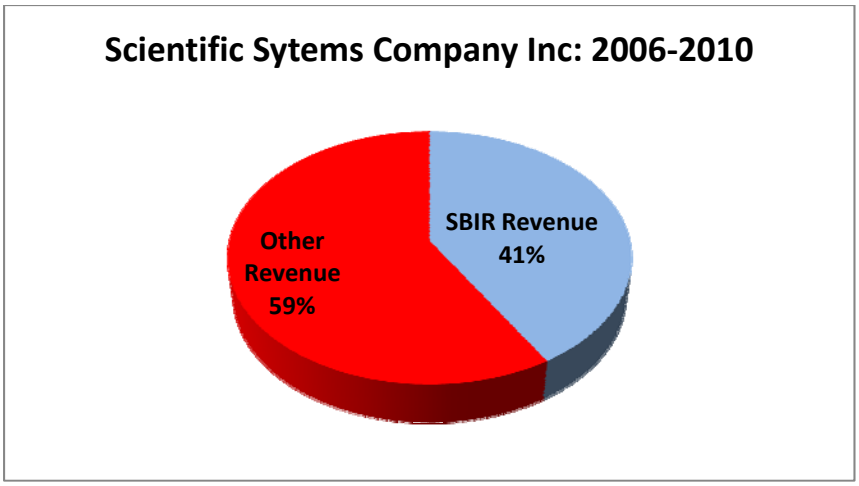

Figure 29. Scientific Systems Company Inc., SBIR Percent of Total Revenue

12. Decisive Analytics Corporation

The Decisive Analytics Corporation (DAC) was founded in 1996 and is the largest firm analyzed in this research in terms of reported annual revenues. The DAC is based in Arlington, VA, currently employs 150 people, and has reported a three-year average annual revenue of $40 million, which correlates to a company profile report published in the Inc. 500 that reports annual revenue of $41.1 million ("Decisive Analytics Corporation," 2011). The DAC is an employee-owned systems engineering company that provides products and services supporting the DoD and other federal agencies through direct prime contracts; in 2010, the DAC's federal contracts recorded in the FPDS–NG database accounted for approximately 90% of the firm's reported annual revenue. However, its website indicates that the DAC has several commercial customers as well—including defense-oriented consulting services—that appear to account for approximately 10% of revenue. The DAC's core competencies include intelligent decision support systems, video asset management, systems analysis, acquisition support, strategic and operational user support, international support, and system security engineering (Decisive Analytics Corporation, n.d.).

The DAC demonstrated a 32% growth in revenue from 2006–2010, and was recognized as one of the 50 fastest growing firms in Virginia in 2004, 2005, 2006, and 2007. Figure 30 compares total annual revenue, while Figure 31 depicts the SBIR percent of total revenue for the DAC over the 2006–2010 time period. According to data recorded in the FDPS-NG database, between 2006 and 2010, SBIR phase I and phase II funding accounted

for approximately 9% of annual revenue (see Figure 31). Figure 30 demonstrates that SBIR contracts for the DAC remained fairly constant over time, which suggests the firm uses SBIR funding for R&D efforts to support its existing products and facilitate technology transition into DoD programs.

One PI that was interviewed for this research indicated that the DAC participates in the SBIR program primarily to augment R&D funding, as well as to guide R&D efforts and ensure that the firm has identified a potential customer who specifically requires a certain technology. The interviewee stated that the underlying goal of SBIR research at the DAC is to develop "new" technology that can be integrated into a larger product/platform: "SBIR research is always new research, but it is tangential to something that we've already done so that it can be integrated" (personal communication, 2012) into existing products.

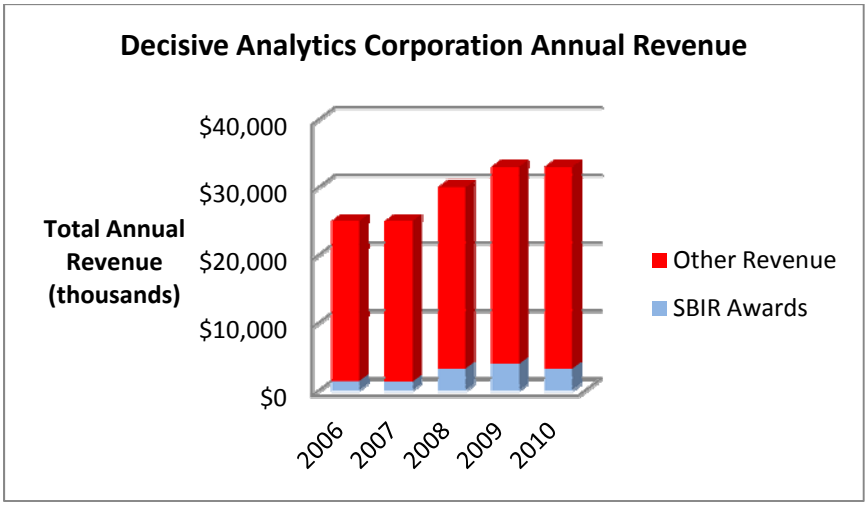

Figure 30. Decisive Analytics Corporation Annual Revenue

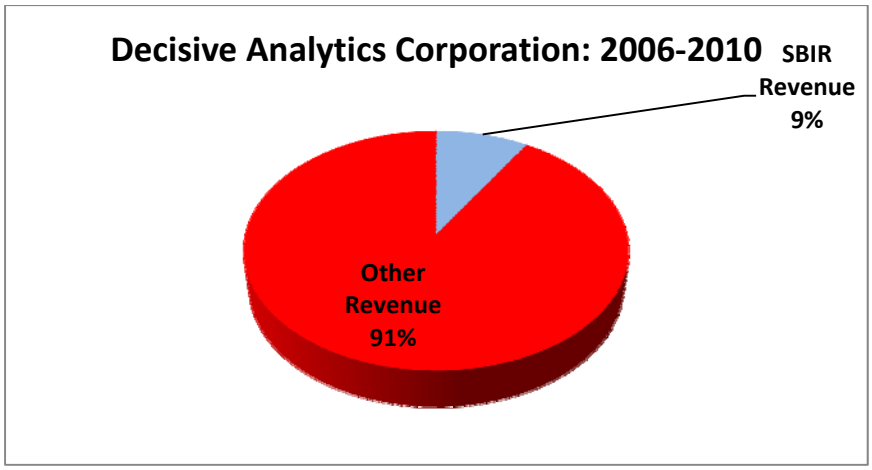

Figure 31. Decisive Analytics Corporation, SBIR Percent of Total Revenue

13. Stottler Henke Associates Inc.

Stottler Henke was founded in 1988 in San Mateo, CA, and is primarily a research and software development firm that specializes in artificial intelligence products and advanced software technologies that support a wide range of clients, including government agencies such as the DoD, Department of Energy, Department of Commerce, Department of Education, as well as NASA; Stottler Henke's commercial customers include Bombardier Learjet, Boeing, Northrop Grumman, and Lockheed Martin. According to its website, Stottler Henke products fall into the following categories: education and training, knowledge management and discovery, planning and scheduling, decision support, and computer security and reliability. Stottler Henke has a variety of software technologies including tutoring systems, ReadInsight, a variety of military training tools, knowledge management tools (i.e., "InfoTracker," which can detect text overlaps and identify plagiarism), as well as computer security, reliability, and scheduling systems used by aircraft manufacturers such as Bombardier Learjet. As of March 2012, Stottler Henke reported 60 employees and a three-year average annual revenue of $8 million on DD350 forms recorded in the FPDS–NG database, which correlates to information published on the company's website highlighting 2006 annual revenue of $9 million ("About Stottler Henke," n.d.).

Figure 32 compares total annual revenue, while Figure 33 depicts the SBIR percent of total revenue for Stottler Henke over the 2006–2010 time period. According to DD350 form data maintained in the FPDS–NG database, between 2006 and 2010, SBIR phase I and phase

II funding accounted for approximately 48% of revenue (see Figure 32); most awards were from DoD components, particularly with the Army. "Other revenue" appears to be the result of additional federal contracts and commercial sales of a variety of software technologies developed by Stottler Henke. The company has longstanding participation in the SBIR program; Held et al. (2006) identified Stottler Henke as a "continuing DOD-SBIR frequent award winner" (p. 128) for the period of 1994–2003. Additionally, the company has been repeatedly recognized as having realized outstanding commercial success and technology transition in the SBIR program. In 2012, Stottler Henke received the Tibbetts Award; 10 technologies have been designated SBIR success stories; four systems received accolades by NASA for successful commercialization; and the firm was awarded the Brandon Hall Excellence in Learning award for innovative technology.

In an interview with a PI employed at Stottler Henke who was intimately involved in the SBIR program, the interviewee stated that the firm uses the SBIR program as a means of external R&D funding for projects that *would not* be funded by the private sector. The PI, who has been involved in the SBIR program since 1988, stated, "I don't think that I've worked on an SBIR that the private sector would fund" (personal communication, 2012). Additionally, the interviewee stated that about 50% of Stottler Henke's SBIR funds are used as a means to supplement existing projects within the scope of the contract, while the remaining half of SBIR contracts are used as a means to explore and "open" a whole new area of research for the firm, which provides a means to expand the firm's organic R&D projects and expertise, and, ultimately, to develop technologies for commercialization or transition. Asked how the SBIR program has contributed to company growth, the interviewee stated that R&D projects funded through the SBIR program frequently require the company to hire additional employees. Additionally, SBIR projects often stimulate other projects or research within the firm that require resources to develop and transition the technology and results in further growth of the company. The interviewee stated that company growth from the SBIR program is "about half and half" (personal communication, 2012) attributed to these two areas.

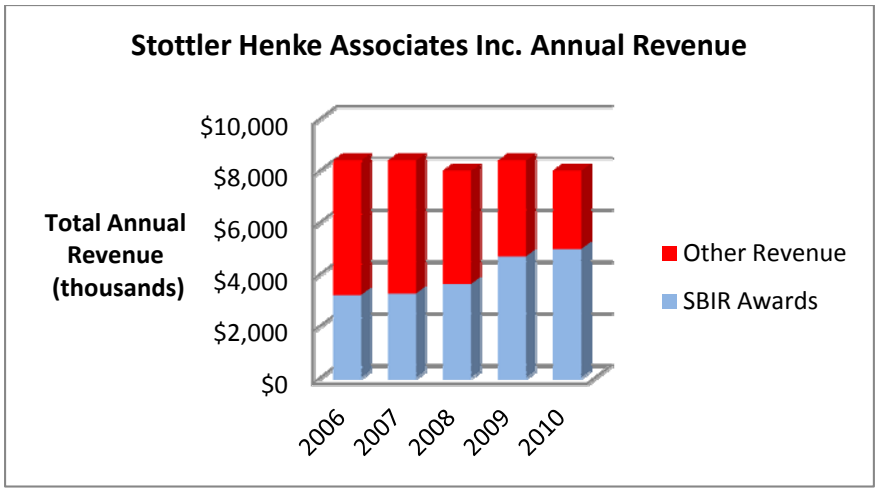

Figure 32. Stottler Henke Associates Annual Revenue

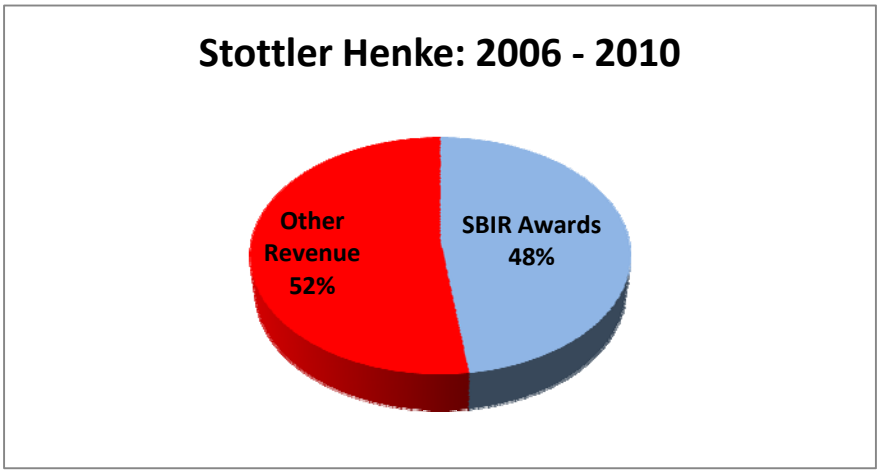

Figure 33. Stottler Henke Associates, SBIR Percent of Total Revenue

14. Architecture Technology Corporation

The Architecture Technology Corporation (ATC) was founded in 1981 and is headquartered in Minneapolis, MN, with offices located in Washington, DC; Ithaca, NY; Rome, NY; and Dayton, OH. The ATC is primarily a software technology company that provides research, development, engineering services, and a variety of software products to its customers who include the DoD and a number of different federal agencies, as well as several corporate customers. Although the ATC does not necessarily appear to be specifically oriented to the defense industry, a significant portion of annual revenue reported on DD350 forms maintained in the FPDS–NG database is the result of contracts with various federal agencies for products and services. For the past 25 years, the ATC has worked

extensively with the Federal Aviation Administration (FAA), largely focusing on improving runway safety, and with the National Institute of Justice to develop forensic analysis software. As of March 2012, the ATC reported 41 employees and a three-year average annual revenue of $5.9 million on DD350 forms recorded in the FPDS–NG database.

Figure 34 compares total annual revenue, while Figure 35 depicts the SBIR percent of total revenue for the ATC over the 2006–2010 time period. According to DD350 form data maintained in the FPDS–NG database, between 2006 and 2010, SBIR phase I and phase II funding accounted for approximately 21% of ATC revenue. The ATC has participated in the SBIR program since it developed an R&D group in 1994. Held et al. (2006) identified Architecture Technology Corporation as a "new DOD–SBIR frequent award winner" (p. 125) for the period of 1994–2003, which is defined as a firm whose participation in the program rose steadily during the 10-year period. SBIR contract obligations shown in Figure 34 suggest ATC continues to participate in the program at a fairly steady rate. Most of the ATC's SBIR activity appears to be with the U.S. Army; 22% of the 22 SBIR awards received during this time period were with the Army.

In an interview with an ATC SBIR PI, the interviewee stated that the SBIR program is a good program to use for external R&D funding, particularly because it aligns R&D efforts with potential customers. Additionally, the interviewee stated that the ATC tends to use the SBIR program to advance existing R&D projects within the firm, but also as a resource to create new projects and explore new product areas. The comments tended to agree with the notion that participants use the SBIR program both as a funding resource and as a "guide" to steer R&D projects that have potential customers in mind. The ATC has had to hire additional employees directly as a result of SBIR-funded research; the interviewee stated that the company is currently "looking to hire quite a few people" to support SBIR R&D projects. Additionally, the company has hired in order to "get leverage" into another R&D SBIR proposal in another project (personal communication, 2012). The interviewee stated that the ATC has been very successful in phase III commercialization and commented that his firm has had about 16 phase II SBIR projects that have resulted in some kind of follow-on funding.

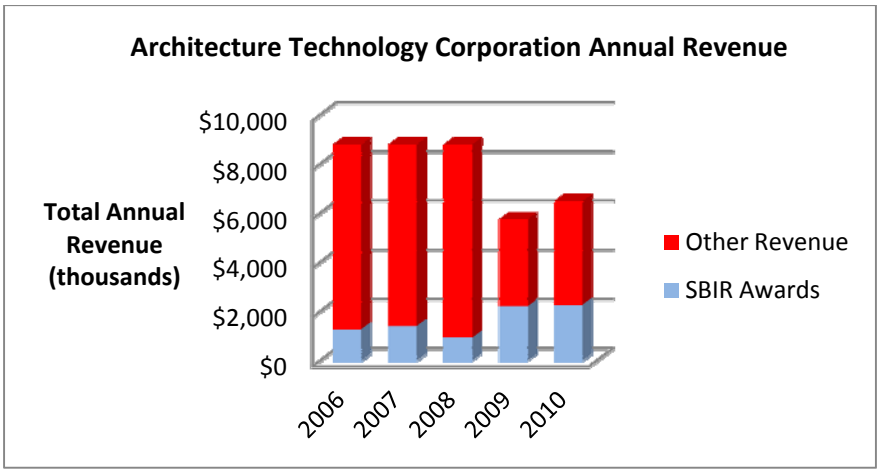

Figure 34. Architecture Technology Corporation Annual Revenue

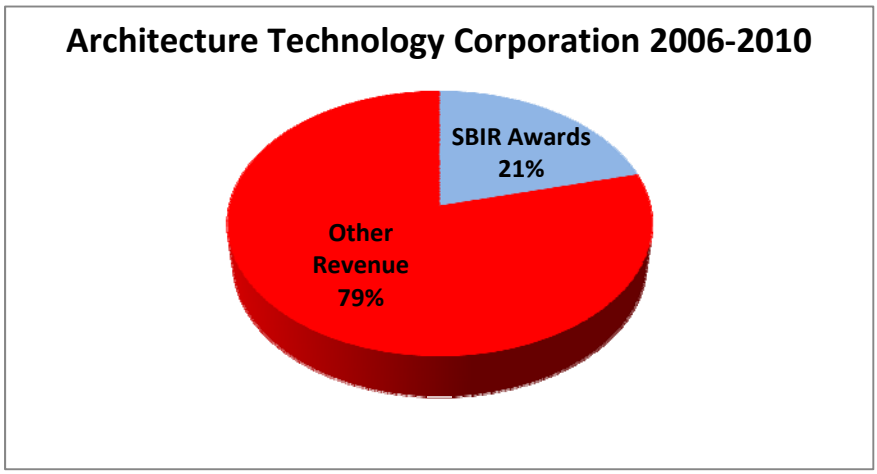

Figure 35. Architecture Technology Corporation, SBIR Percent of Total Revenue

15. Summary of Participating Firm Characteristics

Small businesses were chosen for this case study analysis because they have competed in the SBIR program and received phase I or phase II funding for an IST R&D project. Additionally, these firms possess the unique skills to develop IT systems and components that advance OSA initiatives in the DoD to enhance innovation and reduce program life-cycle costs. Most firms described in the case studies appear to be oriented toward defense industry and federal government R&D by providing specialized products and services that are unique to government use. Most participating companies receive additional revenue through the sale of products or services either as prime contractors to the DoD, or as sub-contractors who partner with larger defense prime contractors in the defense industry;

however, many also sell or lease technology in the commercial marketplace. As a point of comparison between firms, Figure 36 graphically depicts revenue sources of the firms reviewed in this research. These case studies, as well as information obtained from interviews with program participants, highlight how small businesses use the SBIR program to align R&D efforts with identified customers and with the specific needs of the DoD and, consequently, the defense industry. This supports the notion that the SBIR program is an effective mechanism for the DoD to communicate R&D requirements directly to small businesses to achieve maximum participation.

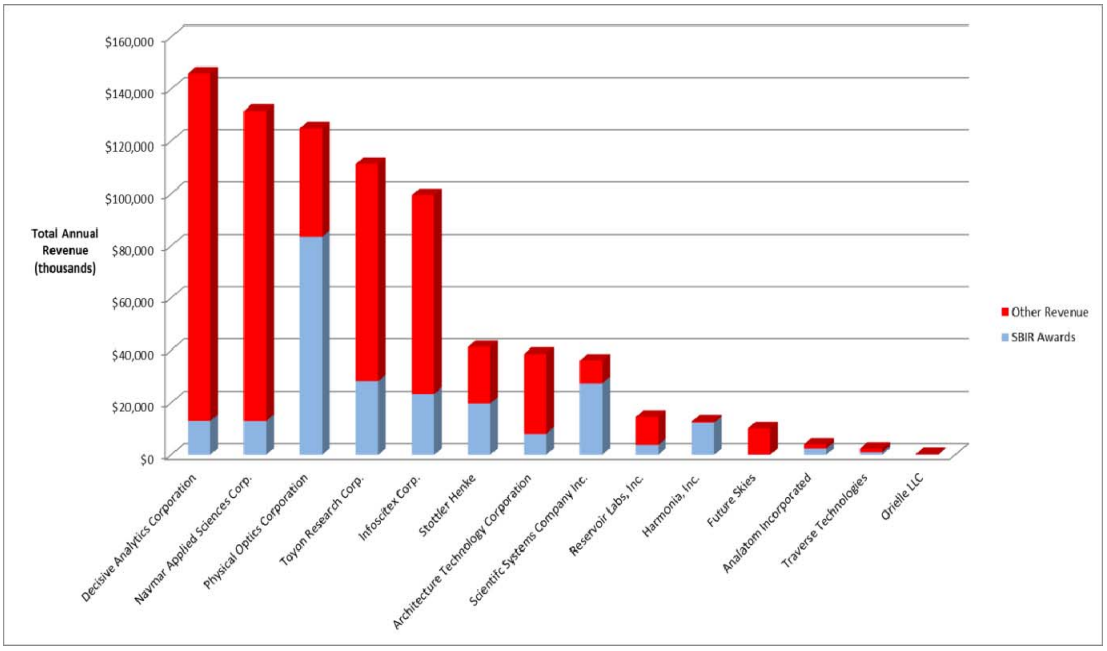

Figure 36. SBIR Firm Annual Revenue Comparison

Participants tend to be fairly young companies; nine of the 14 were founded within 10 years of the time period used in this research and the average founding date was 1991. The businesses reviewed in these case studies employed an average of 76 people and most companies were classified in the industry *Research and Development in the Physical, Engineering, and Life Sciences (Except Biology)* by the SBA (NAICS code 541712; Executive Office of the President, OMB, 2007). The largest firms reviewed in these case studies regularly participate in the SBIR program and have consistently received numerous SBIR awards; excluding first-time award winners, SBIR participants received on average approximately $4.3 million annually through SBIR phase I or phase II awards. Furthermore,

of the 14 firms reviewed, only three (Future Skies, Traverse Technologies, and Orielle LLC) appear to be first-time award winners entering the SBIR program; of those, only Future Skies appears to still be an active company in software development and sales. The steady participation in the program by most participants demonstrates how small businesses participating in the program leverage SBIR R&D financing to augment R&D financing and develop IST products and services for transition to DoD programs or for commercialization. Furthermore, the information obtained from interviews as well as the data collected from these case studies support the notion that successful participation in the SBIR program facilitates company growth and frequently contributes to commercialized products and services.

One of the congressional goals of the SBIR program is to "foster and encourage participation by minority and disadvantaged persons in technological innovation" (SBID Act, 1982). Three major categories used to track participation by minority and/or disadvantaged persons are women owned, minority owned, or located in a HUB zone. These case studies presented very little evidence that the SBIR program is effectively fostering and encouraging participation by minority and disadvantaged persons in technological innovation; of the firms reviewed in these case studies, only 29% reported to be woman owned, 7% minority owned, and 7% in a HUB zone. However, generalizing program effectiveness at meeting this congressional objective is difficult because no data is collected on the number of SBIR proposals submitted by these types of small businesses, and, therefore, an analysis of the trends in SBIR proposals is difficult to accomplish.

Finally, revenue data collected in the case study portion of this research provided me with a point of comparison between participating SBIR firms. Figure 37 compares total revenue for the 2006–2010 time period with the percent of that revenue received from SBIR awards in terms of contract obligations received. Smaller firms (total revenue of less than $40 million) have much more variability in the percent of total revenue attributed to SBIR awards than do their larger counterparts, who, with one exception, do not exceed 25% of total revenue from SBIR-related contracts. Some small high-tech R&D companies are young and rely heavily on SBIR funding to provide or supplement startup costs, other small businesses appear to focus primarily on DoD R&D through SBIR contracting, while other small

companies use SBIR funding to augment existing external R&D funding, but rely heavily on private-sector sales (or other federal contracting) as a primary source of revenue. This demonstrates higher volatility, and, thus, potentially higher risk, among the smaller firms participating in the SBIR program.

As total revenue increases, reliance on SBIR funding tends to decrease. The percent revenue attributed to SBIR awards among larger firms does not exceed 25%, with the two largest firms having only 10% and 9% of total revenue from SBIR-related contracts. This suggests that larger, well-established firms in the program use SBIR funds primarily to augment R&D funding and to align technologies with potential customers, and that the primary sources of revenue result from commercial market sales/lease and/or federal contracting action other than SBIR. The one outlier represented in the data is the POC, which appears to be a larger firm that relies heavily on SBIR funding as a source of total revenue (67%, according to data collected in this research). Although this seems to suggest the POC's failure to commercialize SBIR products and, subsequently, increase revenue from other sources, the POC has, in fact, successfully commercialized SBIR products by spinning off separate companies to develop, manufacture, and sell those technologies. This common approach to phase III commercialization highlights the difficulty in assessing phase III commercialization success and SBIR program performance. If this approach to technology transition/commercialization is not thoroughly understood by researchers attempting to quantify the performance of firms in the SBIR program, it could result in underestimating the performance of participating firms or even the success of the SBIR program in general. Attempts to estimate the SBIR program's return on investment of federal funding can become particularly complex when revenue resulting from a commercialized SBIR technology is received by a *different* firm than the one who initially received the award. This highlights the difficulty in any academic research that attempts to assess program performance by evaluating revenue from commercialized technologies of SBIR participants if the research excludes spin-off companies that might exist solely as a result of SBIR-funded technology.

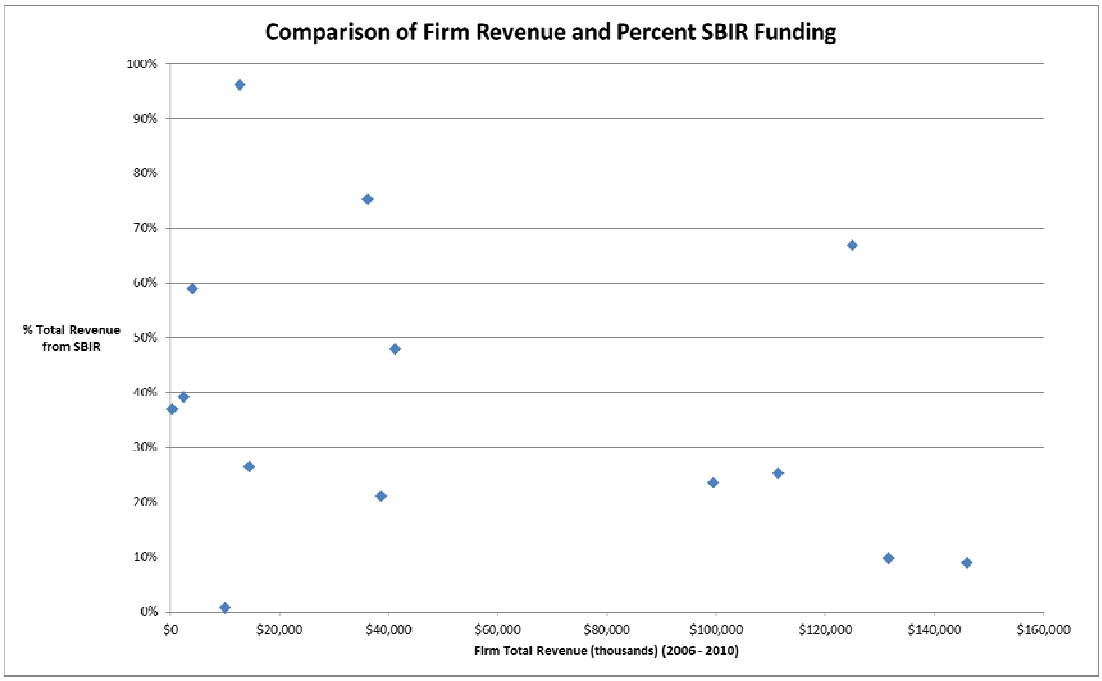

Figure 37. Comparison of SBIR Firm Revenue and Percent SBIR Funding

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VI. CONCLUSIONS

A. CONCLUSIONS

The purpose of this thesis was to examine the extent to which the DoD uses the SBIR program to incorporate small businesses in the R&D of IT systems to advance open systems initiatives. In addition, this thesis focused primarily on exploring and analyzing SBIR IT firms in an effort to better understand participant experiences and the characteristics of small IT businesses that participate in the SBIR program to meet the IT R&D challenges the DoD faces. The research was divided into a literature review, an analysis of information contained on SBIR solicitation topics, and a review of participating SBIR IT firms in order to answer the research questions posed at the beginning of this thesis.

1. Does the DoD leverage the SBIR program to incorporate small, innovative IT firms into DoD R&D?

First, I reviewed existing literature on the SBIR program and previous attempts to measure the overall performance of the program, most notably from the NRC, GAO, and RAND. Although an ambiguity of goals makes the SBIR program difficult to measure, existing research generally suggests that the SBIR program is meeting its stated objectives. I reviewed additional literature suggests that small businesses, particularly those in the PS&T industry and IT sector, which describe the type of SBIR firm of interest to this research, are underrepresented in DoD acquisition efforts. Furthermore, existing research suggests there is a declining trend in DoD contracting with small innovative high-tech businesses in general, although not necessarily in the SBIR program.

In my analysis of IST initiatives in Chapter IV, I found that, on average, SBIR topics categorized as IST critical technology areas account for approximately 12% of total SBIR solicitation topics the DoD released. Furthermore, data collected in this analysis reaffirm earlier research conducted by Held et al. (2006), which suggests that the SBIR program continues to moderately underfund IST programs as compared to the percent to total R&D funding for information systems.

2. Does the DoD leverage the SBIR program to further advance open systems architecture initiatives?

Of the 375 SBIR topic requests for proposal identified for this analysis, only 22 (approximately 6%) included relevant language that solicited small businesses for R&D of IT systems that advance OSA initiatives through the SBIR program. To account for the inconsistency of SBIR topics, I conducted further analysis on the sample to determine which SBIR topics were directly applicable to, or could be integrated with, contracts for NSSs. Because the DoD's objective is to incorporate OSA principles in NSSs, this essentially narrowed the number of SBIR solicitation topics down to only the ones where we might expect to see OSA principles, or in accordance with DoD guidance, *should* see OSA principles. Twenty-six percent of SBIR topics solicit small business participation in R&D of IST that supports NSSs. Of those, only 23% had incorporated elements of OSA characteristics into the SBIR topic request-for-proposal language during the time period used for this research. Furthermore, this research found that OSA-related SBIR projects were disproportionately underfunded as compared to NSS SBIR projects in general. This suggests that the DoD SBIR program does not thoroughly incorporate and embrace OSA initiatives within the SBIR program, which can inhibit system interoperability and integration when attempting to insert SBIR technologies into larger DoD platforms.

Additionally, my analysis revealed incremental improvements within the DoD SBIR program to incorporate OSA characteristics into SBIR RFPs, suggesting increased importance over time is being placed on clarifying SBIR solicitations to ensure OSA principles are included in the firm's R&D efforts. Finally, efforts to incorporate OSA principles in SBIR topic requests for proposals have been led primarily by the Navy; 40% of Navy SBIR topics for NSSs contained OSA principles in the RFP. This result reflects the Navy's early adoption and continuous use of OSA principles and illustrates that the principles of OSA have been more widely accepted within the Navy than within other components of the DoD, particularly in the DoD SBIR program.

However, despite the empirical analysis that suggests that the DoD SBIR program is failing to communicate its intent to leverage OSA principles in SBIR projects, 78% of PIs interviewed during this research agreed that they were fully aware of open systems initiatives

within the DoD and that, while the specific requirement might not be communicated on the SBIR solicitation, SBIR program managers often instruct small businesses to use OSA when submitting SBIR proposals. This highlights how the use of open systems and OSA principles in industry is regarded as an industry "best practice," and can be leveraged to the maximum extent possible to increase SBIR technology transition, enhance innovation, and reduce program life-cycle costs.

3. What are the experiences of small businesses in the IT sector who were awarded SBIR contracts?

To better understand the experiences of small IT businesses participating in the SBIR program, I conducted phone interviews with SBIR participants; the interview response rate was 32% and resulted in nine interviews. The original intent of the interview questions was to assess participant perceptions of DoD open systems initiatives and whether the DoD SBIR program has effectively communicated those initiatives to participating businesses. However, these interviews provided an additional opportunity to better understand these small firms, how successful they have been in the SBIR program, and what their general experiences have been in the SBIR program. As a result of these interviews, I made a number of observations that help describe the experiences of small, innovative IT firms participating in the SBIR program.

- Responses indicate that SBIR participants enter the program to augment funding as well as to align R&D efforts with identified customers. In fact, most participants interviewed for this research who were aware of their company's history in the program cited SBIR awards as a major component in early stage funding.
- The SBIR program is an effective mechanism for the DoD to communicate R&D requirements directly to small firms to achieve maximum participation of small businesses in government R&D and contracting.
- Most successful firms continuously participate in the SBIR program over time; 89% of those interviewed for this research intended to submit another SBIR proposal in the near future.
- Participants find the SBIR program very competitive, which is supported by the high number of proposals and limited number of contracts awarded by the DoD.
- The SBIR program provides external funding that successfully supports high-tech startup firms and their continued participation has been a result of a

perception that private funding would not adequately support the R&D project.

- Participating firms submit SBIR proposals that support the firm's "core technologies"; typically 50% of the time SBIR funds are used to advance or modify an existing product or technology, while the other 50% of the time the funds are used as a resource to create new projects, explore new product areas, and research and develop new technologies.
- Participants did not generally find the SBIR proposal process overly cumbersome and believed the process to be in line with expectations of federal contracting in general. Problems that occur are the result of differing SBIR proposal submission requirements imposed on small businesses by different components within the DoD.
- Small innovative IT businesses that participate in the SBIR program generally agreed that IT requirements were adequately defined in the SBIR RFP; some vagueness in SBIR RFPs is the result of a statement of objective language designed to promote innovation. Additionally, the SBIR program is improving in adequately defining IT requirements in SBIR RFPs.
- Participants overwhelmingly agreed that the SBIR program had directly contributed to company growth. Examples of SBIR-driven company growth provided in this research include the creation of new jobs to work directly on SBIR-funded R&D, particularly during phase II; stimulating other R&D projects within the company that are not funded by SBIR; and expanding firm revenue through technology transition into both a DoD program and commercial market.
- The research provided evidence that the SBIR program meets congressional objectives "to stimulate technological innovation" in the following ways: The SBIR-funded research often results in intellectual property, including patents and SBIR data rights; the program helps to develop technical expertise within the organization; and higher-risk basic research in the SBIR program results in more technical innovation because the efforts are often specifically focused on developing entirely new technologies.
- Seventy-eight percent of those interviewed for this research reported that they have personally received phase III commercialization funding, and most indicated that they have experienced considerable success obtaining phase III funding for multiple projects.
- Phase III commercialization of IST SBIR projects is evenly split between transitioning the technology into DoD acquisition programs and commercializing the product for sale or lease in the commercial marketplace.
- The most common best practices for successful SBIR phase III commercialization included identifying and communicating with potential customers upfront, focusing on developing the technology to meet specific customer requirements to achieve technology readiness level (TRL) 6 or 7 by

the end of phase II, and obtaining defense acquisition workforce point of contact information early for potential technology transition into a major defense acquisition program.

- Cost-plus contracts awarded to prime contractors for technology development can act as a disincentive for transitioning existing SBIR technologies into defense programs because the cost-plus contracts awarded to larger companies often provide a larger profit margin incentive to develop a technology in-house than potential cost savings from leasing it from a small SBIR firm.
- SBIR participants expressed concern regarding the implications of the SBIR/STTR Reauthorization Act of 2011 and subsequent policy directives, specifically SBA policies that allow foreign-owned entities access to the program, as well as new policies that allow small businesses competing in the SBIR program to be majority owned by non-small business entities.

4. What are the characteristics of small businesses in the IT sector who were awarded SBIR contracts?

A final objective of this research was to better understand the characteristics of small IT firms that participate in the SBIR program. To do so, I researched 14 firms and built case studies to illustrate what types of IT firms compete in the SBIR program and what the characteristics are of these small IT firms. Additionally, I used financial data made publicly available through the FPDS–NG database in order to draw comparisons between firms. Most firms described in the case studies appear to be heavily oriented toward the defense industry and federal government R&D activity. Additionally, most appear to receive additional revenue through the sale of products or services either as prime contractors to the DoD, or as sub-contractors to larger prime defense contractors; however, many also sell or lease technology in the commercial marketplace, often as a result of SBIR-funded activity.

The firms described are fairly young; nine of the 14 selected were founded within 10 years of the time period used to select topic and award data for this research. Employment ranged from in excess of 200 people (e.g., Navmar Applied Sciences Corp.) to two (e.g., Orielle LLC); the average employment for firms in this study was 76. Small IT firms participating in IST- and OSA-related SBIR awards tended to be categorized in the Research and Development in the Physical, Engineering, and Life Sciences area by the SBA (NAICS code 541712; Executive Office of the President, OMB, 2007).

Most well-established firms regularly participate in the SBIR program and are continuously awarded SBIR contracts for DoD R&D. Interview data collected suggests that most participants plan to continue participating in the SBIR program by submitting a proposal in the near future. On average, SBIR IT firms received $4.3 million in SBIR contract awards annually, excluding first-time award winners.

Of the firms reviewed for this research, only 29% were reported to be woman owned, 7% were minority owned, and 7% were located in a HUB zone. This suggests that the SBIR program has not adequately targeted disadvantaged small businesses; however, additional information on the demographics of firms submitting proposals would be required to make any substantiated finding.

The case studies did provide anecdotal information supporting phase III commercialization success by most small IT businesses; data collected from interviews reaffirms that the SBIR program has regularly led to phase III commercialization, and that the program has been a significant contributor to company growth. Comparing total revenue data to SBIR-related revenue for these small firms demonstrates higher volatility, and, thus, potentially higher risk, among the smallest firms participating in the SBIR program. This can be explained by the different uses of SBIR firms by this population: as startup funding, as a primary revenue source for DoD-specific R&D, or as a way to augment existing R&D funds. As total revenue increases, participation in SBIR tended to decrease with the two largest firms having less than 10% of total revenue from SBIR-related contracts. This suggests that larger, well-established firms in the program use SBIR funds primarily to augment R&D funding and to align technologies with potential customers, and that the primary sources of revenue result from commercial market sales and technology lease as well as federal contracting actions other than SBIR.

Finally, the case studies and interviews demonstrate and reveal two technology commercialization strategies for SBIR participants. Some firms develop SBIR technologies and subsequently enter commercial markets to sell or lease that technology; resulting revenue can be easily traced back to the SBIR firm. Some firms, on the other hand, develop technologies under the SBIR program and subsequently commercialize the products by spinning off separate companies to develop, manufacture, and sell those technologies in the

commercial marketplace. The latter approach to phase III commercialization highlights one roadblock to effectively assessing phase III commercialization success and SBIR program performance. If this "spin-off" approach to technology transition/commercialization is not thoroughly understood by researchers attempting to quantify the performance of firms in the SBIR program, it could result in underestimating the performance of participating firms or even the success of the SBIR program in general. Attempts to estimate the SBIR program's return on investment of federal funding become complex when revenue from a commercialized SBIR technology is received by a *different* firm than the one that initially developed it. Future attempts to assess program performance by tracing firm revenue to SBIR technologies, or the lack thereof, must account for the spin-off approach to SBIR technology commercialization to accurately describe and measure SBIR program performance.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Both the interviews and the case studies in this research revealed a spin-off approach to SBIR technology commercialization; however, little literature exists that attempts to study, evaluate, and further analyze this approach to technology transition. Future research could expand upon this observation and attempt to add to existing literature to describe how SBIR firms commercialize, and to evaluate how successful spin-off firms are after developing, manufacturing, and selling/leasing an SBIR technology.

Acceptance of OSA in DoD IT acquisition represents a major new SBIR access opportunity. Research conducted by a Tiger Team for the Navy SBIR program (Navy SBIR Program, 2008) identified that incorporating OSA principles in DoD acquisition facilitates SBIR technology transition (pp. 25–27). The report briefly discussed existing major defense acquisition programs, such as the littoral combat ship (LCS), that are currently integrating SBIR technologies: "Programs like the LCS have taken the first practical steps to integrating SBIR products into the systems designed by their prime contractors by utilizing DFARS language . . . in SBIR contracts" (Navy SBIR Program, 2008, p. 27). Future research could further examine the SBIR technology transition process in major defense acquisition projects. The research could use a case study methodology to identify transition best practices and

areas of concern, or provide an additional analysis specifically of those SBIR firms that participate in technology transition into a major defense acquisition program.

Intellectual property in the SBIR program is managed by the Defense Federal Acquisition Regulation Supplement (DFARS), which gives small businesses SBIR data rights. These data rights allow government access to technology developed under the SBIR program but afford small businesses legal protection from unauthorized use. This research did not address how intellectual property is developed in the SBIR program, nor did I attempt to further explore SBIR participant expectations or experiences of SBIR-related intellectual property. In my interviews, some PIs did allude to SBIR data rights as nearly as strong as a patent. Future research could further explore this topic and assess how well SBIR data rights provide legal protection to SBIR firms, whether they are considered by outside private investors, and how SBIR firms leverage SBIR data rights in future research.

This research was firm focused, rather than government focused. My interviews were explicitly focused on SBIR participants, and the case studies presented in this research seek only to better understand the nature and characteristics of SBIR firms. As such, this research could be expanded by reviewing how the DoD SBIR program offices incorporate OSA into SBIR topic RFP language, conducting interviews of SBIR program managers to better understand how OSA principles facilitate technology transition, and/or evaluating how IT-specific SBIR contracts are awarded to small businesses. Additionally, this research provides a snapshot only of FY2006–FY2010, which falls short of providing an updated assessment of open systems in the DoD SBIR program. Future research could use a similar framework to reassess the DoD SBIR program and focus on existing conditions, rather than presenting trends over time as was the case in this thesis.

Finally, many SBIR participants shared concerns regarding the implications of the SBIR/STTR Reauthorization Act of 2011 and subsequent SBA policy directives that appear to negatively affect small business participation in the SBIR program. The Act (2011) expanded funding for the SBIR program through 2017 and increased allowable award size thresholds; the SBA policies include allowing foreign-owned entities—including non-domestic businesses and foreign governments—access to compete in the SBIR program, as well as new policies that allow small businesses competing in the program to be majority

owned by non-small business entities, which includes large corporations, multiple VCOCs, hedge funds, and private equity firms. Future research could further examine the impact (positive and/or negative) of the expansion of the SBIR program under the SBIR/STTR Reauthorization Act of 2011, as well as the potential impacts of any subsequent SBA policy changes and how they have affected participation by small businesses in the SBIR program.

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APPENDIX A: FY2006–FY2010 SBIR SOLICITATION TOPIC SAMPLE

FY2010.3

	Topic Number	Component	Topic Title
1	MDA10-032	MDA	Radiation Hardened, Low Power, Variable Bandwidth/Resolution Digital-to-Analog or
2	MDA10-010	MDA	Smart Infrared Focal Plane Arrays and Advanced Electronics
3	AF103-107	Air Force	Thermal Control for Operationally Responsive Space (ORS) Satellites
4	N103-229	Navy	Gas Turbine Engine Exhaust Waste Heat Recovery Shipboard Module Development
5	AF103-219	Air Force	Jet Engine Passive Optical Sensor Technology
6	MDA10-013	MDA	Divert, Attitude Control and Axial Propulsion System Technologies
7	AF103-145	Air Force	Novel Analytical and Experimental Methods for Evaluating Repairs in Composite
8	AF103-134	Air Force	Munitions Effects on Building Infrastructure Components
9	AF103-070*	Air Force	Airborne Networking: Using Context-Awareness for Better Network Routing and Management
10	AF103-144*	Air Force	Fault Tolerant Mid-Wave Infrared (MWIR) Detector
11	AF103-085*	Air Force	Agile Space Radio (ASR)
12	N103-211	Navy	Automated Ultrashort Pulsed Laser (USPL) Tailoring Technology
13	AF103-200	Air Force	Thermal Interaction of High Performance Gas Turbine Engines Combustor Exit Products on Downstream Components
14	AF103-207	Air Force	Hypersonic Propulsion: Improvements in Control and Thermal Management Techniques
15	AF103-089	Air Force	Improved Solar Cell Power for Cubesats
16	AF103-073	Air Force	High-Power Satellite Communications Traveling Wave Tube Amplifier
17	AF103-125	Air Force	Cumulative Structural Damage from Multiple Weapons
18	AF103-136*	Air Force	Layered Sensing Bio-Signatures for Dismount Tracking
19	AF103-014	Air Force	Phase Locked Magnetrons
20	MDA10-019	MDA	Manufacturing Process Maturation for Propulsion Technology
21	AF103-090	Air Force	Light-Weight, High-Gain Receive/Transmit Navigation/Communication Antennas
22	AF103-250	Air Force	Covert Precision Aerial Delivery System
23	AF103-179*	Air Force	Real-Time Dismount Detection and Tracking Using Synthetic Aperture Radar (SAR)System
24	A10-161	Army	Electromagnetic Interference Shielding Fabrics for use with Soft Walled Shelters

25[1]	AF103-086	Air Force	High Compliance Thermal Interface Material for Space Applications
26	A10-175	Army	Robot Localization & Navigation for Night Operations in GPS Denied Areas
27	A10-173	Army	Untethered Video Transmission
28	AF103-061	Air Force	Condition-Based Health Management for Space Situational Awareness
29	AF103-166	Air Force	Methods for interfacing broad bandwidth data links to airborne ISR systems
30	AF103-114	Air Force	Strategically Radiation-Hardened Star Tracker

FY2010.2

	Topic Number	Component	Topic Title
1	N102-178	Navy	Combined electricity production and cryocooling
2	A10-113	Army	Electronic Sensing Fiber Scaffold Sensor
3	N102-184*	Navy	Isolation Techniques for Untrusted Software
4	A10-115	Army	Manufacturing Development of Biomimetic Tissue Engineering Scaffolds
5	N102-176*	Navy	Disambiguation of Entity Association Statements
6	A10-139	Army	Lithium Air Rechargeable Battery
7	A10-064*	Army	Light Weight Electric and Magnetic-Field Sensors for Unmanned Aerial Vehicles
8	OSD10-CR1	OSD	Rapid Assessment of Team Cognitive Readiness
9	N102-111	Navy	Ground Tactical Vehicle Prognostics and Health Management
10	OSD10-IA4*	OSD	Preventing Sensitive Information and Malicious Traffic from Leaving Computers
11	N102-153	Navy	Innovative materials/manufacturing for a prototype 600-1000VDC DC/DC Converter for Shipboard Radar
12	A10-100*	Army	Standoff-Biometric for Non-Cooperative Moving Subjects
13	A10-058	Army	Development of a Two Color Polarimetric Forward Looking Infrared (FLIR) Camera System
14	N102-171*	Navy	Compact Control Module for Short Towed Arrays
15	A10-122	Army	Lightweight EMI Resistant Wiring Solutions
16	N102-137	Navy	Near Infrared Lasers for High Energy Laser Applications

[1] SBIR solicitation topic data was obtained on the first 25 unique SBIR topics. To account for potential repetition of SBIR topics when creating a randomized sample, 30 topics were selected at random from each SBIR solicitation to create a randomized data set, as depicted in this appendix.

* SBIR solicitation topic supports research and development effort directly supporting a system defined as a National Security System (NSS).

17	SB102-005*	DARPA	Revolutionary Advances in Large-Scale Manufacturing in Quantities of One
18	N102-165	Navy	Optically Precise Conformal Sensor Window
19	N102-148	Navy	Develop Radar Radome Materials, Processes and Test Methodology
20	A10-116	Army	Miniaturized Fluidic Chip for Impedance Monitoring of Vertebrate Cells
21	N102-106	Navy	High Strength Stress Corrosion Resistant Aluminum Casting Alloys
22	N102-128	Navy	Predictions of the Acoustic Nearfield on a Carrier Deck
23	A10-099	Army	Solid Hydrogen Fuel Cartridges
24	A10-126*	Army	Reduction of vehicle display-induced motion sickness
25	A10-093*	Army	Intelligent Human Motion Detection Sensor
26	A10-033	Army	Non-Metallic/Metallic Debris Sensor
27	N102-173	Navy	Fire Simulation and Residual Strength Prediction Tool for Aluminum Ship Structures During and After Fire
28	N102-157	Navy	Light High-Speed Amphibious Vehicle
29	A10-101	Army	Repeatable Virtualization of Intelligence, Surveillance & Reconnaissance (ISR) System Servers
30	A10-094	Army	Advanced Thermoelectric Milli-Power Source

FY2010.1

	Topic Number	Component	Topic Title
1	N101-069	Navy	Innovative Wideband Antenna Technology for Ultimate Consolidated Submarine Mast
2	N101-073*	Navy	Terminal Guidance for Autonomous Aerial Refueling
3	SB101-006*	DARPA	Adaptive Data Visualization Under Cognitive and Communications Bandwidth Limitations
4	CBD10-110	CBD	Nanofluidic Sensor Platforms for THz-Frequency Spectroscopic Fingerprinting of Bio-Molecules
5	A10-028	Army	Innovative and Novel Concepts for Eye-Safe Wavelength High Power Fiber Lasers for Increased Performance
6	N101-037	Navy	Investigation of the Debye Effect for Submarine Detection
7	A10-020	Army	Advanced Molded Glass Lenses
8	A10-009*	Army	Automation of the Operational Test Data Process
9	N101-001	Navy	Mitigation of Blast Injuries through Modeling and Simulation
10	N101-087	Navy	Counter Directed Energy Weapons (C- DEW)
11	A10-021	Army	Lightweight, Wide Field-Of-View Wave-guided Head-mounted Display
12	A10-001	Army	Innovative Method to Correlate Sub-Scale to Full-Scale Insensitive Munition Tests

13	N101-021*	Navy	Innovative Structures for Sonobuoy Applications
14	SOCOM10-006*	SOCOM	Micro Weather Sensor (MWS)
15	N101-028	Navy	Computational Characterization of Aeroengine Combustor/Augmentor Fuel Injectors
16	N101-099*	Navy	Spectrum Agile Network Distributed Subcarrier Allocation
17	CBD10-107	CBD	High Throughput Screening to Identify Enzyme Variants with Increased Affinity for Organophosphorus Compounds
18	A10-006*	Army	Missile Delivered UAV
19	CBD10-103	CBD	In vitro Models Suitable for High-throughput Screening of Drug Toxicities in Human Tissues
20	N101-051	Navy	Simplified Topside Design and Assessment Tool
21	SOCOM10-006*	SOCOM	Micro Weather Sensor (MWS)
22	N101-021	Navy	Innovative Structures for Sonobuoy Applications
23	N101-067	Navy	Material Multi-Solution for Hypersonic Systems
24	N101-002	Navy	Modular Lightweight Armor System
25	A10-012*	Army	Coordinated Responses through Knowledge Sharing in Mobile Agent-Based Intrusion Detection Systems
26	A10-018	Army	In-Vacuo Passivation of High Aspect Ratio HgCdTe Surfaces
27	N101-084	Navy	Strained Layer Superlattice (SLS) Dual Band Focal Plane Array (FPA) (Appears to be a topic canceled by DoN)
28	N101-092	Navy	Cost-Effective PiezoCrystal Transducer Assembly Technologies
29	N101-053	Navy	Low-cost Cabling Infrastructure for Naval Electronics Systems
30	N101-083	Navy	Fast, High Resolution 3-D Flash LIDAR Imager

FY2009.3

	Topic Number	Component	Topic Title
1	AF093-054*	Air Force	Securing personal mobile devices for use as digital proxies
2	MDA09-034	MDA	Terahertz Signature Modeling for Kill Assessment and Warhead Materials Identification
3	AF093-031*	Air Force	Intuitive Interfaces for "Layered Sensing"
4	N093-190	Navy	Opportunistic Energy Harvesting
5	AF093-075*	Air Force	Discrimination and Identification of Closely-Spaced Objects (CSO)
6	A09-146*	Army	Proactive Automatic Information Requests
7	AF093-141*	Air Force	Airborne Detection of Spoofed ADS-B Reports
8	AF093-147	Air Force	Highly Linear E-Band Traveling Wave Tube Amplifier

9	OSD09-H12	OSD	Application of semantic web technologies to alert providers regarding poly-pharmacy issues in traumatic brain injury (TBI) and/or post-traumatic… (PTSD) military patients
10	AF093-175	Air Force	Innovative Thermal Management Technologies for Dissipating Full Authority Digital Engine Control (FADEC) Electronics Heat
11	N093-227*	Navy	Automated Analysis and Verification of Application Program Interfaces (APIs)
12	N093-214*	Navy	At-sea Reliability with Predictive Modeling
13	N093-162	Navy	DOD Engine Efficiency Enhancement Technology
14	OSD09-H22	OSD	Treatment of mTBI Balance Dysfuntion via Multimodal Biofeedback
15	AF093-064	Air Force	Canisterized Satellite Development for Operationally Responsive Space
16	MDA09-023*	MDA	Enhanced Spacecraft Survivability
17	AF093-098	Air Force	High Density or Multi-Functional Compact Power Source
18	A09-178	Army	Development of High Power Lithium-ion Batteries
19	AF093-088*	Air Force	Modular Cubesat Architectures and Components
20	A09-196	Army	Autonomous Indoor Mapping and Modeling
21	AF093-174	Air Force	Improved Full Authority Digital Engine Control (FADEC) System
22	A09-193	Army	Variable Speed Alternator Drive
23	AF093-165	Air Force	Robust Spark and Plasma Ignition Systems for Gas Turbine Main Combustors and Augmentors
24	OSD09-H10	OSD	Natural Polymers for Cranio-facial Tissue Engineering
25	OSD09-H07	OSD	Evidence-Based Evaluation Process for Traumatic Brain Injuries and Co-morbid Psychological Disorders in Service Members
26	SB093-003	DARPA	Combat Resilience: Inoculating the Warfighter Against Combat Stress
27	AF093-164	Air Force	Efficient Implementation of Models for Improved Prediction of Gas Turbine Combustor and Augmentor Robustness
28	A09-192	Army	System Design Optimization Model
29	OSD09-H25	OSD	Remote Diagnostic Access and Automated Proactive Medical Equipment Monitoring in support of Hospital of the Future Initiatives
30	A09-192	Army	Nano-Lubricant/Fluid for Improved Weapons System

FY2009.2

	Topic Number	Component	Topic Title
1	A09-042	Army	Approaches and Techniques for Specialized Character Recognition (CR) and Hand Writing Recognition (HWR) of Named-Entity Categories… Romanized Document Images
2	A09-026	Army	Innovative Real Time Probes
3	SB092-006	DARPA	Digital Analysis Computing Software Solutions for the Supply Chain
4	A09-091	Army	Rapid Frame Rate Focal Plane Arrays for Active Electro-Optic Applications

5	N092-101	Navy	Electromagnetic Scattering Effects of Sea on the Radar Cross Section (RCS) of Small Boats in Littoral and Deep Ocean Environments.
6	A09-088*	Army	Context Based Data Abstraction
7	A09-031	Army	Automated Manufacturing of Composite Materials including Armament Applications
8	A09-057	Army	Ultraviolet photodetectors based on wide-bandgap oxide semiconductors
9	A09-027	Army	Nanostructured High Performance Energetic Materials
10	A09-096	Army	Self Healing, Self-Diagnosing Fiber Reinforced Multifunctional Composites
11	A09-069	Army	High Output and Multi-Band Laser for Electro-Optical/Infra Red Counter Measure (EO/IRCM)
12	A09-113	Army	Advanced low-power personnel/vehicle detecting radar for smart unattended ground sensor/munition systems
13	A09-039	Army	Innovative Coatings for Lightweight Alloys
14	A09-054	Army	Full Field, Out-of-Plane Digital Image Correlation (DIC) from Ultra-High Speed Digital Cameras
15	OSD09-SP4*	OSD	Designing Large Data Handling Architectures
16	N092-126	Navy	Light-weight Power Dense Distribution Cable
17	A09-109	Army	Personnel High Rate Data Recorder
18	A09-046*	Army	Ultra Resolution Camera for C4ISR Applications
19	A09-063	Army	Chaotic Modulation for Satellite Communications (SATCOM) Communications Systems
20	A09-081*	Army	Identity Management of Biometric Data (IMBD) across the Global Information Grid (GIG) using a Service Oriented Architecture (SOA) Framework
21	A09-092	Army	50- 100 Watt Wind Energy Harvesting in Light Tactical Applications
22	A09-051	Army	Innovative manufacturing research on forming of large light armor alloy sections resistant to blast and penetration
23	A09-101	Army	Passive Standoff Detection of Chlorine
24	A09-015*	Army	Self-Powered, High-Temperature, Wireless Sensors for Rotorcraft Applications
25	A09-017*	Army	Reactive Real-time Planners for Coordinated Aggressive Maneuvers
26	A09-102	Army	Application of Finger-Mounted Ultrasound Array Probes
27	N092-118	Navy	Fiber Optic Connector Inspection Test Set
28	SB092-016	DARPA	Networked Cubesat Clusters
29	A09-066	Army	Distributed Satellite Communications (SATCOM) On-the-Move (OTM) Aperture
30	N092-156	Navy	Advanced Breakwater and Causeway Design Concepts

FY2009.1

	Topic Number	Component	Topic Title
1	N091-005	Navy	Alternative Lightweight Solution to the E-SAPI
2	AF091C-001	Air Force	Affordable Accurate Robot Guidance (AARG)
3	A09-009	Army	Low-Cost Method for Metal Nano-Coating of Anisotropic Carbon Fibers
4	A09-006	Army	Missile Interceptor Base Flow Simulation
5	CBD09-103	CBD	Real Time Detection of Trace Amounts of Methyl Salicylate
6	SB091-007	DARPA	Integrated Low Jitter Mode Locked Lasers
7	SB091-012*	DARPA	Robust Distributed GPS Apertures
8	A09-005*	Army	Polarimetric Sensor for Air-to-Surface Missile Systems
9	A09-012*	Army	Tactical Ballistic Missile (TBM) Composite Tracking and Discrimination Capability for Army System of Systems (ASoS) Integrated Air and…
10	SB091-001	DARPA	Multiferroic Approach to Heat Pumps
11	N091-011	Navy	Innovative Approaches to Develop Advanced Matrix Materials for High Thermal and Environmental Stability of Ceramic Matrix Composites (CMCs)
12	N091-068*	Navy	Autonomous Fusion and Processing of Data from a Distributed Sensor System
13	OSD09-C04	OSD	Innovative Approaches for the Development of Ultra-High Strength Intrinsically Corrosion Resistant Steel
14	N091-079	Navy	Portable Sources of Ultracold Atoms
15	N091-058	Navy	Shape Changing, Reduced Density, Towed Array Hose
16	A09-003	Army	High-Speed Surface Measurement Device
17	N091-048*	Navy	Fiber Optic Temperature Sensors for Long Cryogenic Thermal Paths
18	N091-023	Navy	Assessing Electromagnetic Scattering Properties of Small Boats in Littoral Environments Using Hardware Accelerated Computing
19	N091-067	Navy	Improved Optical Filters to Support Submarine Optical Communications Links
20	N091-045	OSD	Lattice Block Structures for Missile Structural Components
21	OSD09-H01	DARPA	Cognitive/Motor Therapy Application Using Console-Based Videogame Platform
22	SB091-001	DARPA	Multiferroic Approach to Heat Pumps
23	SB091-008	DARPA	Design and Fabrication Techniques for 3-Dimensional Integrated Circuits
24	N091-076*	Navy	Translation of network metrics to behavior attributes
25	N091-035	Navy	Elimination of Carbon Monoxide From Pilot’s Breathing Oxygen
26	N091-020	Navy	Environmentally Protective Coatings for CeramicMatrix Composites
27	A09-009	Army	Low-Cost Method for Metal Nano-Coating of Anisotropic Carbon Fibers
28	N091-048*	Navy	Fiber Optic Temperature Sensors for Long Cryogenic Thermal Paths
29	N091-074	Navy	High Velocity, Compact Cooling Coils for Naval Systems

30	N091-082	Navy	Replanning and Operator Situation Awareness Tools for Operation of Unmanned Systems in Complex Airspaces and Waterspaces

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	Topic Number	Component	Topic Title
1	N08-211	Navy	Rapid Electrical Outfitting For Shipbuilding
2	AF083-257	Air Force	High Heating Rate Calorimeter Calibration System
3	AF083-143*	Air Force	Coherent Change Detection for Predictive Battlespace Awareness: Ground Moving Target Identification (GMTI) Forensics
4	AF083-090	Air Force	Retrofittable Laser Protection for Weapons
5	AF083-235	Air Force	Environmental Boundary System
6	OSD08-H18	OSD	Pro-Active Dynamic Accommodating Socket
7	AF083-005	Air Force	Innovative, Lightweight Methods For Thermal Management of HEL Mirror Subsystems
8	A08-185	Army	Greywater Recycling System for Mobile Kitchens and Sanitation Centers
9	N08-205*	Navy	Radar Detection and Tracking of Small Maritime Targets at High Grazing Angles
10	N08-220	Navy	Innovative Deployment & Stowage Technologies
11	MDA08-010	MDA	Improved Cryogenic Cooling Technology
12	AF083-043*	Air Force	Rate-Adaptive High-Availability RF Links
13	AF083-193*	Air Force	Bandwidth Efficient SATCOM Waveform Techniques
14	N08-209*	Navy	Embedded Training Techniques for Target Discrimination Systems
15	N08-217	Navy	Low Cost, Low Power, SAASM GPS Receiver with Up Finding Capability for Gun Launched Projectiles
16	AF083-135*	Air Force	Geolocation of RF Emitters
17	AF083-216*	Air Force	ESPA Based Satellite Bus
18	OSD08-M03	OSD	Assessment and Modeling of Shock and Vibration Performance of Lead-Free Alloys
19	MDA08-050	MDA	Passive Range Estimation from Angle-only Sensor Data (Acq Pointing & Tracking)
20	AF083-190	Air Force	Innovative Lasing Techniques for Satellite Signal Distribution
21	AF083-215	Air Force	Space-based Carbon Nanotube Ultracapacitor
22	AF083-224	Air Force	Electro-Optical (EO), Infrared (IR) and Radio Frequency (RF) Calibration Structures
23	MDA08-049	MDA	Advanced Light-Weight Solid State Laser Cooling System (High Power Solid State Laser)
24	AF083-137*	Air Force	Miniature Multi-Spectral Imaging for Small and Micro Unmanned Air Vehicles (UAVs)
25	AF083-005	Air Force	Innovative, Lightweight Methods For Thermal Management of HEL Mirror Subsystems

26	MDA08-038	MDA	Global Missile Defense Battle Management
27	MDA08-022	MDA	Ballistic Missile Defense System Innovative Power
28	AF083-194	Air Force	Autonomous Vehicle Awareness Sensors
29	AF083-126	Air Force	Tough Ultra High Temperature Ceramic Materials for Structural Applications
30	AF083-171	Air Force	Trust-Based Dynamic Routing Protocol for Wireless Sensor Network (WSN)

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	Topic Number	Component	Topic Title
1	A08-118	Army	Malaria Diagnostic Methods to Replace Microscopy in Clinical Trials
2	N08-127	Navy	Non-Contact Cure State Measurement
3	A08-041	Army	Improved Field of Regard for Strap Down Semi Active Laser Seekers
4	SB082-040	DARPA	Self-Seeded Programmable Parametric Fiber Comb Source
5	A08-028	Army	Complementary Non-Destructive Evaluation (NDE)/Testing (NDT) Techniques for Stockpile Reliability Programs (SRP) of U.S. Army Tactical…
6	N08-165*	Navy	Processing Signals In High Density Electromagnetic Environments
7	SB082-060*	DARPA	Wireless Avionics Architecture for Payload Delivery Launch Systems
8	N08-109*	Navy	“Smart Dust” and Nanotechnology for Joint Weapons Systems Diagnostics/Prognostics
9	N08-160	Navy	Micro-Lens Array Based Night Vision Optical Components
10	A08-068	Army	Cold Spray Nanostructured Powders
11	N08-151	Navy	Non-GPS Sonobouy Positioning System
12	N08-196*	Navy	An Asynchronous SINCGARS (Single Channel Ground and Airborne Radio System) Frequency Hopping Notch Filter Based on Canceller Technology
13	OSD08-H06	OSD	Interactive Cognitive Interface and Health Monitoring System (Army)
14	A08-035	Army	High Aspect Ratio EMI Grid Application Technique
15	SB082-016	DARPA	Multi Input Wireless Look-Through Heads Up Display (HUD) for Use in Multiple Extreme Environments
17	A08-129	Army	Encrypt/Decrypt Mobile Devices with Biometric Signature
18	SB082-043	DARPA	Template-Based Lithography for Advanced Low-Volume Electronics
19	A08-028	Army	Complementary Non-Destructive Evaluation (NDE)/Testing (NDT) Techniques for Stockpile Reliability Programs (SRP) of U.S. Army Tactical…
20	N08-140	Navy	Improved Low Light Level, Wide Multi-Band Infrared Imager
21	A08-129	Army	Encrypt/Decrypt Mobile Devices with Biometric Signature
22	A08-028	Army	Complementary Non-Destructive Evaluation (NDE)/Testing (NDT) Techniques for Stockpile Reliability Programs (SRP) of U.S. Army Tactical…

23	A08-139	Army	Vertical Cavity Surface-Emitting Laser (VCSEL) pumps for Reduced Eye Hazard Wavelength High Energy Fiber Lasers
24	N08-188	Navy	Edge Bonding of Infrared Windows Canceled
25	A08-049	Army	Structurally Integrated Position and Orientation Sensor and Seeker Technologies
26	A08-069	Army	Scalable & Adaptive Munitions Technologies
27	SB082-041	DARPA	Extended Duration Arbitrary Waveform Generation over Large Bandwidths
29	A08-058*	Army	Situation Awareness Assessment Tools for Network Enabled Command and Control Field Evaluations
30	A08-103	Army	Passivation Innovations for Large Format Reduced Pixel pitch strained layer superlatticeFocalPlane Array Imagers Operating in the Long Wavelength

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	Topic Number	Component	Topic Title
1	OSD08-IA1	OSD	Software Partitioning to Migrate Critical Software Components to Trusted Hardware
2	AF081-053	Air Force	Monitoring and Prognostics for Rolling Element Bearing Health in Gas Turbine Engines
3	AF081-031	Air Force	Wideband,Lightweight, Beamformer
4	N08-058 *	Navy	Approaches to Directly Measure Heave, Pitch and Roll Onboard Navy Ships
5	N08-050	Navy	High-Energy Short-Pulse Fiber Amplifier at Eye-Safe Wavelengths
6	SOCOM08-005	SOCOM	Lightweight, Compact Atmospheric Gas Sensor
7	AF081-051*	Air Force	Processing for Flexible Sensors
8	N08-071	Navy	Lightweight, High Temperature, Low Cost Materials for Mach 4-5 Cruise Missiles
9	A08-001	Army	Locus of Control as a Mediator of Risk Perception and Decision Making Among Army Aviators
10	DTRA08-002	DTRA	High-energy Neutron Interrogation for Special Nuclear Materials Detection
11	N08-008*	Navy	Commandable Mobile Anti Submarine Warfare Sensor (CMAS)
12	AF081-011	Air Force	Head Mounting Device for Advanced Night Vision Goggle (NVG) Systems
13	A08-013	Army	High-Fidelity Runtime Database Engine
14	N08-068	Navy	Reference Template Generation for Cross-Correlation Based Receivers
15	N08-018	Navy	Cylindrical/Ogive Phased Array Transmitter for Jammers
16	AF081-008	Air Force	Optical Limiters Without Focal Planes
17	N08-039	Navy	Wide Bandgap Amplifier Linearization
18	AF081-101	Air Force	Development of Cad Plating Replacement with Alkaline Zinc-Nickel Electroplating for Threaded Fasteners/Components
19	AF081-053	Air Force	Monitoring and Prognostics for Rolling Element Bearing Health in Gas Turbine Engines
20	DTRA08-001	DTRA	Directed Mono-Energetic Gamma Source Generation and Detection

21	OSD08-PR1	OSD	Variable Thrust Liquid or Gel Propulsion for Mission Flexibility
22	A08-002	Army	Leader Training for Building and Maintaining an Ethical Unit Climate
23	OSD08-UM5	OSD	Integrated Power Generation for Small Unmanned Vehicles
24	AF081-055*	Air Force	Expanding the Processing Capability of On-Line Propulsion Health Management (PHM)
25	AF081-062	Air Force	Bismuth Hall Thruster Contamination Characterization and Mitigation
26	N08-067*	Navy	Live Fire Virtual Sniper/Counter Sniper Training System
27	AF081-101	Air Force	Development of Cad Plating Replacement with Alkaline Zinc-Nickel Electroplating for Threaded Fasteners/Components
28	OSD08-IA4	OSD	Assuring Trust between the Edges
29	AF081-038	Air Force	Modeling and Simulation for Robust Ceramic Matrix Composite (CMC) Manufacturing Processes
30	SOCOM08-004	SOCOM	Wireless Low Probability of Detection (LPD) Capability Onboard Surface Combatant Craft

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	Topic Number	Component	Topic Title
1	AF073-014	Air Force	Rapidly Configurable Modular Litter System for Use in Aeromedical Transport
2	N07-206	Navy	Advanced Direct Energy Conversion for Power Electronics Cooling
3	N07-194	Navy	Shipboard Low Noise Amplifier Assembly.
4	MDA07-040*	MDA	Configuration Validation Technologies
5	AF073-100	Air Force	Ultra-Low-Power Radiation-Hard Electronics
6	MDA07-018*	MDA	High Fidelity Missile Hardbody Plume Interaction Modeling
7	AF073-020*	Air Force	Reservation Based Quality of Service (QoS) in an Airborne Network
8	AF073-131	Air Force	Linear Cryo-Motion for Space Simulation Testing
9	MDA07-007	MDA	Passive Cooling of Laser Diodes for Use on Satellites
10	MDA07-001	MDA	Advanced Sensor Materials for Space
11	MDA07-033*	MDA	Forecasting IR Satellite Imagery for Adaptive Sensor Tasking
12	MDA07-037*	MDA	Distributed Aperture Radar Signal Processing Algorithms, Waveforms, and Signal Processing
13	MDA07-023	MDA	Ballistic Missile Defense System Innovative Power Generation and Storage Devices
14	MDA07-019	MDA	Hypervelocity Intercept Modeling with First-Principle, Physics-Based Tools
15	AF073-102	Air Force	Satellite Structures with Engineered or Variable Electromagnetic Properties
16	AF073-051	Air Force	Test Method for Inducing Steep Thermal Gradients in Thin-Walled Structures

17	NGA07-001*	NGA	High-Sensitivity Military GPS Receivers
18	AF073-029*	Air Force	Proactive Determination of Network Node Vulnerability
19	AF073-066	Air Force	Low Profile Wideband Antennas for the Joint Tactical Radio System (JTRS)
20	MDA07-004	MDA	Improved Cryocooling Component Technologies
21	N07-215	Navy	Fiber Optic Vector Sensor Arrays
22	AF073-043	Air Force	Development of High-Definition (HD), Low-Light-Level Detector
23	AF073-025*	Air Force	Metadata & Information Tagging Technologies for Application Interoperability and Services
24	AF073-074*	Air Force	Multi Channel Radio Frequency Application-Specific Integrated Circuit (RFASIC) for Handheld GPS Receiver Anti Jam Enhancement
25	AF073-080	Air Force	Managing Uncertainty in Anticipatory Exploitation
26	N07-194	Navy	Shipboard Low Noise Amplifier Assembly.
27	AF073-048	Air Force	Temperature-Tolerant Processor for Reliable Control
28	AF073-003	Air Force	Cryogenic High Powered Laser Pump Diodes
29	AF073-123	Air Force	Trace Level Sulfur Sensor
30	AF073-130	Air Force	Wireless Fire Detector

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	Topic Number	Component	Topic Title
1	N07-142*	Navy	Assessing the Impact of GPS Degradation Using Campaign-level Warfare Modeling
2	A07-020*	Army	Virtual Sensor Wiring Harness for Hazardous Environments
3	A07-123*	Army	Novel Representations of Elevation Data
4	N07-154	Navy	Multi-carrier VHF/UHF amplifier with suppressed intermodulation products
5	A07-117	Army	Standoff Explosives Detection
6	A07-188	Army	Power Conditioning for Explosive Pulsed Power for Missiles and Munitions
7	SB072-038	DARPA	Wireless Power Transmission with Electromagnetic Inductive Coupling
8	N07-157	Navy	Geoacoustic Sea Bottom Characterization Using Passive, Cost-Effective Sensors
9	A07-164	Army	Lightweight, low-cost armor panels for installation in soft-walled shelters
10	A07-071*	Army	Development of Innovative Fusion Algorithms for Color Night Vision
11	A07-163	Army	Off-Grid Pallet Chilling for Bottled Water
12	A07-008	Army	Smart Autonomous Miniaturized Contamination Condition Sensor with Embedded Prognostics

13	N07-142*	Navy	Assessing the Impact of GPS Degradation Using Campaign-level Warfare Modeling
14	A07-183	Army	Accessory Rail Communication and Power Transfer
15	A07-010*	Army	Computational Fluid Dynamics Co-processing for Unsteady Visualization
16	A07-204	Army	Develop Aluminum Metal Matrix Components (Al MMC) and Manufacturing Applications for both Military and Commercial Vehicles
17	A07-212	Army	Application of Spot Cooling Technologies for the Thermal Management at the Source
18	N07-131*	Navy	Innovative Flow Control Devices for Shipboard Fluid System Rupture Isolation
19	A07-023	Army	Embedded Vibration Monitoring and Real-Time Data Analysis and Reduction
20	SB072-029	DARPA	Electro-Optic Polymer Based Ultra-Linear Directional Coupler
21	A07-040	Army	High-flux electronically generated thermal neutron source for radiographic applications
22	A07-120	Army	Body Wearable Diversity Antenna Systems for Increased Antenna Performance
23	SB072-007	DARPA	Tracked Vehicle Barriers
24	N07-131*	Navy	Innovative Flow Control Devices for Shipboard Fluid System Rupture Isolation
25	A07-042	Army	Visible to Short Wavelength Infrared Hyperscope for Armaments
26	A07-170	Army	Innovative Propulsion Methods for Small Arms Projectiles
27	A07-023	Army	Embedded Vibration Monitoring and Real-Time Data Analysis and Reduction
28	A07-178	Army	Multi-mechanism, Mine Blast Protection
29	A07-161	Army	Novel Interactive Insignia for Combat Uniforms
30	A07-114	Army	Low-Cost, Multi-Channel Arbitrary Waveform Generator

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	Topic Number	Component	Topic Title
1	N07-075	Navy	High Frequency Broadband Hybrid Transducer/Amplifier
2	AF071-116	Air Force	Novel Aircraft Anti-Ice Coating Material
3	AF071-022*	Air Force	Helmet-Mounted G-Tolerant Eye Tracker
4	N07-097	Navy	Erosion Resistance Coatings for Composite Propulsor/Fan Blades
5	AF071-086	Air Force	Antenna Array Structures for Composite Airframes
6	AF071-037	Air Force	Accelerated Skill Acquisition for Intelligence Analysts
7	AF071-256	Air Force	Improving Weapons Bay Acoustical Environments
8	AF071-239*	Air Force	Spatially Registered Multispectral Polarimetric Sensor

9	N07-023	Navy	RF Sensor Performance in Electrically Large, Complex Environments
10	DTRA07-005	DTRA	The Characterization and Mitigation of Single Event Effects in Ultra-Deep Submicron (< 90nm) Microelectronics
11	AF071-221*	Air Force	Identify Alternative Information Assurance (IA) Mechanisms
12	AF071-061*	Air Force	GMTI Forensics Analysis Tools
13	N07-057	Navy	Advanced Emergency Leak Arresting Technology
14	AF071-356	Air Force	Optical Ground Vibration Test
15	N07-081	Navy	Transient Electrical Power Response Enhancement for Turbine Driven Generators
16	AF071-266	Air Force	Innovative Control Effectors for Common Aerovehicle (CAVs)
17	AF071-127	Air Force	Health Management of High Temperature Polymer Composites
18	AF071-327	Air Force	Universal Method of Bonding Steel Repairs to Aluminum Structures
19	CBD07-105	CBD	Enhanced Capability Point Combined Bio and Chem Sensor
20	AF071-217	Air Force	Directional Finding for Sources with Unknown Bandwidths and Center Frequencies
21	N07-048	Navy	Innovative Approaches for Improving the Hot/Wet Performance of Polyimide Matrix Composites
22	N07-102	Navy	Finding Repetitive Crime Supporting Structures (Building Intent)
23	AF071-317	Air Force	Development of Pulse Water Strip of Tungsten Carbide HVOF Coatings and Chrome Plating on Landing Gear Components
24	CBD07-107	CBD	Enhanced Respirator Exhalation System
25	N07-102	Navy	Finding Repetitive Crime Supporting Structures (Building Intent)
26	N07-008	Navy	Fast And Accurate Radar Signal Processing In Non-Gaussian Stable Environments
27	N07-058	Navy	Affordable Virtual Environment for Shipbuilding
28	AF071-135	Air Force	Weld Repair of Titanium Alloys for Turbine Engine Applications
29	AF071-002	Air Force	Aero-Optics Beacon
30	N07-075	Navy	High Frequency Broadband Hybrid Transducer/Amplifier

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	Topic Number	Component	Topic Title
1	AF063-006	Air Force	Multi-Orbit Earth Sensor for Earth Pointing and Attitude Determination
2	MDA06-039	MDA	Hypergolic Chemical Leak Detector
3	MDA06-028	MDA	Advanced Missile Materials and Process Technologies
4	MDA06-027	MDA	Manufacturing Processes for Propulsion Technology

5	N06-179*	Navy	Real-Time, Secure, and Fault Tolerant Discovery for Publish-Subscribe Middleware in a WAN Environment
6	OSD06-EP2	OSD	Innovative Motor and Generator Technologies
7	N06-172	Navy	Affordable Alternative Power Supply for Uninterruptible Power Supply (UPS) Systems
8	OSD06-PR1	OSD	Solid Propellant Binders for Solid Rocket Motors
9	N06-173	Navy	Technologies to Improve Mid-tiered Shipbuilding Design and Planning Functions
10	OSD06-UM3	OSD	Human-Robot Manipulation for Complex Operations
11	OSD06-EP6	OSD	Reduced Temperature, High Power Thermal Battery Chemistry
12	MDA06-003*	MDA	Integration Framework for Heterogeneous Distributed Systems
13	OSD06-CR3	OSD	Skill Training in a Cultural Context through Distributed Simulations
14	MDA06-044*	MDA	Manufacturing Technology Innovations for Radiation Hardened Electronics for Interceptor and Satellite Control Systems.
15	OSD06-UM3	OSD	Human-Robot Manipulation for Complex Operations
16	OSD06-UM5	OSD	Peer-to-Peer Embedded Human Robot Interaction
17	N06-176	Navy	Advanced Bridge Windows for Surface Ships
18	OSD06-CR4	OSD	Inserting Cultural Context in Distributed Simulations
19	OSD06-EP5	OSD	Anode Materials for Rapid Recharge High Energy Density Lithium Ion Batteries
20	MDA06-042*	MDA	Radiation Hard Electronic Components
21	OSD06-UM2*	OSD	Cooperative Tracking of Elusive Dismounts by Human Assisted UAV-UGV
22	MDA06-051	MDA	Ballistic Missile Defense Anti-Tamper Coating Manufacturing
23	MDA06-047 *	MDA	Development of High-Fidelity Techniques to Model Impact Flash and Post-Impact Thermal Signature Prediction and Support Kill Assessment
24	AF063C-011	Air Force	Terminally Guided Robots and Robotic Applications in Confined Spaces
25	OSD06-IA6*	OSD	Kernel-mode Software Protection to Prevent Piracy, Reverse Engineering, and Tampering of End-Node Applications
26	OSD06-IA8	OSD	Software Protection for Embedded Applications
27	N06-175	Navy	High Energy Material Containment
28	N06-172	Navy	Affordable Alternative Power Supply for Uninterruptible Power Supply (UPS) Systems
29	AF063-002	Air Force	Radiation Hard High Precision Agile Star Tracker
30	MDA06-052	MDA	Ballistic Missile Defense Anti-Tamper Volume Protection

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	Topic Number	Component	Topic Title

1	A06-144	Army	“Smart” Intermodal Shipping Containers
2	A06-181	Army	Pressure Measurement System for Parachute Fabrics And Other Textiles
3	A06-151	Army	Ultrasound or Ophthalmodynamometry Technologies for Battlefield Diagnosis of Traumatic Brain Injury
4	A06-111	Army	Compact Fast Tunning Direct Digital Synthesizer (DDS) Signal Generator for Electronics Warfare (EW) Jammer Systems
5	N06-123*	Navy	AESA-based RADAR Performance in Complex Sensor Environments
6	A06-225	Army	Advanced Fuel Injection System and Valve Train Technologies
7	A06-069	Army	Structural Damage Effects to Army Vehicles
8	A06-203*	Army	UGV Dynamic Mobility Updates Using Real Time Prognostic and Diagnostic Information
9	SB062-021	DARPA	Multiple Foveated Vision Sensor for Bandwidth Optimization
10	N06-148*	Navy	Collaborative Knowledge Management for Net-Centric Systems
11	A06-047	Army	Innovative Harware-Based Chip Control Technologies
12	N06-118	Navy	Advanced Blade-Damping Coatings
13	A06-211	Army	Reusable Synthetic Tissue for Severe Trauma Training
14	A06-055	Army	High Temperature Sensor for Consolidation of Refractory Metals and Alloys
15	A06-155	Army	Automated Laser Debridement System for Cutaneous Injuries
16	N06-153*	Navy	Semantical Machine Understanding
17	A06-064*	Army	Dynamic Ad-Hoc Network Communications Visualization and Control
18	SB062-020	DARPA	Sparse Array Applications for Small Satellites
19	A06-238	Army	Remote Autonomous Robot Mounted Laser Night Vision Surveillance System
20	A06-059	Army	Virtual Demonstrations for Infantry Training
21	N06-105	Navy	Marine Portable Power Unit
22	A06-127	Army	Dual Band X/Ka On-The-Move Antenna System
23	N06-109*	Navy	Data Fusion Handoff
24	N06-140	Navy	Power Generation and Management Module
25	A06-226	Army	Demonstrate Novel Techniques to Manufacture Advanced Complex Three-dimensional Fuel Injector Nozzle Shapes to Improve Combustion Efficiency and Reduce Emissions
26	N06-130	Navy	LIDAR Sensor for Underwater and Airborne Mine Detection
27	A06-110	Army	Compact, Wideband, Single or Dual Antenna Geolocation
28	A06-235	Army	Army Tactical Wheeled Vehicle Emulator for Improved Simulation Characterization and Reliability Assessment
29	A06-120	Army	High Efficiency Erbium/Ytterbium (Er/Yb) Doped Fibers for Eye-safe Fiber Laser Sources
30	A06-077	Army	High Power Density Gears Using a Systems Engineering Approach for Selection, Test, and Evaluations of Emerging Materials, Surface Engineering, and

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	Topic Number	Component	Topic Title
1	AF06-109	Air Force	Photo-Electrochemical Generation of Hydrogen for Fuel Cell Operation
2	AF06-030	Air Force	Knowledge Assessment System for Evaluating Performance in Dynamic Environments
3	AF06-163	Air Force	Thermal Barrier Coatings (TBC) Lifing Technologies
4	N06-073	Navy	Back Illuminated CMOS Detector Arrays
5	AF06-060*	Air Force	Enabling Monitoring and Analysis of Concept-Based Event Information in Text.
6	N06-081	Navy	Blast Resistant/ Fire Resistant Polymer Coating
7	AF06-340	Air Force	Tiled Ultra High-Resolution Light Engine
8	AF06-351*	Air Force	Eliminating Legacy Performance Barriers Imposed on New Systems
9	AF06-029	Air Force	Untethered Datalinks for Use in Simulation Environments
10	AF06-166	Air Force	Accessory Health Management Based on Very High Frequency (VHF) Characteristics
11	AF06-010	Air Force	Electric OxygenIodine Laser Diagnostics
12	N06-002	Navy	Sea Surface Slope and Elevation Statistics To Support Radar Performance Modeling
13	N06-013*	Navy	Technology Development for a Multi-Mission Passive Anti-Submarine Warfare (ASW) Turret Capability
14	CBD06-105	CBD	Electro Osmotic Membrane Development for Chem-Bio Protection
15	N06-015	Navy	High-Performance Passively Q-Switched Microchip Laser
16	N06-020	Navy	Innovative Methodologies to Determine Remaining Fatigue Life of Aircraft Dynamic Components
17	AF06-130	Air Force	Improved Omnidirectional Multiband Antenna for Miniature Munitions
18	AF06-009	Air Force	Turbulence Inner Scale Sensor
19	AF06-208	Air Force	Adaptive Signal Processing to Counter Jamming
20	AF06-065*	Air Force	Acquiring Probabilistic Knowledge for Information Fusion
21	AF06-320	Air Force	Ground Loads Predictive Analysis
22	AF06-222*	Air Force	Hyperspectral Detector Enhancement Using Auxiliary High-Resolution Imagery
23	AF06-302	Air Force	Volatile Particle Condensing Chamber for Turbine Engine Emissions
24	AF06-024*	Air Force	Enhanced Transmission Control Protocol/Internet Protocol (TCP/IP) for Distributed Network Applications
25	DTRA06-010	DTRA	New Thermobaric Materials and Weapon Concepts
26	AF06-141	Air Force	Micro Munition Technologies

27	AF06-269	Air Force	Cold Atom Optical System for Space
28	AF06-273	Air Force	Plug-and-Play Structures for Satellite Applications
29	N06-016	Navy	Adjustable Attachment Device for Aircraft Blankets
30	AF06-340	Air Force	Tiled Ultra High-Resolution Light Engine

APPENDIX B: ANALYSIS OF FY2006–FY2010 SBIR TOPICS CONTAINING OPEN SYSTEMS ARCHITECTURE RFP LANGUAGE

	OSA Ranked	SBIR Topic Number	Agency	Title	Technology Area(s)	Summary / Comments	Phase I Awards	Phase II Awards	Awarded Firms
1	High	OSD09-SP4	OSD	Designing Large Data Handling Architectures	Information Systems	The objective of this SBIR is to design innovative architectures to assemble large amounts of data, automate understanding of content, and alert operators to critical events. This SBIR explicitly directs R&D of open and standards based architectures based on service-oriented architecture. It directs a common ontology to distribute, assemble, and evaluate multiple sources of content. It seeks to explore alternatives to current DoD data-sharing strategies. Finally, it explicitly directs the use of open standards	(2) awards totaling $195,105	(1) award totaling $1,246,335	Analatom Incorporated (P1); Harmonia, Inc. (P1/P2)
2	High	A09-081	Army	Identity Management of Biometric Data (IMBD) across the Global Information Grid (GIG) using a Service-Oriented Architecture (SOA) Framework	Information Systems; Electronics	The objective of this SBIR is to develop an approach and system that can enable commanders to disseminate and share biometric data across the GIG using a service-oriented architecture framework. This solicitation explicitly directs the implementation of SOA principles to enhance the ability of DoD components and federal agencies (i.e., Homeland Defense) to collect and share biometric data. The solicitation directs contractors to standardize data to enhance interoperability and reinforces "openness" in system design	(2) awards totaling $133,369	(2) awards totaling $1,157,112	Future Skies (P1/P2); Physical Optics Corporation (P1/P2)
3	High	N08-058	Navy	Approaches to Directly Measure Heave, Pitch and Roll Onboard Navy Ships	Ground/Sea Vehicles, Sensors	The objective of this SBIR is to develop a ruggedized sensor that will measure the heave of a ship and can be integrated with other ship systems. This SBIR explicitly directs the use of open architecture principles in system design to ensure the sensor can integrate with existing shipborn systems: "All concepts should be based on Open Architecture (OA) principles where practicable to ensure the solutions are able to integrate as needed with existing and future naval sea keeping, navigation and weapons systems."	(2) awards totaling $169,893	(1) award totaling $399,954	Creare Inc. (P1/P2); PHYSICAL OPTICS CORP. (P1)
4	High	AF073-025	Air Force	Metadata & Information Tagging Technologies for Application Interoperability and Services	Information Systems	The objective of this SBIR is to investigate, develop and demonstrate methods to support metadata and information tagging schemas to facilitate data interoperability and system application interaction through web-based services. This solicitation makes multiple explicit references to the requirement to use an open systems architecture approach to system design, and explicitly requires the use of service-oriented architecture. Statement of work language includes XML, SOAP standard protocols, use of web services, open source components, and software reusability.	(2) awards totaling $199,727	(1) award totaling $739,884	ORIELLE LLC (P1); Traverse Technologies (P1/P2)

5	High	N07-131	Navy	Innovative Flow Control Devices for Shipboard Fluid System Rupture Isolation	Ground/Sea Vehicles, Materials/Processes	The objective of this SBIR is to develop flow control devices for isolating fluid system ruptures onboard naval ships. This solicitation explicitly requires open architecture principles be used in system design: "For this reason, the approach(es) proposed should employ the use of open architecture principles as practicable."	(2) awards totaling $139,872	N/A	BIG HORN VALVE, INC. (P1); SEA CORP. (P1)
6	Medium	AF103-070	Air Force	Airborne Networking: Using Context-Awareness for Better Network Routing and Management	Information Systems	The objective of this SBIR is development of complete prototypes that demonstrate the use of wide-area network states and user intents in a complex and uncertain environment to automatically enhance network routing and management. This solicitation includes contracting language that advances open systems architecture; the solicitation explicitly requires use of open standard protocols, solutions that leverage service-oriented architecture (SOA), and requires the solution to be inserted into existing DoD C2 systems.	(2) awards totaling $199,962	N/A	Architecture Technology Corporation (P1); UtopiaCompression, Corporation (P1)
7	Medium	SOCOM10-006	SOCOM	Micro Weather Sensor (MWS)	Information Systems; Materials/Processes; Sensors; Electronics; Battlespace	The objective of this SBIR is to design and build a weather sensor to be mounted on small UAV aircraft platforms. The solicitation specifically addresses (1) the use of common software languages to integrate into current C2 systems; (2) data output compliant with XML standards; (3) the ability to integrate with existing weather sensors and transmit data to C2 systems; (4) the requirement that the system be networked with existing C2 systems using common message formats; and (5) the ability to communicate to existing weather sensor polling stations.	(3) awards totaling $299983	(1) award totaling $1,827,811	Advanced Distributed Sensor Systems, Inc. (P1); Physical Optics Corporation (P1/P2); UES, Inc. (P1);
8	Medium	A10-064	Army	Light Weight Electric and Magnetic-Field Sensors for Unmanned Aerial Vehicles	Air Platforms; Sensors	The objective of this SBIR is to develop passive small light weight electric-field and magnetic-field sensors for small inexpensive unmanned aerial vehicles. While this solicitation lacks significant language directing that OSA principles be incorporated into system design, it does direct that the contractor "demonstrate that the sensor autopilot/computer interface is an open architecture that can be utilized through standard autopilot/computer interfaces."	(3) awards totaling $209,902	N/A	QUASAR Federal Systems, Inc. (P1); Physical Optics Corporation (P1); Scientific Applications and Research Association (P1)
9	Medium	A07-123	Army	Novel Representations of Elevation Data	Information Systems	The objective of this SBIR is to research and develop novel approaches to representing terrain elevation as an upgraded capability of current DTED technology. The solicitation lacks significant discussion of open systems architecture principles; however, it does require that the system software be developed to incorporate service-oriented architecture approaches and requires the software can be integrated into existing DoD C2 systems.	(1) award totaling $69,990	N/A	ANDREWS SPACE, INC. (P1)
10	Medium	N07-142	Navy	Assessing the Impact of GPS Degradation Using Campaign-level Warfare Modeling	Information Systems, Battlespace, Space Platforms	The objective of this SBIR is to develop simulation models to demonstrate the impact on C2 systems and weapons systems of a GPS DoS attack. The SBIR suggests contractors consider approaches that include an open system architecture design, explicitly stating high-level architectures, XML, and web-based paradigms for passing data between nodes.	(2) awards totaling $168,463	(1) award totaling $598,507	MAXIM SYSTEMS (P1); Metron, Inc. (P1/P2)

11	Medium	N06-179	Navy	Real-Time, Secure, and Fault Tolerant Discovery for Publish-Subscribe Middleware in a WAN Environment	Information Systems, Ground/Sea Vehicles, Battlespace	The objective of this SBIR is to develop protocols, services, and methodologies for performing real-time, fault-tolerant discovery of publish-subscribe entities over WAN environments. The SBIR seeks to develop a method to use smart-push to share information across the GIG, and while little reference is made to "open systems architecture," the SBIR explicitly supports "PEO-IWS 7.0 Open Architecture."	(2) awards totaling $139,887	N/A	REAL-TIME INNOVATIONS (P1); TECH-X CORP. (P1)
12	Low	N102-176	Navy	Disambiguation of Entity Association Statements	Information Systems; Human Systems	The objective of this SBIR is to develop fusion (disambiguation) algorithms that can be applied to large resource description framework (RDF) data stores. While open system architecture contracting language is not adequately addressed the solicitation does require that "the prototype should be a software application that is compatible with a service-oriented architecture and demonstrated against real tactical data sources."	(4) awards totaling $339,972	(2) awards totaling $993,624	DECISIVE ANALYTICS Corporation (P1/2); Knowledge Based Systems, Inc. (P1); Modus Operandi, Inc. (P1/P2); SEMANDEX NETWORKS, Inc (P1
13	Low	A10-009	Army	Automation of the Operation Test Data Process	Information Systems	The objective of this SBIR is to develop the capability to automate the operational test data process in support of weapon system and other DoD program acquisition initiatives. This SBIR does not significantly direct OSA principles be incorporated into system design; however, some requirements do loosely support advancing open systems architecture including (1) requiring that applications be integrated with a variety of data types; (2) reusing existing technology; and (3) requiring a phased spiral development plan.	(2) awards totaling $139,906	N/A	Frontier Technology, Inc. (P1);Soar Technology, Inc. (P1)
14	Low	N102-184	Navy	Isolation Techniques for Untrusted Software	Information Systems	The objective of this SBIR is to develop techniques to protect an embedded computing platform from malware contained in a large open source or commercial software package. This SBIR supports the acquisition of national security systems that incorporate open source software using an open system architecture approach. While the solicitation does not implicitly direct open system architecture principles, the fundamental purpose of the SBIR research contributes to safely advancing the use of open source software when implementing an open systems approach to program acquisition.	(2) awards totaling $159,497	N/A	DornerWorks, Ltd. (P1); PRO-telligent LLC (P1)
15	Low	A09-017	Army	Reactive Real-time Planners for Coordinated Aggressive Manuevers	Air Platform; Information Systems	The objective of this SBIR is to develop a system that can dynamically plan 3D routes for a team of manned or unmanned aircraft to aggressively maneuver and avoid collision. This solicitation seeks to develop a system that uses a modular approach such that it can be incorporated into various aircraft platforms. The solicitation explicitly directs the "feasibility of a modular approach with common algorithms that can be tailored to individual manned and unmanned platforms should be assessed." However, the solicitation lacks substantial use of open system architecture principles in describing the statement of work.	(2) awards totaling $189,998	(1) award totaling $729,866	Scientific Systems Company, Inc. (P1); Stottler Henke Associates, Inc. (P1/P2)

16	Low	N091-076	Navy	Translation of network metrics to behavior attributes	Information Systems; Human Systems	The objective of this SBIR is to develop mappings of N-dimensional human network space to a relevant behavior space to translate human network data into actionable intelligence. This solicitation lacks any significant discussion or direction of open systems architecture principles in system design; however, phase III development requires that the "application must be severable from the data and visualization layers and conform to service-oriented architecture standards."	(5) awards totaling $379,587	(1) award totaling $500,000	21st Century Technologies Inc. (P1); CHI Systems, Inc. (P1); DECISIVE ANALYTICS Corporation (P1); Infoscitex Corporation (P1); Intelligent Systems Technology, Inc. (P1/P2)
17	Low	N093-227	Navy	Automated Analysis and Verification of Application Program Interfaces (APIs)	Information Systems	The objective of this SBIR is to develop an approach that supports an automated solution in verifying a set of standard Application Program Interfaces with developer source code and seeks to support the reuse of software in the JTRS family of radios. This SBIR supports open architecture principles incorporated into the JTRS radio. While the solicitation does not explicitly direct open system architecture principles, the fundamental purpose of the SBIR research facilitates efficient software reuse within the JTRS acquisition program.	(4) awards totaling $265,702	(1) award totaling $600,028	Charles River Analytics Inc. (P1); DataSoft Corp. (P1/P2); Harmonia, Inc. (P1); Trident Systems Inc. (P1)
18	Low	N08-008	Navy	Commandable Mobile Anti Submarine Warfare Sensor (CMAS)	Information Systems, Ground/Sea Vehicles, Sensors, Battlespace, Weapons	The objective of this SBIR is to develop and demonstrate mobile sensor technologies to support anti-submarine warfare training and operations. This solicitation incorporates MOSA principles by directing the use of modular sensor packages and the communication packages required to support them, as well as a modular payload sensor design. Additionally, the solicitation directs investigation of aircraft communication links to integrate the system with existing aircraft communication systems.	(3) awards totaling $308,883	(1) award totaling $746,507	Advanced Avionics Incorporated (P1/P2); NAVMAR APPLIED SCIENCES CORP. (P1); PHYSICAL OPTICS CORP. (P1)
19	Low	N08-067	Navy	Live Fire Virtual Sniper/Counter Sniper Training System	Human Systems	The objective of this SBIR is to develop a containerized counter-sniper virtual environment to enhance weapon system training. While the solicitation does not explicitly direct open system architecture principles be incorporated in system design, it does address the requirement that GOTS software be incorporated (suggesting software reuse) and requires the use of open source software in system design.	(2) awards totaling $139,664	(1) award totaling $1,398,475	LASER SHOT, INC. (P1/P2); REFERENTIA SYSTEMS, INC. (P1)
20	Low	N08-209	Navy	Embedded Training Techniques for Target Discrimination Systems	Sensors, Electronics, Human Systems	The objective of this SBIR is to develop training technology for human-machine target sensor systems with the ultimate objective to integrate the product into existing Navy radar sensors. The solicitation does not explicitly direct open system architecture approaches to system design; however, it does specify that the system have testable software interfaces to integrate into existing systems, and requires spiral development processes. Additionally, the SBIR specifies the system must be compatible with existing standards to encourage software reuse.	(3) awards totaling $239,969	(1) award totaling $599,949	Phoenix, Inc. (P1/P2); Colorado Engineering Inc. (P1); Stottler Henke Associates, Inc. (P1)
21	Low	SB101-006	DARPA	Adaptive Data Visualization Under Cognitive and Communications Bandwidth Limitations	Information Systems	The objective of this SBIR is to develop and enhance the presentation of geospatial data in C2 systems. While the solicitation does not explicitly direct the use of open systems architecture in systems design, it encourages the use of open standards for communication and display and requires the end product to be interoperable with existing systems	(2) awards totaling $197,793	N/A	Kitware (P1); Stottler Henke Associates, Inc. (P1)

22	Low	N06-153	Navy	Semantical Machine Understanding	Information Systems, Human Systems	The objective of this SBIR is to develop the capability to extract semantic content from large volumes of multilingual text to support intelligence gathering. This solicitation does not adequately address an open systems architecture approach to system design; however, it requires interoperable knowledge sharing and intelligence analysis across joint and coalition forces—a characteristic best achieved using an open system architecture approach to system design.	(3) awards totaling $239,824	(1) award totaling $743,120	Aptima Inc.. (P1/P2); Quantum Intelligence Inc. (P1); Stottler Henke Associates Inc. (P1)

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