SYSTEMS ENGINEERING APPLICATIONS FOR SMALL BUSINESS

INNOVATIVE RESEARCH (SBIR) PROJECTS

THESIS

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THESIS

Presented to the Faculty

Department of Engineering and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Engineering

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September 2012

AFIT/GSE/ENV/12-S01

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Abstract

The purpose of this research was to define Systems Engineering applications for Small Business Innovative Research (SBIR) projects. Specifically, this thesis sought to answer five research questions addressing the essential elements and application of Systems Engineering processes within the SBIR community. Information was collected from multiple organizations throughout the SBIR community to support this research. The research identified that current DoD and Air Force Systems Engineering Policy do not adequately address SBIR projects and SE processes are not well documented within the community. This research identified the need to tailor a Systems Engineering approach for SBIR projects as overarching policy is not tailored for SBIR. Results from this work identified the applicable SE tasks identified in Air Force policy. The culmination of this effort defined the current SE tasks applicable in the SBIR community as well the overall SE rigor being applied in the different Systems Engineering Process areas identified in DoD and Air Force Systems Engineering Policy.

Acknowledgments

I would like to express my sincere appreciation to my faculty advisors, Dr. Som Soni and Lt Col Joseph Wirthlin, for their guidance and support throughout the course of this thesis effort. Their insight and experience was certainly appreciated. I would, also, like to thank my sponsor, Dr. James Malas, from the Air Force Research Lab for both the support and latitude provided to me in this endeavor.

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I. Introduction

Background

The Air Force Small Business Innovation Research (SBIR) program is vital element of the Air Force Research Laboratory (AFRL) contracts portfolio operated under the guidance of the Air Force SBIR/Small Business Technology Transfer (STTR) Program Manager within AFRL at Wright Patterson Air Force Base. The SBIR program funds early-stage R&D projects at small technology companies that support a Department of Defense (DoD) need and have the potential for commercialization in private sector and/or military markets. The DoD's SBIR program is a large part of the multibillion dollar federal SBIR program administered by twelve federal agencies across the country [www.sbir.gov/about/about-sbir]. The DoD and Air Force provide top level Systems Engineering guidance and policy for the acquisition community. However the current guidance and policy has not yet been tailored specifically for the SBIR community.

Challenges

The DoD has well defined system engineering processes documented in the acquisition 5000 series for typical acquisition programs. However a number of challenges exist with applying Systems Engineering to SBIR projects since they are unique compared to typical acquisition programs. They are managed by many different small businesses that may or may not have an organic SE capability. Additionally they vary significantly in scope, are small in size, short in project length, and are early research projects. They are categorized as 6.1 Basic Research or 6.2 Applied Research projects which are further defined in AFRLI 61-204 Scientist and Engineer Manuel. Topics are generated across the Air Force by Program Executive Officers, Technolgy Directorates, Air Logistics Centers and Test Centers. SBIR projects are developed in three phases. Phase 1 is a technical feasibility study that allocates up to $150k and 9-12 months. Phase II is concept development and allocates up to $1M and 24 months. There are also Critical Manufacturing SBIR projects that are allocated up to $5M for Phase II. Phase III is the commercialization stage [www.sbir.gov]. SBIR projects managed by many different organizations throughout the DoD. Within the Air Force, SBIR projects are managed by AFRL Technology Directorates, Test Centers and Air Logistics Centers.

Systems engineering is a technical management process that can be used to help ensure that projects are successfully implemented to the next phase of development if selected. As SBIR projects vary considerably in scope, are managed by many different organizations within the government, and work is accomplished by varying small businesses it presents a problem of ensuring that consistent systems engineering processes are being applied across all projects.

Past Research

AFIT past research efforts have helped to identify areas for improvement for applying SE to the S & T community. Most notably a thesis completed by AFIT called "A Tailored SE Framework for S & T Projects" developed a tailored systems engineering approach for typical S & T projects. This work is discussed further in Chapter II as part of the literature review. SBIR however is not a typical S & T project and AFRL has expressed interest in a similar project that would define the SE rigor needed for a SBIR project and provide a tailored approach for implementing SE processes into their SBIR projects. Past research for governing this material is covered in Chapter II.

Problem Statement

Systems engineering processes are not fully defined in policy and are not being implemented consistently and to adequate levels for all SBIR projects. SBIR is a unique program that challenges small and large business participants to work together. Small business participants may or may not have SE principals as defined by the DoD incorporated into their culture. Identifying the adequate level of SE and ensuring it is incorporated in a consistent manner across all organizations for SBIR projects will help to ensure projects are ready to proceed to the next phase of development. This will aid in the future transition of their projects.

Current DoD or Air Force policy does not specifically define SE processes for SBIR projects. AFRL has mapped their SE policy to the Defense Acquisition Guidebook (DAG) in AFRL Instruction 61-104 Science and Technology Systems Engineering. However application of Air Force Systems Engineering policy has yet to be identified for application within the SBIR program. Current Air Force policy for AFRL programs are outlined in AFRL Instruction 61-104, AFRL Manuel 61-204 AFRL Scientist and Engineer Manuel and AF Instruction 63-1201 Life Cycle Systems Engineering. These policies are in alignment with the DoD's Systems Engineering guidance captured in the DoD 5000 series and the DAG.

Research Focus

The focus of this thesis is to identify how current systems engineering practices apply for SBIR projects. This included identifying how and what current DoD and Air Force SE policy apply to SBIR project during Phase I and II and how to best tailor the guidance to develop a solid SE approach for the technical management of the project. Thus this thesis focuses on implementation of early systems engineering processes for Phase I and II SBIR projects. Without a solid SE approach SBIR projects are at risk to fail. Good SE processes will help to ensure projects better prepared for proceeding to their next phase of development while adequately managing technical risk.

Methodology

Preliminary research included identifying relevant SBIR documentation, past case studies and previous work. It was quickly identified that there was insufficient SBIR documentation to support this approach. Very little Systems Engineering documentation was found to be associated with SBIR projects and varied among organizations. Thus it became essential to conduct interviews to gather the information needed. Then interview and literature review data could be analyzed using a triangulation approach to identify the relevant Systems Engineering application of principles.

Assumptions/Limitations

No case studies that focused on direct application of systems engineering on SBIR projects were found. Since organizations managing SBIR projects are geographically separated it is not feasible to gather data from enough organizations to have valid data that represents all SBIR projects. Therefore, this study is based on representative sampling.

Implications

Though this project focuses specifically on SBIR projects, findings will likely be applicable to similar S & T projects. Projects in early developments will have many similar attributes to the SBIR projects analyzed in this research. This work could be used to guide a tailored SE approach for similar projects/programs.

Summary

This chapter provided an overview of research. Chapter II will review relevant literature. Chapter III will provide an in depth look at the methodology. Chapter IV will analyze data for this research. Chapter V will provide results and conclusions for this research.

II. Literature Review

Chapter Overview

The purpose of this chapter is to review past work accomplished on Systems Engineering in AFRL and identify current SE policy as it pertains to the S &T Community. The Department of Defense has published the Defense Acquisition Guide and the DoD 5000 series to identify SE processes. The Air Force has published Air Force Instruction (AFI) 63-1201" Life Cycle Systems Engineering" for the acquisition community. Additionally, Air Force Material Command developed the Air Force Systems Engineering Assessment Model (AF SEAM) for assessment of Air Force programs. AF SEAM is a very useful SE assessment tool for typical Air Force acquisition programs. Differences between the DAG, AFI 63-1201 and AF SEAM can be confusing since they vary in terminology. The below graphic identifies the SE processes identified in each document.

Table 1: SE Processes (AF SEAM, Sept 2010)

AF SEAM	Defense Acquisition Guide	AFI 63-1201
Requirements	Reqts Analysis, Reqts Mgmt, Stakeholder Reqts Definition	Reqt Dev & Mgmt, & Architecture
Design	Architectural Design, Integration & Interface Mgmt	Design & Interface Mgmt
Verification & Validation	Verification & Validation	Test & Evaluation, Verification & Validation
Manufacturing	Implementation	Design
Transition, Fielding, & Sustainment	Transition	Design
Project Planning	Technical Planning	Planning
Configuration Management	CM, Data Mgmt, Technical Data Mgmt	Configuration Mgmt, Data Mgmt
Risk Management	Risk Mgmt	Integrated Risk Management
Technical Mgmt & Control (PMC)	Technical Assessment	Technical Reviews & Measurements
Decision Analysis	Decision Analysis	Decision Analysis

Defense Acquisition Guidebook

The Defense Acquisition Guidebook (DAG) is designed to complement DoD policies identified in DoD Directive 5000.01 “The Defense Acquisition System” and DoD Instruction 5000.02 “Operation of Defense Acquisition System”. Chapter 4 of the DAG covers Systems Engineering. It “covers the system design issues facing a program manager, and details the Systems Engineering processes that aid the program manager in designing an integrated system that results in a balanced capability solution” [DAG, 2012].

It defines Systems Engineering as:

> an interdisciplinary approach and process encompassing the entire technical effort to evolve, verify and sustain an integrated and total life cycle balanced set of system, people, and process solutions that satisfy customer needs. Systems Engineering is the integrating mechanism for the technical and technical management efforts related to the concept analysis, materiel solution analysis, engineering and manufacturing development, production and deployment, operations and support, disposal of, and user training for systems and their life cycle processes [DAG, 2012].

The DAG section 4.1.3.1.1 discusses early Systems Engineering and emphasizes the importance of early SE during technology development. The DAG also defines the role of the Program Manager and Chief Engineer illustrated in figure 2 below. The DAG also separates the above 16 SE processes into two areas shown in figure 3.

Table 2: DAG Processes and Roles of the PM and SE (DAG Table 4.1.1T1, 2012)

Life-cycle Processes	Program Manager	Chief / Systems Engineer
Stakeholder Management	Primary	Support
Technical Planning	Support	Primary
Decision Analysis	Primary	Support
Technical Assessment (Includes Program Status: Technical Progress, Schedule & Cost Management)	Shared	Shared
Configuration Management	Primary	Support
Data Management	Primary	Support
Requirements Management	Support	Primary
Contract Management	Primary	Support
Requirements Analysis	Support	Primary
Architecture Design	Support	Primary
Implementation	Support	Primary
Risk Management	Primary	Support
Interface Management	Support	Primary
Integration	Support	Primary
Verification	Support	Primary
Validation	Shared	Shared

Table 3: DAG SE Processes (DAG Table 4.2.3.T1, 2012)

Technical Management Processes	Technical Processes
Decision Analysis	Stakeholders Requirements Definition
Technical Planning	Requirements Analysis
Technical Assessment	Architectural Design
Requirements Management	Implementation
Risk Management	Integration
Configuration Management	Verification
Technical Data Management	Validation
Interface Management	Transition

AFRLI 61-104 attempts to translate these processes from the DAG for the science and technology community. Also section 4.3.2.3 of the DAG identifies the following SE tasks relevant to the S & T community:

- Key Systems Engineering Activities During Technology Development
- Interpret User Needs; Analyze Operational Capability and Environmental Constraints
- Develop System Performance (and Constraints) Specifications and Enabling/Critical Technologies and Prototypes Verification Plan
- Develop Functional Definitions for Enabling/Critical Technologies/Prototypes and Associated Verification Plan
- Decompose Functional Definitions into Critical Component Definition and Technology Verification Plan
- Design/Develop System Concepts, i.e., Enabling/Critical Technologies; Update Constraints and Cost/Risk Drivers
- Demonstrate Enabling/Critical Technology Components Versus Plan
- Demonstrate System and Prototype Functionality Versus Plan
- Demonstrate/Model the Integrated System Versus the Performance Specification
- Demonstrate and Validate the System Concepts and Technology Maturity Versus Defined User Needs
- Transition to Integrated System Design
- Interpret User Needs, Refine System Performance Specifications and Environmental Constraints

- Develop System Functional Specifications and Verification Plan to Evolve System Functional Baseline
- Evolve Functional Performance Specifications into System Allocated Baseline

The DAG also identifies the following for SBIR:

> 2.2.10.1. Small Business Innovation Research (SBIR) Technologies
>
> Consistent with the direction of DoD Instruction 5000.02, the program manager (PM) should prepare a Technology Development Strategy (TDS) that appropriately uses the SBIR program to develop needed technologies, includes the use of technologies developed under the SBIR program, and gives fair consideration to successful SBIR technologies. During TDS preparation, the PM should ensure that the strategy addresses transition of relevant SBIR technologies and includes budgeting of follow-on funds for test, evaluation, and integration, as needed, to achieve the desired technological maturity. In addition, the PM should consider SBIR technologies as candidates for incremental and block system improvement initiatives as well as to address competitive prototyping requirements, particularly at the subsystems and component levels. To effectively leverage SBIR, the PM review and ensure compliance with DoD SBIR Phase III policy guidance and should engage their program office, Program Executive Office, systems command, product center, or DoD Component SBIR program coordinator for assistance. The PM should also consult the DoD SBIR program Web site for online resources and information including a program description, database of past awards and key points of contracts.
>
> 2.3.10.1.3. Small Business Innovation Research (SBIR) Consideration
>
> Consistent with the direction of DoD Instruction 5000.02, the PM should include SBIR and give fair consideration to successful SBIR-funded technologies in Acquisition Strategy planning. Note that SBIR follow-on development and acquisition (Phase III, not funded with the SBIR set-aside budget) may be able to be pursued on a sole-source basis without further competition. Competition for Phase I and Phase II awards (contracts funded by the SBIR set-aside budget) satisfies all statutory competition requirements. SBIR Phase III contract awards have SBIR status and thus must be accorded SBIR data rights. SBIR Phase III work may be pursued directly through Phase III contracts or encouraged through subcontracts via incentives. To effectively leverage SBIR, the PM review and ensure compliance with DoD SBIR Phase III policy guidance and should engage their program office, Program Executive Office (PEO), systems command, product center, or Component SBIR program coordinator for assistance.

Air Force Instruction 63-1201 Life Cycle Systems Engineering

AFI 63-120 identifies SE as encompassing "the entire set of scientific, technical, and managerial efforts needed to conceive, evolve, verify, deploy, support, and sustain a robust product, platform, system, or integrated system-of-systems (SoS) capability to meet user needs". It currently defines 12 SE processes that were shown earlier in Table 1. It also defines SE responsibilities for the program manager and engineers. It however does not specifically address SBIR projects.

AFI 63-1201 is currently under revision and is projected to better align with AF SEAM and the DAG. The revised draft is projected to align with AF SEAM's 10 SE processes. The DAG defines 16 SE processes as also illustrated in Table 1. This disconnect in policy can be confusing for project managers and engineers trying to decipher how policy applies to their projects and how best to develop a solid SE approach. The revised version of AFI 63-1201 should reduce this significantly by eliminating the current differences in the AFI. The author noted these changes in his review of the 2011 draft versions of the updated AFI 63-1201. Discussions to make the new version AFI62-101 have been held but no decision has yet been made whether the updated version will be AFI 63-1201 or 62-101.

With these changes coming to the AFI organizations should be considering these changes for future policy updates. Also, they should be ready to ensure that these SE processes are being executed properly once the new policy is published.

Air Force Systems Engineering Assessment Model (SEAM)

The primary purpose of AF SEAM is to promote the application and use of standard SE processes across the AF and to improve the performance of these processes through Continuous Process Improvement [AF SEAM, September 2010]. AF SEAM is not yet mandated across the Air Force however it is used as a reporting tool in some AF communities. It is also projected that the revised AFI 63-1201 will align with AF SEAM. AF SEAM identifies "ten AF standard SE process areas" and lists associated goals for each. Specific practices and generic practices are identified for each area. Those areas are seen below in Table 4 along with the number of practices for each area.

Table 4: AF SEAM SE Total Practices (AF SEAM, Sept 2008)

Process Area	Goals	Specific Practices	Generic Practices	Total Practices
Configuration Mgmt	3	8	7	16
Decision Analysis	1	5	7	12
Design	3	14	7	21
Manufacturing	4	12	7	19
Project Planning	3	15	7	22
Requirements	4	13	7	21
Risk Mgmt	3	7	7	14
Trans, Fielding, & Sus	4	15	7	22
Tech Mgmt & Control	4	15	7	18
Verification & Validation	5	16	7	23
Total	34	120	70	190

As seen above AF SEAM identifies 190 total practices. This suggests a significant SE effort for any program to implement AF SEAM. There are three different training modules developed to support AF SEAM describe in further detail in section 7 of AF SEAM. My experience as a SE instructor has taught me that this is a good rigorous tool for a major acquisition programs. However it must be tailored to a smaller scope to be value added for a smaller project since it requires a large manpower effort. This is significant for SBIR projects since their limited scope and resources require an even more tailored approach to be value added. AF SEAM was designed to facilitate use tailoring. Not applicable tasks can be coded N/A and not be assessed. Generic practices can also be omitted. This ability to tailor it to a specific project still requires a considerable effort since so many of the task may not apply for S & T projects. This is even more so for SBIR projects.

Additionally, discussions with AFRL Plans and Programs quickly identified that AF SEAM is a very rigorous tool for implementing SE that is not tailored to an appropriate level for AFRL projects. It is not tailored for the S&T community. In its current configuration, as many of the 190 SE tasks may or may not apply given the attributes of the AFRL project or program implementing this “as is” does not make sense for the SBIR community due to the uniqueness of their projects, limited resources and limited value added to the project. A more tailored approach is required. Analysis of interview results in chapter IV for each SE process will identify what SE tasks are being implemented and what are applicable for the SBIR community.

Air Force Research Lab Policy

The Air Force Research Labs have two main documents that provide guidance for Systems Engineering. The first is AFRL Instruction 61-104 which specifically addresses Systems Engineering in the S&T environment. The second is AFRL 61-204 Manual for Scientist and Engineers.

AFRL Instruction 61-104 S&T Systems Engineering

AFRL Instruction 61-104 "Science and Technology Systems Engineering" provides SE guidance for all of the AFRL community. It is in alignment with DoD and Air Force policy but tailors it to the S&T community. It identifies Eight Systems Engineering Key Questions to guide and assess the SE health of a project. The questions are:

1. Who is your customer?
2. What are the customer's requirements?
3. How will you demonstrate you have met the requirements?
4. What are the technology options?
5. Which is the best approach?
6. What are the risks to developing the selected technology?
7. How will you structure your program to meet requirements and mitigate risk?
8. What is your business-based transition plan that meets customer approval?

AFRLI 61-104 maps these questions back to the Systems Engineering "Vee" identified below from the Defense Acquisition Guidebook.

Figure A1.1. The Systems Engineering Vee

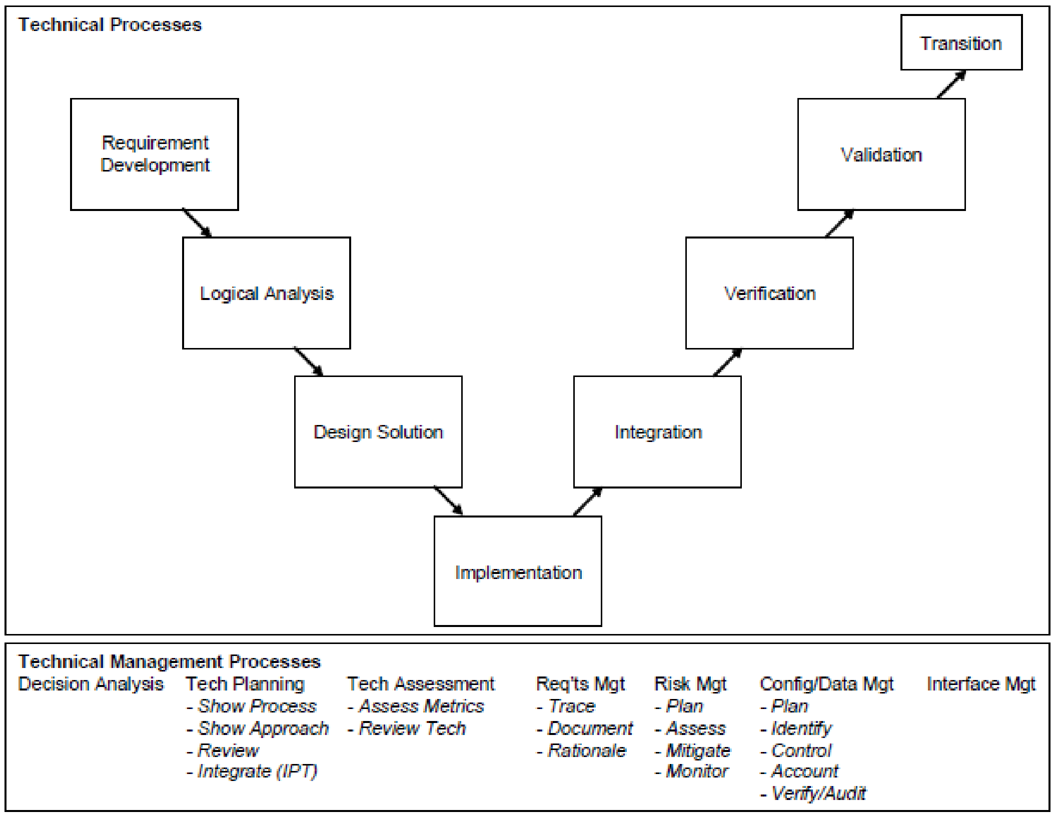

Figure 1: AFRL Processes Mapped to the SE Vee (AFRLI 61-104, 2008)

AFRLI 61-104 Attachment 1 also maps the Eight SE Key Questions back to the DAG SE areas which is illustrated below in Table 5.

Table 5: AFRL 8 SE Key Questions Mapped to the DAG

Question	Design Analysis	Tech Planning	Tech Assessment	Req Mgmt	Risk Mgmt	Conf. Mgmt	Data Mgmt	Interface Mgmt	Req't Dev	Logical Analysis	Design Solution	Implementation	Integration	Verification	Validation	Transition
1. Who is your customer?				x					x							
2. What are the customer's requirements?				x		x	x	x	x						x	
3. How will you demonstrate you have met the requirements?	x	x	x	x		x		x		x			x	x	x	x
4. What are the technology options?		x								x		x				
5. Which is the best approach?	x		x								x	x	x			
6. What are the risks to developing the selected technology?		x			x						x					
7. How will you structure your program to meet requirements and mitigate risk?		x			x		x		x	x	x	x	x	x	x	x
8. What is your business-based transition plan that meets customer						x	x	x								x

AFRLI 61-104 Attachment 1 provides a question and answer matrix for the Eight SE Key Questions. It breaks the Eight SE Key Questions down to further detail, identifies "What the Program Manager should know about his or her program" and defines the color assessment basis. It also identifies that "Use of the key questions during reviews of basic research programs is optional." It does this separately for 6.1 Basic Research, 6.2 Applied Research, 6.3 Advanced Technology Development, Advanced Technology Demonstration and Manufacturing Technology.

Also in Attachment 1, AFRL translates the 16 SE DAG processes for the AFRL community. It defines the DAG process, defines the process for AFRL and explains the importance. Review of this attachment identified that it is tailored for the typical AFRL program and not tailored for SBIR projects specifically.

Additionally AFRLI 61-104 is currently being revised. The AFRL Systems Engineering Council is currently reviewing the document. The new version is much shorter and uses an AFRL Systems Engineering Guidebook to companion the document. The guidebook details how to implement SE processes into a program or project. Both the instruction and guidebook define the S&T SE Process in the below illustration:

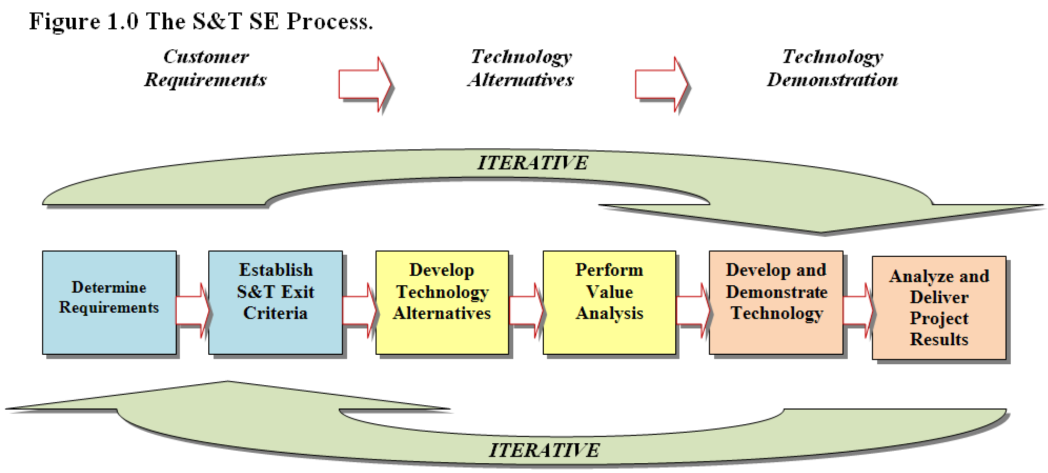

Figure 2: AFRL S&T SE Process (Draft AFRL SE Guidebook, 2012)

This is similar to the SE streamlined process identified in the case study review. This process was successfully implemented in past case studies. Each step is explained in further detail to identify what SE tasks should be performed. The guidebook also indentifies the Eight SE Key Questions and explains what should be done for each as indentified in the current instruction.

AFRL Manuel 61-204 AFRL Scientist and Engineer Manuel

The intent of this manual is to "enhance DoD Directives and Air Force Instructions by placing actions into a chronological process flow specifically developed for the management of AFRL Work Units". Thus the manual provides guidance on how to technically manage work units within AFRL.

The manual identifies SBIR as a three phase congressionally mandated program "established to stimulate technological innovation, use small businesses to meet federal R&D needs, increase innovative, private sector R&D commercialization, and to encourage minority and disadvantaged persons to participate in technological innovation" [AFRLM 62-204, 2003]. It identifies the different phases, funding and duration. It also defines the SBIR schedule from initial topic call to phase completions.

The manual defines 6.1 Basic Research as a "systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind." It also defines 6.2 Applied Research as a "systematic study to understand the means to meet a recognized and specific national security requirement" [AFRLM 62-204, 2003]. More information for both research categories can be found in the manual.

Policy Summary

Review of Systems Engineering policy within the DoD, Air Force and AFRL has identified very rigorous defined SE guidance and instruction. AFRL has done a good job tailoring their policy to be in alignment with higher level guidance. Additionally AFRL's System Engineering Council continues to be proactive in the development of the new SE Guidebook for better implementing good SE processes within AFRL. However current policy at all the reviewed levels is not specific enough for the SBIR community. Since SBIR is unique in many aspects as previously discussed SE guidance needs to be better defined and tailored for the SBIR community to ensure it is being implemented successfully. SBIR projects are at risks to not incorporate adequate SE processes without better guidance. Additionally any future efforts to tailor SE processes for the SBIR community should be in alignment with AF SEAM processes as the revised AFI 63-1201 is projected to align with AF SEAM.

Past Research

Several efforts including AFIT graduate thesis work and past studies have been accomplished to analyze Systems Engineering efforts within AFRL. The author identified most notably a past research project "A Tailored SE Framework for S & T Projects" authored by Maj Pitzer, Maj Behm and Jane White that captured the Systems Engineering tasks and rigor applicable for typical AFRL projects. They developed a tool called the "Systems Engineering Tailoring tool for Science & Technology Projects" that defined projects by 6 parameters:

1. RDT&E Category (6.1, 6.2 or 6.3)
2. Project Budget (less than $500k, $500k-$2M, greater than $2M)
3. Core Process (CP-1,2 or 3)
4. Technology Readiness Level (1 thru 9)
5. Integration Level (subsystem, system or mission)
6. Requirements Maturity (Technology Push or Requirements Pull)

The tool then outputted what SE best practices (mapped from the 16 DAG processes) that would apply to that project/program. This tool is notably similar to AF SEAM however it tailors the tasks for a project based on the stated parameters. The SETT tool provides a good initial baseline however SBIR projects are unique as previously identified. Preliminary analysis of the SETT Tool identified that it also does not tailor specifically to the SBIR community. Like AF SEAM, SETT identifies many tasks that may not be applicable to a specific SBIR project due to its unique attributes. . Implementing a process or tool that is not tailored to the appropriate level risks creation of non value added work and can drain valuable resources from a project. Both the SETT Tool and AF SEAM are good baselines to consider when identifying what SE tasks may apply to SBIR projects. Typical parameters for a SBIR project inputted into the SETT Tool to establish a baseline are illustrated in Appendix 3.

Additionally the author identified four notable AFRL studies that were significant for this research:

1. High Energy Laser On a Large Tactical Platform (HELLTP)
2. Deployed Base Energy Alternatives Report
3. Company Grade Officer Initiative Program
4. AFRL Transformational Activities in Systems Engineering (TASE) Assessment Phase Final Report Findings from 2006

The first two studies focused on the successful tailoring and streamlining of SE efforts on two larger AFRL projects. The third study listed focused on tailoring and streamlining SE efforts to smaller projects within AFRL as part of CGOIP. This study was very interesting since the projects were being managed by CGOs with limited SE backgrounds. And like the first two studies listed, CGOIP was also very successful in implementing good SE processes into their projects using a streamlined SE approach. The last study focused on making AFRL research programs more effective and efficient, and improving the transition of technology to the warfighting community through the use of good SE processes. A number of very interesting findings were documented in this report.

The studies selected focused on S&T projects that successful implemented SE processes. The goal was to establish a successful baseline from historical examples that define the SE rigor needed in the S&T community. The case studies focused on projects that formed a multi-disciplinary team and implemented a tailored streamlined SE approach for their projects. This approach proved to be very successful in implementing good SE processes for the projects. This approach could be very beneficial for SBIR projects if tailored to the appropriate level. The four studies identified were analyzed for SE artifacts that contributed to their success.

High Energy Laser On a Large Tactical Platform (HELLTP)

The initial phase of this project implemented the Air Force's Integrated Product and Process Development (IPPD) process. The project was considered a Multi-directorate SE Initiative. It had three main objectives:

1. Apply the IPPD process to the selected High Energy Laser on a Large Tactical Platform (HELLTP) problem across multiple directorates, with "customer" involvement.
2. Assess the tools and process in the course of executing the program.
3. Capture lessons learned with comments and recommendations for going forward in the Phase II program.

The project was able to establish a successful team framework throughout the IPPD process. As a result the team was able to tailor their SE approach for the project. The below figure illustrates their approach.

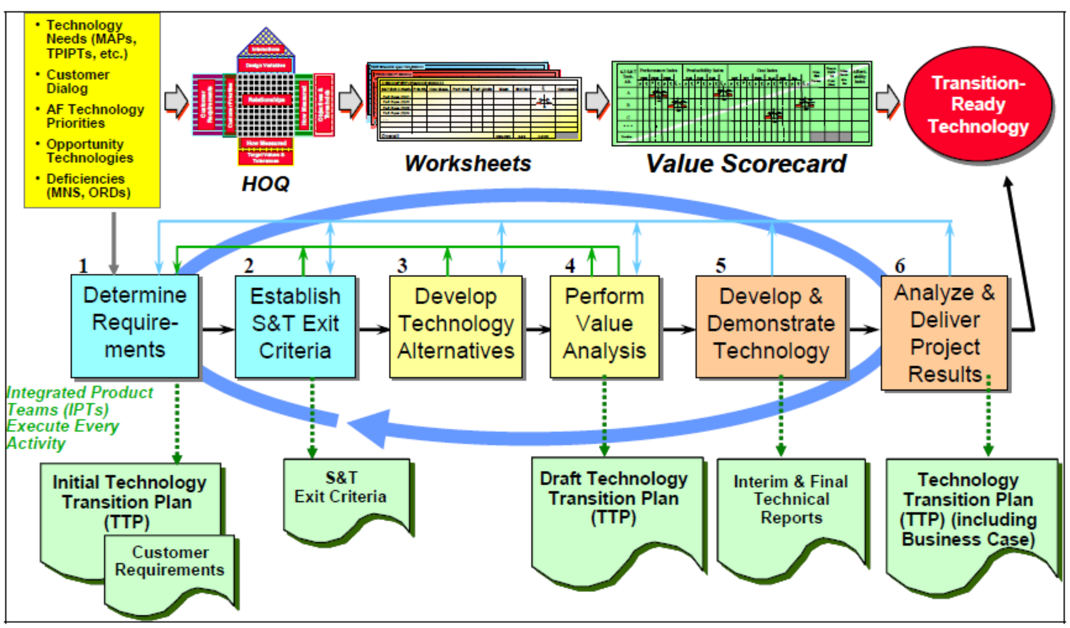

Figure 3: HELLTP Top Level IPPD Model

The team identified the need to tailor their approach as well as tailor the SE tools for the project. They classified their tools into four classifications: Preliminary SE, Requirements Management and Evaluation, System Architecture Tools, and Modeling and Simulation. From there they were able to select the tailored tools needed for their project. Additionally, the team relied on a SE contractor to provide just in time training to the team. As part of the IPPD process the team conducted reoccurring meetings to access project status and progress.

Deployed Base Energy Alternatives Report

The study focused on application of Systems Engineering principles to improve technology investment outcomes. The project elected to use a contractor developed method called Systems Engineering Tailored for Science and Technology (SETFST). The following steps were implemented:

1. Establish the study team (IPT) and define the overall program objectives.
2. Define Desirements with team.
3. Generate alternatives.
4. Score alternatives.
5. Exercise a value analysis model, and prioritize the alternatives.

Formal team meetings were held with the IPT to review project status. All key stakeholders were represented with membership on the IPT. The team developed a defined technical approach for the project. As a result the team successfully implemented the SE processes identified in the SETFST method selected.

Key findings:

Review of the report clearly identifies that success of the project was in direct relationship with the success of the IPT. The team construct ensured that they had the right mix of expertise for the project as well as team members with the expertise in Systems Engineering to successfully implement the process. This technical approach to the problem was very successful. The team implemented the SERFST method which is consistent with DoD and AF policy. The SETST method is similar to the streamline S&T process outlined in current AFRL policy and is being incorporated into the AFRL SE Guide to companion the revised AFRLI 61-104.

Company Grade Officer Initiative Program (CGOIP)

AFRL/RX piloted the Company Grade Officer Initiative Program (CGOIP) in an effort to streamline and tailor the SE effort for their projects. The projects were managed by CGO's that had minimal experience in SE. These projects had an emphasis on transition their projects. The projects were successful in implementing SE into the projects by using the 5 step Streamlined SE Approach and Proposal Checklist illustrated below.

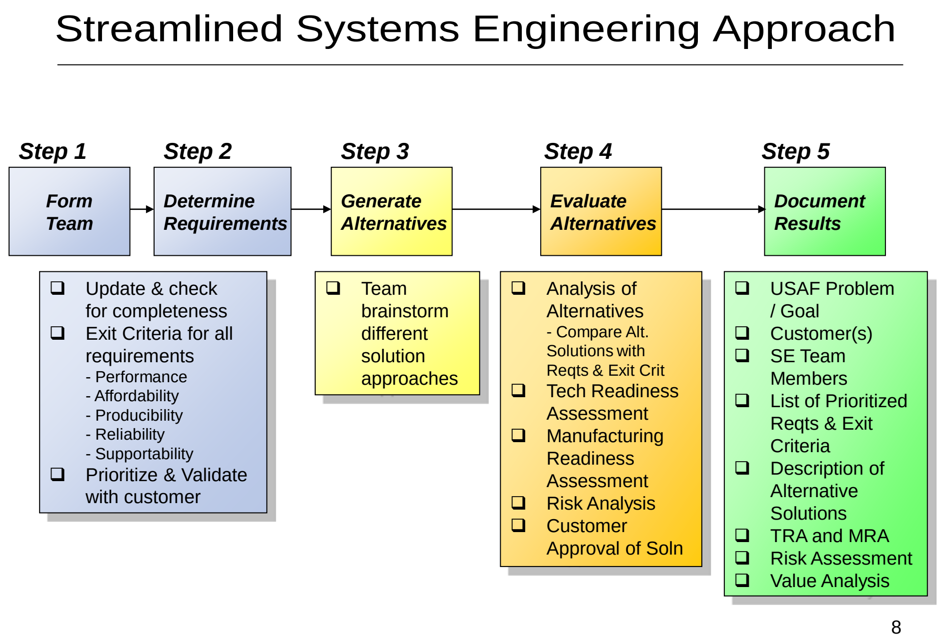

Figure 4: CGOIP Streamlined SE Approach

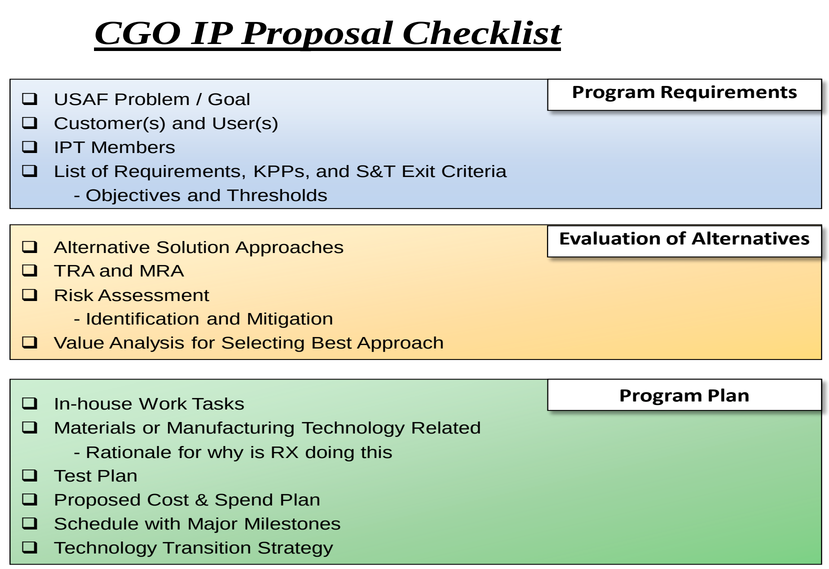

Figure 5: CGOIP Proposal Checklist

Following this streamlined approach enabled the teams to successfully implement SE into their processes. As a result their programs were successful. This method was similar to the streamlined SE process used for case study 2.

AFRL Transformational Activities in Systems Engineering (TASE) Assessment Phase Final Report Findings from 2006

The goal of the project was to "make AFRL research programs more effective and efficient (improve S&T program performance), and improve the transition of technology to the warfighting community (improve technology transition)". The team found a number of interesting findings as seen below.

Main trends discovered:

- AFRL program personnel already have guidance on sound Systems Engineering practices (AFRLI 61-104, *Science and Technology (S&T) Systems Engineering (SE) Initiative*). However, this guidance has some shortcomings. AFRL should use the Defense Acquisition Guidebook (Chapter 4) as a framework for improving its Systems Engineering guidance because it is complete from a process viewpoint and is supported by DoD (the former USD/AT&L; now the SecAF).

- Very few AFRL technology program leads follow the AFRL Instruction or a complete set of Systems Engineering processes. This has led to problems in requirements management, risk management, and other areas that sometimes result in poor program performance (including schedule/cost overruns) and transition.

- Systems Engineering is not foreign to AFRL personnel. Although it is not widespread or consistently practiced, institutionalizing Systems Engineering processes should not be as difficult as if they were concepts new to AFRL.

The team also discovered that:

- Some AFRL personnel are concerned that Systems Engineering processes are focused on acquisition (as opposed to research) programs and might stifle the creative atmosphere essential to the discovery of new technologies.

- AFRL has a requirement to implement robust Systems Engineering processes in support of the DoD and AF acquisition process. DoD has recommended a series of “best practices” for Systems Engineering (described in Chapter 4 of the Defense Acquisition Guidebook).

- Current AFRL Systems Engineering guidance (AFRLI 61-104) is not adequate to ensure such a Systems Engineering process. In addition to not being implemented by most programs, it does not address a sufficient number of Systems Engineering sub processes.

- Most Systems Engineering practices are represented somewhere amongst the set of programs and ATDs assessed, so the core understanding of good Systems Engineering practices exist today in pockets throughout AFRL.

- ATDs and other programs are most successful when they have both strong initial processes (requirements development and decision analysis) and ongoing processes to address requirements changes and risk. Integrated Product Teams (IPTs) that include all stakeholders are essential.

- Programs have the most difficulty with transitioning technology to acquisition customers and warfighting users. This is due in part to changes in customer priorities and funding

- Uniqueness in the way AFRL performs S&T programs lies not in what they are developing or how they develop technologies; rather AFRL’s unique nature lies in how it focuses its energies on the front and back end of the Systems Engineering process, making much of the intermediate functions the responsibility of the contractor.

- The Technology Directorates have many best practices that can be used by the rest of AFRL.

This project focused on S&T projects within AFRL however all of these findings do apply to the SBIR community within AFRL. They identify the risk of inconsistent application of Systems Engineering and failure to follow best practices. The findings also identify that current SE policy is not adequate to ensure good SE processes are being followed. This validates further the need to develop a tailored approach for the SBIR community since SBIR is even more unique then typical S&T projects.

Case Study Summary

The past research indentified successfully implemented SE processes for their projects. The studies had these key SE attributes:

- Formed a multi-disciplinary team that involved all relevant stakeholders
- Held team reviews to monitor project progress
- Successfully tailored their SE approach using a streamlined S&T process tailored to their project that was consistent with Air Force policy

In addition the TASE report validated the need to develop a tailored SE approach for the SBIR community as it identified many weaknesses in the S&T community and policy for good implementation of SE processes. It highlighted that current policy is not sufficient with AFRL and that varying levels of SE are being implemented. The report also noted that AFRL relies heavily on the contractor to complete many SE tasks as is true with SBIR thus making it unique. Overall the literature review identified many pertinent SE processes for the SBIR community as well some of the struggles within the S & T community to fully integrate good SE processes.

III. Methodology

Chapter Overview

The purpose of this chapter is to develop the methodology for analysis. Following the topic selection for this research the author began his literature review. The first step was to review all past research, SBIR documentation and applicable SE policy. Several past research efforts on AFRL projects were identified to be relevant. Figure 6 illustrates the approach that was developed to gather and analyze data.

Preliminary review of AFRL SBIR projects quickly identified varying degrees of SE documentation among the different directorates. In most cases there was little if any SE documentation. Within AFRL projects are required to submit a Form 2913 Laboratory Management Review at the beginning, annually and end of a phase. Some directorates require the project managers to answer the Eight SE Key Questions identified in AFRL policy as an attachment. A color scale was used to assess each question. Out of approximately two dozen reviewed all of them showed a green status for all tasks. No additional comments were documented for any of them. Project Managers were only required to provide comments for yellow and red status questions. These became small vignettes however it was evident that additional data would need to be collected. Other documentation for SBIR includes proposals, contracts and final reports. SE was found to not be well documented for SBIR projects within AFRL.

The lack of SBIR SE documentation identified that additional data would be required. An interview instrument to collect data from SBIR project managers was developed and participants from different organizations were identified. This approach is illustrated below:

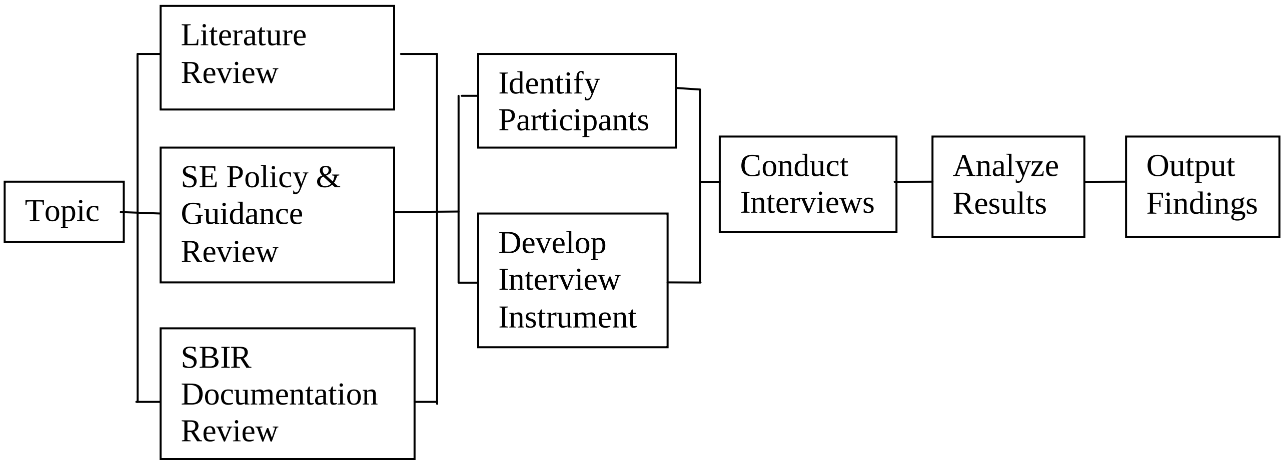

Figure 6: Grounded Theory

Once all data had been collected results were analyzed to identify the applicable SE tasks for SBIR projects. This research is an exploratory work using a mixture of qualitative and quantitative methods in addition to using existing written materials as evidence. With the help of the SBIR program office ideal participants managing or overseeing SBIR projects were identified for the interviews. The interview is semi-structured so that open-ended responses were encouraged and snowball sampling could occur. Using data gathered from the literature review and interviews enabled a structured content analysis through triangulation to define data and the SE rigor that is associated with SBIR projects. Using a triangulation analysis approach enabled the author to improve the validity and reliability of this research [Glafshani, 2003].

Research Objectives

The objective of this research project is to define the SE rigor that should be best applied for SBIR projects. To define the rigor and design a tailored approach will require identifying what degree of SE is applicable in the SBIR environment and how those SE processes vary amongst projects with respect to project maturity, size and other factors.

Research Questions

To define the research objectives the following question must be answered:

1. How well do SBIR projects currently implement Systems Engineering policy?
2. How are SE policies implemented?
3. How do DoD and Air Force SE processes apply to SBIR projects?
4. To what level of rigor does each SE process apply to SBIR projects?
5. What is the best way to implement these processes?

Hypothesis

Different organizations implement varying levels of Systems Engineering into their SBIR projects. Organizational SE policies and SE knowledge base vary amongst SBIR project managers. Therefore, projects are at risk to fail meeting DoD and AF standards with implementation of SE and SE processes. This research is going to test or measure the degree to which SE processes are applied to SBIR projects. Then I will analyze the results to determine commonalities and differences between organizations. From this I hope to generalize working SE principles for the SBIR community.

Interview Instrument Development

As identified in the literature review, AF SEAM fully defines the SE process involved in a major acquisition program. However these processes are defined differently in the DAG and AFI 63-1201 as illustrated earlier in Table 1. AFRL policy maps the DAG process to their Eight SE Key Questions. The interview was created with this understanding and is designed to map directly back to AFRL policy that maps to the DAG. One question for each SE process outlined in the DAG was created with the specific tasks called out in AFRL policy identified. The interview instrument is attached in Appendix 1. Additional questions were asked about the effectiveness of the Eight SE Key Questions outlined in AFRL policy. AFRL identifies that the Eight SE Key Questions guide project managers in implementing the SE process.

The areas targeted during the interview were:

1. Job, Organization, Experience, APDP Education, SBIR Experience for demographic analysis
2. Stakeholders Requirements Definition
3. Requirements Analysis
4. Requirements Management
5. Decision Analysis
6. Technical Planning
7. Technical Assessment
8. Technical Data Management
9. Risk Management
10. Configuration Management
11. Interface Management
12. Architectural Design
13. Implementation
14. Integration
15. Verification
16. Validation
17. Transition
18. Usefulness of the AFRL Eight SE Key Questions

Test Subjects/Sample Size

The day to day management of SBIR projects for the government is typically performed by a single SBIR project manager. These project managers are engineers or program managers with varying levels of experience. In some cases the project manager may have little experience working in the government and even less experience with systems engineering. In other cases they have been working in the government for 30+ years. Additionally Chief Engineers for the directorates oversee the management of these projects. The ideal participants for the interview were identified as SBIR Project Managers, Engineers and Chief Engineers because they are the most familiar with the daily technical management of a SBIR project. The project goal was to interview the Chief Engineer and several project managers/engineers from each organization. Participants for the interview were identified through purposeful and snowball sampling. Interviews started with two local directorates that were very supportive of this SE research project to establish a baseline. Additional interview participants were selected from multiple organizations to represent the broader SBIR community. The following AFRL Technology Directorates participated: Materials Directorate, Propulsion Directorate, 711 Human Performance Wing, Space Vehicles Directorate and Munitions Directorate. Organizations outside of AFRL that manage SBIR projects that participated included: Hill AFB Robins AFB Air Logistics Centers, Arnold AFB Test Center and WPAFB Aeronautical Systems Center.

Summary

Analysis of the interview data and SE artifacts discovered in the literature review will allow identification of SE processes and best practices within the SBIR community using a triangulation method during analysis. Using this method will help to validate results from the different sources. The results collected from the interviews will also help to gauge the level of SE rigor being implemented within the different organizations managing SBIR projects and help to identify the level of rigor needed for applicable SE tasks for SBIR projects. Comparing those results with current guidance and policy discussed in Chapter II will identify the current Systems Engineering gap in policy for the SBIR Community and allow the author to compare and contrast the current policy with the research findings to identify and develop a tailored SE approach for the SBIR community that aligns with DoD and Air Force guidance and policy.

IV. Analysis and Results

Chapter Overview

This chapter captures results from the interviews conducted. It provides a consolidated representation of results as well a detailed analysis for each SE process area. Using results from the interview provides a SBIR community analysis of the Eight SE Key Questions and it answers the research questions outlined in Chapter III.

Interview Results

Interviews conducted varied in size from one to several participants. The data was collected by interviewing each organization separately. AFRL XP helped to identify potential survey participants for each organization. Participants selected were SBIR Project Engineers/Program Managers and Chief Engineers. The following number of participants represented each organization and the interview results color scale is seen below:

Table 6: Total Participants

Technology Directorates					Test Centers	Air Logistics Centers	Other
Materials & Manufacturing	Propulsion	Space Vehicles	Human Effectiveness	Munitions	Arnold	Robins	ASC
4	7	3	2	2	2	3	1

Table 7: Interview Results Color Scale

Red	Yellow	Light green	Green
Usually not accomplished	Sometimes accomplished	Usually accomplished	Almost always accomplished

Usually not accomplished: Less than 25% participants identified it as applicable

Sometimes accomplished: 25-50% of participants identified it as applicable

Usually accomplished: 50-75% of participants identified it as applicable

Almost always accomplished: 75% or greater of participants identified it as applicable

When interpreting the below results make sure to consider that the specific SE tasks were derived from AFRL policy. Air Logistics Centers and Test Centers have a different focus. Thus some of the tasks in the interview are in S & T terms which may not apply in some areas as they are written for the ALC's and Test Centers. The additional comments documented for each question may better represent the SE tasks currently being accomplished in those cases.

Stakeholders Requirement Definition

Overall results for Stakeholders Requirements Definition were very positive. Most of the participants identified with the tasks defined in AFRL Policy. ALCs however did not identify as well with these tasks.

Table 8: Stakeholders Requirement Definition

Stakeholders Requirement Definition	Technology Directorates	Test Centers	ALCs	Total
o All inputs from relevant stakeholders translated into technical requirements.	71%	100%	33%	70%
o Requirements made quantifiable, have unique definitions, and specified thresholds and objectives.	71%	100%	67%	75%
o Work with the user to establish and refine goals, attributes, performance parameters, and financial and schedule constraints, and then ensure that all relevant requirements are addressed during the science and technology effort.	71%	0%	33%	60%
o Translate the "customer needs" into S&T program and system requirements.	79%	100%	33%	75%

Noteworthy or Significant Comments

Technology Directorates stated:

- Review PEO/TEO Needs with WBS managers and Chief Engineers.
- Evaluate cost, feasibility (are the users requirements attainable and can the company actually deliver the product with their organic capability?) and the technology maturity level.
- Work to refine requirements by interacting with the sponsor.
- Identify likely transition and what requirements are needed to give the tech a chance at transition

Test Centers stated:

- We attempt to include other government agency requirements if applicable (ie Edwards AFB / NASA Aeronautics/ etc.
- In general we do all of these, however we do not include schedule constraints into our planning. Schedule estimates for S&T efforts are too uncertain to include

them in our planning. Also, most of these are really only applicable to the Phase II and beyond efforts. Phase I is to show us your capabilities, whereas Phase II is where we really drive technical requirements.

Air Logistics Centers:

- Develop/lead technology development/transition teams to navigate R&D to implementation.
- Our requirements are started in house as we perform the maintenance on all their assets. Our projects are based on reducing total ownership costs from what we see in the field.

Even though most inputs and comments identified with these tasks about 30% of participants did not identify with the SE tasks identified. Sponsor involvement and requirements definition to ensure valid requirements are being derived to meet the operation need is an essential part of acquiring a successful system. Thus all participants should have identified with these tasks. Better education of SE principals would likely help community to better identify with importance of these tasks.

Requirements Analysis

Technology Directorates identified well with the identified tasks. ALCs and Test Centers did not relate to the tasks as written in AFRL language. Also the scope of SBIR projects can vary considerably from location so the task wording my not seem applicable as phrased in some cases.

Table 9: Requirements Analysis

Requirements Analysis	Technology Directorates	Test Centers	ALCs	Total
o Obtain sets of logical solutions to improve understanding of the defined requirements and the relationships among the requirements (e.g. functional, behavioral, temporal).	71%	0%	33%	55%
o Performance parameters and constraints allocated and derived technical requirements defined.	86%	0%	100%	80%
o Partition the technical problem into self-contained, cohesive, logical groupings of elements and, where appropriate, defined the key interfaces.	50%	0%	33%	40%

Noteworthy or Significant Comments

Technology Directorates stated:

- Don't identify a solution, just help with providing the expertise.
- Sounds a bit "ivory tower" (not the way things really work). We look at each project on its own relative merits. We have to make an inexact mental calculus on the impacts a successful proposal could have in addressing (1) primary sponsoring customers needs, (2) broader needs of USAF. We typically work with these same customers throughout the program and try to maximize relevance. And it's more complicated than that. Sometimes we have to work with requirements in a more "diffuse" manner. A new rad-hard memory chip for example, may not have a direct connection to requirements at the customer level, but trickle down through specific developments involving memory chips that would benefit. We would never get that from a direct customer. This is the essence of being a technical expert in a laboratory organization and working across a longer temporal perspective.
- Try to get the most capability that can reasonably be expected.

Air Logistics Centers stated:

- Map the R&D into self-contained, cohesive, logical groupings which can be incrementally funded seek funding.
- Our primary focus is reducing the maintenance costs, total ownership costs.

Responses for these SE tasks were mixed. These tasks were proved to be more applicable to the Technology Directorates. Good Requirements Analysis is an essential part of any system to ensure that requirements map back to valid performance parameters and constraints. Results identify that the task “Performance parameters and constraints allocated and derived technical requirements defined” is valid for SBIR projects.

Requirements Management

Overall the majority of participants identified with the listed tasks for Requirements Management. However the ALC’s and Test Centers did not in all cases. SBIR phases are short in duration and requirements typically to do not formally change during an early phase which likely accounts for some of the negative responses.

Table 10: Requirements Management

Requirements Management	Technology Directorates	Test Centers	ALCs	Total
o Maintain the traceability of all requirements from needs	79%	100%	100%	80%
o Document all changes to those requirements	64%	0%	33%	50%
o Record the rationale for those changes.	64%	0%	33%	50%
o Traceable to some current or potential future military capability need.	71%	100%	33%	70%

Noteworthy or Significant Comments

Technology Directorates stated:

- I do all of these, but do not document. Just keep in my mind and notes of progress of project and how the project is leaning towards meeting an application requirement, etc.
- Sponsors are involved with requirement changes.
- Increase in scope done through interacting with sponsor and contractor.
- Letters and email are used for documenting small changes.
- Contract changes are required for significant deviation.
- It is still an inexact calculus. Customer needs are not necessary sufficiently precise for the exercises you believe happen in requirements management. In a Phase 1 for example, the time frame is almost like an impulse function (a single snapshot in time), like less than one fiscal year. Only Phase 2 projects have a gestation interval long enough to matter in terms of evolving needs. It is a judgment call at that point, and we find some Phase 2 projects are / are not flexible enough to respond to changing needs. Using significant changes are not possible, since the company could indicate that the scope changes impact ability to deliver. In some cases, we may even identify alternate / additional customers.

Test Centers stated:

- The end user makes all decisions on requirements. In general we require the end user to either be at all technical reviews or be the project manager.

Inputs and comments confirm that these tasks are valid in the SBIR environment. SBIR requirements are captured at a top level and tied to the research objectives and do not change typically within the short scope of the phase. Requirements Management is performed with increased rigor in later phases of the project as it becomes more relevant. However Technology Directorates, Test Centers and ALCs should be accomplishing all of these tasks when ever requirements change.

Decision Analysis

Results from the interviews identified that the tasks identified for Decision Analysis are not always accomplished. Responses were higher for Technology Directorates in most cases.

Table 11: Decision Analysis

Decision Analysis	Technology Directorates	Test Centers	ALCs	Total
o Criteria selected for decision and methods to be used in conducting the analysis.	64%	0%	33%	55%
o Analysis conducted to help choose among alternatives to achieve a balanced, supportable, robust, and cost effective program.	64%	0%	33%	50%
o Analysis methods include some of the following: trade studies, modeling and simulation, cost/benefit analysis, and the analytic hierarchy process (AHP).	50%	0%	100%	50%
o Studies are augmented with virtual and/or physical prototypes, where applicable, prior to making decisions on best alternative.	50%	0%	67%	45%

Noteworthy or Significant Comments

Technology Directorates stated:

- I look at the performance of the small business, the likelihood of transition, the approach, and for innovation.
- Identify the best approach through a multi-disciplinary team Feasible cost.
- Trade studies are typically not accomplished.
- Like to use modeling and simulation when applicable.
- This “criteria” business does not track with SBIR award selection criteria. We are bound by law to follow the fairly vague, broad, and PUBLISHED criteria (e.g. technical merit, experience, dual-use/commercial/transition potential.
- The projects themselves may embed technical trades, modeling, feasibility demonstration, prototype development.

Responses to the interview and additional comments varied for Decision Analysis. A limited amount of Decision Analysis is accomplished during Phase I and II

SBIR projects due to the limited scope. Focus is on translating the research into solutions. SBIR projects must work within the limited time frame and resources allocated. Formal analysis methods and prototypes are used only when applicable and the project has the resources.

Technical Planning

Technical Planning establishes and maintains documentation that defines the technical aspects of the project. Participants identified well the need to define the scope of the effort to include exit criteria, constraints and interfaces.

Table 12: Technical Planning

Technical Planning	Technology Directorates	Test Centers	ALCs	Total
o Technical Planning made to ensure that the technical activities were conducted properly throughout the system's life cycle.	43%	0%	0%	30%
o Define the scope of the technical effort required to achieve program technical goals which includes exit criteria and products/deliverables which can be tracked with progress measured.	93%	100%	67%	90%
o Indentify constraints and interfaces that will result in derived technical requirements.	64%	100%	67%	70%
o Contribute input to the Systems Engineering Plan, which is owned and maintained by the acquisition activity.	7%	100%	33%	20%

Noteworthy or Significant Comments

Technology Directorates stated:

- I don't know what these mean. The planning goes as far as informing the SBIR awardees the expectations, why I like their innovative ideas, and any adjustments I think should be taken based on the apparent effectiveness of their proposed work.
- Time tables are associated with budget.

- Reoccurring interaction with contractor is needed.
- IMP does not apply for projects under 20M.
- Prior to proposal following topic call RZ provides feedback on expected evaluation criteria.
- I am not even sure what this means. We typically negotiate topics with sponsors, along the lines of requirements. These topics usually (but not always) track with their top priorities. It is subjective, because we and they are human. Sometimes as a result we live with "not the best defined" topics, and we have to do the best we can to ensure that the work is relevant. On the scale of the SBIR program, it is impossible to get this right 100% of the time.

Test Centers stated:

- For AEDC, the end user is also the acquisition activity. Our SBIR's are designed with a specific AEDC use in mind. We try to incorporate other centers' technical requirements to enable better commercialization but these are secondary to the AEDC requirements.

Technical Planning for throughout the life cycle and development of a Systems Engineering Plan (SEP) are tasks more applicable later in the development. Results for those areas identified them to not be applicable for SBIR phase I and II projects. Though a particular SEP may not exist for those phases' project managers should identify and follow the overarching SEP if one exists for the platform that the SBIR project will eventually integrate to or the overarching organizational SEP.

Technical Assessment

Several of the tasks for Technical Assessment were identified during the interviews as displayed in green below. However two of the tasks (highlighted in yellow) were identified as not always applicable.

Table 13: Technical Assessment

Technical Assessment	Technology Directorates	Test Centers	ALCs	Total
o Measure technical progress, technology maturity, and the effectiveness of plans and requirements. Activities include: Technical Performance Measurement, Technology Readiness Assessment, and the conduct of technical reviews.	86%	100%	100%	85%
o Demonstrate and confirm completion of required accomplishments and S&T exit criteria.	79%	100%	33%	70%
o Discover deficiencies or anomalies that may result in the application of corrective action and may have formed the technical portion of a continuous process improvement process when used to evaluate application of SE IAW paragraph 2.5.5.2.	43%	100%	33%	45%
o Technical assessment inputs used in support of the Laboratory Management Review process.	86%	0%	0%	71%
o Technical assessment activities conducted in concert with existing reviews where possible to minimize disruption to the research project.	36%	0%	33%	35%

Noteworthy or Significant Comments

Technology Directorates stated:

- As the contract program manager, I do all of these on a subjective basis and a gut feeling using engineering judgment of best approach.
- These things sound like they come from textbooks or acquisition training programs. Most SBIRs are so short in duration and fluid, not to mention limited in scope, that some of these activities (TRA) are too difficult to do on a recurring basis (like every 3-6 months). Also, it is not uncommon for some individuals to have more than 12 SBIRs at any moment. They are usually a secondary duty, as we cannot afford to dedicate even a single individual to 1 or 2 SBIRs.

Test Centers stated:

- Every AEDC SBIR is required to have an onsite demonstration at the midpoint of the Phase II. We also encourage our contractors to provide a demonstration at the end of Phase I in order to show a viable path to the required TRL.

The interview results and comments identified the applicable tasks during phase I and II SBIR projects. The two tasks that were identified in yellow may be applicable in some cases. However due to the short duration and limited scope of the SBIR phase they may not be applicable. Overall Technical Assessment is a critical step in the technical management of the project to ensure the project is mature enough to enter the next phase by meeting entry and exit criteria and should be assessed by all SBIR project managers.

Technical Data Management

The SBIR community identified the formal use of the Defense Technical Information Center. All formal reports are documented in DTIC.

Table 14: Technical Data Management

Technical Data Management	Technology Directorates	Test Centers	ALCs	Total
o Project data managed through the Defense Technical Information Center (DTIC)	100%	100%	33%	85%
o Or similar data base.	0%	0%	0%	0%

Noteworthy or Significant Comments

Technology Directorates stated:

- We have a fairly regular set of actions that are always performed. We have kickoff meeting, periodic technical interchange meetings and telecons, emails on demand for technical clarification, we review these in LMRs, we document research summaries and final technical reports through DTIC.
- We also respond, on customer demand, to participate in industry days or work with their own database initiatives, which come and go over time.

Air Logistics Centers stated:

- Final reports are put in DTIC, we use our local server to store all contract activities.

Risk Management

A good risk management strategy is critical for a successful project. The large majority of participants identified that the five risk management steps apply to the SBIR community. 65% identified acknowledged the existence of a risk management plan for their project. However feedback from the interviews identified that the Small Business perform most aspects of the risk management.

Table 15: Risk Management

Risk Management	Technology Directorates	Test Centers	ALCs	Total
o Develop risk management plan and performed the following:	57%	100%	100%	65%
o Identified risk	86%	100%	100%	85%
o Analyze risk and define probably and likelihood.	64%	100%	100%	70%
o Identify handling options	64%	100%	100%	70%
o Mitigate risk	79%	100%	100%	80%
o Track risk	86%	100%	100%	85%

Noteworthy or Significant Comments

Technology Directorates stated:

- Risk is tracked by the project officer.
- Information is provided by contractor (varies on how often and well PO interacts and follows the contractors progress).
- AFPAM 63-128 is not really being used as a guide formally. Limited knowledge of it in work environment.
- In phase 1s, there is very little time to do any of this except in the brief interchanges that one can have over a 6-9month technical activity. They either “get it” or they don’t, in which case you request / don’t request a Phase 2 proposal. This is Darwinian. You then hope that the best ones will be awarded, but it is a competitive process, so sometimes even a perfect Phase 1 ends without a follow-on. The steps you outline above are typically done in a very “seat of pants” way, but they typically ARE done.
- Risk in a SBIR is generally limited to technical risk as cost is fixed and schedule deliverables are detailed.

Test Centers stated:

- Occasionally use canned Risk Analysis software (ie Crystal Ball).
- We understand every SBIR carries programmatic risk. Therefore these activities are only done for Phase III's.
- For SBIR, we mainly use canned risk analysis software and occasionally use Monte-Carlo methods to conduct risk trade analyses.

Air Logistics Centers stated:

- SBIR programs are inherently at a high technical risk due to the nature of new technological development. However, risk is managed by the outline above. I am always trying to identify schedule, cost and technical risk early and working with the contractor to mitigate. Early detection is essential to risk management and overall program success.
- Risks on our projects are what we over come in the SBIRS the final analysis and subsequence prototype testing will validate success.

Responses and comments identified that the SBIR community is aware of risk management techniques and they are applicable to SBIR projects. Project managers in many cases rely on information from the contractor for their assessments. Project managers must ensure they follow up on a regular basis with the contractor to check the health of the project and ensure the risk is being managed effectively and the project is on scope.

Configuration Management

Most participants identified the need to document results for Configuration Management. However there were mixed results from the interview responses.

Table 16: Configuration Management

Configuration Management	Technology Directorates	Test Centers	ALCs	Total
o Ensure the repeatability of experimental results to include data by knowing and keeping a record of the laboratory set-up as well as tracking changes to it.	64%	50%	33%	55%
o Keep a record of laboratory experimental hardware configuration when measurements are gathered including such things as calibration status, environmental conditions, software version and modifications used, and documentation (data) resulting from the experiment/demonstration?	43%	50%	33%	40%
o A complete audit trail of decisions affecting laboratory equipment/software design modifications maintained.	29%	0%	0%	20%

Noteworthy or Significant Comments

Technology Directorates stated:

- None, these do not seem to apply to the type of SBIR's I manage. Seems more in-house research as opposed to SBIR contracts in which are performed by external to WPAFB contractors.
- Contractor maintains CM records. PO does not have a CMP.
- Gov't PO is not very involved with ensuring CM is accomplished on average.
- Final technical report is published, to document permanently what we did do in terms of the things you describe above.
- Configurations for official tests and demos are documented, we also rely on contractor supplied ICDs, schematics, etc.

Test Centers stated:

- AEDC only configures once the SBIR is ready for transition to an actual test cell. This normally happens at least one year following the close-out of the phase II. For Phase III acquisitions, AEDC follows regular SE processes and requires full configuration management as part of the acquisition.

Air Logistics Centers stated:

- Performed by the SBIR contractor, the information is contained in their interim reports, also much of the testing is performed by an independent testing facility, which will identify the equipment used and calibrations. These data sheets are included with the reports.

Results and comments are concerning since it seems that Configuration Management is dependent on the contractor and not well regulated by the SBIR project managers. A fundamental basic of good SE is to maintain good configuration management for the life cycle of the system. S&T projects are derived to support a potential capability need or requirement. Thus all project results should be documented to ensure traceability to the higher level requirements as well repeatability of results. Lack of proper documentation and traceability risks wasting efforts that do not support the project objectives as well as increase the challenges of transitioning to the next phase with well documented repeatable results.

Interface Management

Similarly to Configuration Management responses varied and not many Interface Management tasks were not validated as being applicable.

Table 17: Interface Management

Interface Management	Technology Directorates	Test Centers	ALCs	Total
o Ensure interface definition and compliance among the elements that compose the laboratory system (internal interfaces), as well as with other systems with which the operational system or system elements might interact (external interfaces).	50%	0%	0%	40%
o Ensure that all internal and external interface requirement changes are properly documented in accordance with the configuration management plan and communicated to all affected elements of the program.	50%	0%	0%	35%
o All interfaces defined in sufficient detail to facilitate necessary communication/interaction among system, subsystem, and components.	71%	0%	33%	55%

Noteworthy or Significant Comments

Technology Directorates stated:

- None apply to the type of SBIR's I manage. My SBIR's relate to component maturation rather than system engineering. We are trying to demonstrate a higher performance component where we need to be aware of the mating technologies. However, interfacing usually comes much beyond Phase II and often times beyond Phase III contracts.
- Defined for Demonstration configuration in showing program met the topic goals.
- Contractor maintains IM records.
- There should be stake holder involvement to ensure interface interactions are defined and acceptable.
- Nothing this formal, except in rare occasions.

Test Centers stated:

- AEDC does not have SBIRs that are intended to be inserted into other systems and therefore do not require ICD's.
- When we transition a SBIR all of the above occurs but not during a SBIR.

Air Logistics Centers stated:

- We work with structural type systems (Shelters, radomes and towers). Each is unique to the individual mission. We don't have formal external interfaces. We do have industry standards and local codes for geographic location that they must meet and pass.

A low level of rigor for Interface Management may only be required for many typical SBIR projects because not all interfaces may yet be fully defined. However stakeholder involvement and early architecture efforts should identify the interfaces necessary and drive the requirements for early Interface Management. Overall the SBIR community did not identify well with the tasks identified. Evidence suggest that SBIR project managers really heavily on the Small Business to manage interfaces. This is a potential risk since good interface management is required to be successful in transitioning the project.

Architectural Design

Responses for Architectural Design did not validate any of the tasks.

Table 18: Architectural Design

Technology Directorates	Technology Directorates	Test Centers	ALCs	Total
o Translate the outputs of the Stakeholder Requirements Definition and Requirements Analysis processes into alternative technical solutions and selects a final technical path to explore.	29%	0%	0%	20%
o Iterate Stakeholder Requirements Definition, Requirements Analysis, and with the technical management processes to identify and select the best solution by first developing a high-level view of the system architecture capable of meeting stakeholder needs.	29%	0%	0%	25%
o Output the design functional or physical architecture sufficiently detailed to allow upward and downward traceability of requirements.	21%	0%	33%	20%

Noteworthy or Significant Comments

Technology Directorates stated:

- Architectural design is not accounted. Rather, we design to meet an objective of a component performance.
- Don't feel architectures apply much for phase I and II projects.
- Architectural design is not accounted. Rather, we design to meet an objective of a component performance.
- Formal Architectural Design rarely has use in the world of SBIR because the customers aren't concerned about this sort of formal representation of impact from a SBIR effort. I am sure we would do it if we sensed any utility.

Air Logistics Centers stated:

- In our case, the stakeholder comes into play after we ensure the product meets the basic standards such as ANSI 1925 for shelters. Then the stakeholders come into play to incorporate their system into our product.

Responses and comments for Architectural Design are very concerning. S&T projects risk being out of scope with DoD objectives without maintaining traceability to requirements. Early architectural mapping to those requirements ensure that projects stay on scope. Results identified that the majority of participants do not formally document architecture and many do not feel architecture is applicable to SBIR which is a discouraging misconception. Even Basic Research should map to a high level capability.

Implementation

Capturing the right information to address the preparation required to support the project transition to the next phase on aspects of production of products and/or services is an important part of the project. The majority of participants identified with the below tasks. However, as results showed below, all are applicable tasks in the SBIR community but only 50 and 55% identified with two of the task.

Table 19: Implementation

Implementation	Technology Directorates	Test Centers	ALCs	Total
o Yield the fundamental capability of the program.	64%	50%	33%	55%
o Include some testing of the individual elements before they passed to Integration.	79%	100%	67%	75%
o Develop supporting documentation for the system; such as the as-built configuration, or discovered limitations of the concept; is also a part of the implementation process.	43%	100%	67%	50%

Noteworthy or Significant Comments

Technology Directorates stated:

- We ensure we are meeting some sort of performance requirement before attempting to look at integration or mating with other technologies. However, this usually comes at the end of a SBIR program where there are not usually sufficient funds left for maturing any more.
- Include some testing of the individual elements before they passed to integration
- We test specific assertions that comprise the program statement of work. To the degree they embody these things, we do them. They are certainly documented – variously – through the status reports and final technical reports that are always required.

Test Centers stated:

- AEDC will normally accept the deliverable and test it in a lab quite some time prior to transition to an actual test cell.

Air Logistics Centers stated:

- Update T.O.s & Drawings, publish new ASTM, etc., Standards.
- For Joint-Service Teams to implement to wider DoD activities.
- Implementation is accomplished through capturing all technical requirements within an Air Force specification which then rolls up into Technical Manuals (T.O.'s).

Results and comments overall were positive for Implementation. Most of the SBIR community interviewed understood the importance of Implementation. It however accomplished with limited rigor during SBIR phase I and II due to the limited scope and early development effort. Implementation should increase in rigor as the project matures.

Integration

Results for the Integration tasks identified that the tasks are typically not applicable in the SBIR phase I and II environment.

Table 20: Integration

Integration	Technology Directorates	Test Centers	ALCs	Total
o Incorporate the lower-level system elements into a higher-level system element in the physical architecture.	36%	50%	100%	45%
o Define the plan or strategy for the Integration process, including the assembly sequence, that may have imposed constraints on the design solution	43%	50%	67%	45%

Noteworthy or Significant Comments

Technology Directorates stated:

- We work with the prime contractors to see if there is interest. If there is, we look for funding to integrate the technology into some relevant system. Unfortunately, things usually die early due to insufficient funds.
- Integration as need to demonstrate the SBIR goals – not a formal plan but may be art of the test plan.
- Do not dictate the process, only indicate the requirements.
- Work with the contactor to see if there is interest to integrate a SBIR into a relevant system and try to locate funding.
- Very limited in Phase I and II SBIRs.

Air Logistics Centers stated:

- Generally we take other "Systems" and incorporate them in our shelter, put on a tower or cover them up with a radome.

As results and comments identified a larger emphasis on integration takes place in Phase III of a SBIR project. Thus results for the tasks identified from AFRL policy for integration were not identified as applicable by the majority of participants for the Phase I & II SBIR community. These tasks may or may not be applicable depending on the maturity of the project. ALCs did identify with these tasks likely because they have more initial information on the platform the SBIR project will be integrated to support.

Verification

Responses identified that SBIR projects verify some elements of the project. However, the tasks in yellow were identified as not applicable for SBIR phase I and II projects.

Table 21: Verification

Verification	Technology Directorates	Test Centers	ALCs	Total
o Confirm that the laboratory/experimental system element meets design specifications.	86%	50%	100%	80%
o Test the system elements against their defined requirements (predicted versus experimental results).	64%	50%	100%	65%
o Design solutions at all levels of the physical architecture were verified through a cost-effective combination of analysis, examination, demonstration, and testing, all of which can be aided by modeling and simulation.	29%	0%	67%	30%
o Answer the verification question "Did we build the thing right?".	29%	50%	67%	40%

Noteworthy or Significant Comments

Technology Directorates stated:

- Some verification takes place with component testing.
- Demos are usually joint test events and we try to test the capability against operational expectations.

Air Logistics Centers stated:

- Perform "Live-Fire", and shop level performance and testing (Zinc-Nickel plating to replace Cadmium on Landing Gear components).
- It's more subtle – and complex – than these simple menu choices.

Results and comments identified that SBIR phase I and II projects only accomplish a limited amount of Verification testing. Further verification testing will be accomplished in later phases. Thus answering the verification question "Did we build the thing right?" will be accomplished later in the development of the project. Similarly design solutions for all levels of the physical architecture are more applicable in the later phases of the project.

Validation

Responses identified Validation tasks are accomplished for SBIR projects. However the validation question "Did we build the right thing was identified as not always applicable.

Table 22: Validation

Validation	Technology Directorates	Test Centers	ALCs	Total
o Test the performance of the technology against the original program goals.	86%	100%	67%	80%
o Capture any testing results/data so that they are available for further development/research/maturation efforts.	79%	100%	67%	75%
o Answer the validation question "Did we build the right thing?".	29%	50%	100%	45%

Noteworthy or Significant Comments

Test Centers stated:

- It is rare in a SBIR development that we receive exactly what we want. Clearly, the small business is interested in commercialization rather than simply delivery of the prototype. Because of this, AEDC must often spend additional mission resources to ensure the system meets our requirements. We do this through additional development once the prototype has been received.
- Usually not enough funding through a SBIR for validation. Full validation takes place as a SBIR is integrated into a system through other funding methods.
- Sometimes, on the scale of a SBIR, we don't even get a WHOLE thing, and we sometimes cannot answer these simplistic questions like "did we build the right thing"
- All are done informally.

SBIR Phase I and II projects only accomplish a limited amount of Validation testing due to their limited scope and duration. Further validation testing will be accomplished in later phases.

Transition

Most participants identified the importance of considering and applying steps for their projects to transition to the next phase.

Table 23: Transition

Transition	Technology Directorates	Test Centers	ALCs	Total
o Deliver a supportable technology project capable of being put in the hands of the warfighter.	43%	50%	67%	45%
o The transition process applied in a step-by-step manner to move the technology to the next level in the developmental cycle.	86%	50%	67%	75%
o Needs of follow-on phases considered early in the program and included in all of the technical management processes.	71%	50%	100%	75%

Noteworthy or Significant Comments

Technology Directorates stated:

- Not much consideration during phase I and phase II.
- There is no such thing as a "step by step" transition process. This seems to reflect a fairly meager understanding of technology development. You are not always able to mature even a piece of a problem to a level that can be transitioned.
- Usually you target a large defense contractor/SPO/gov agency that can integrate the tech into their products rather than straight to warfighter/production.

Air Logistics Centers stated:

- In phase II we focus on one system or customer that has a need for the technology. We find that new technology is met with resistance. That it is important to have a working prototype to customers can "kick the tires" or see a physical item.

As results and comments validated Transition tasks for SBIR not all tasks were identified as applicable. "Deliver a supportable technology project capable of being put in the hands of the warfighter" is an action that takes place in Phase III and is not directly applicable to phase I & II projects until they progress to that phase. That is why only 45% of the participants identified with that task. Some SBIR projects never reach phase III.

Summary of Results

Results below include all the participants. It illustrates that how SBIR is unique since for a major acquisition program all tasks would be applicable.

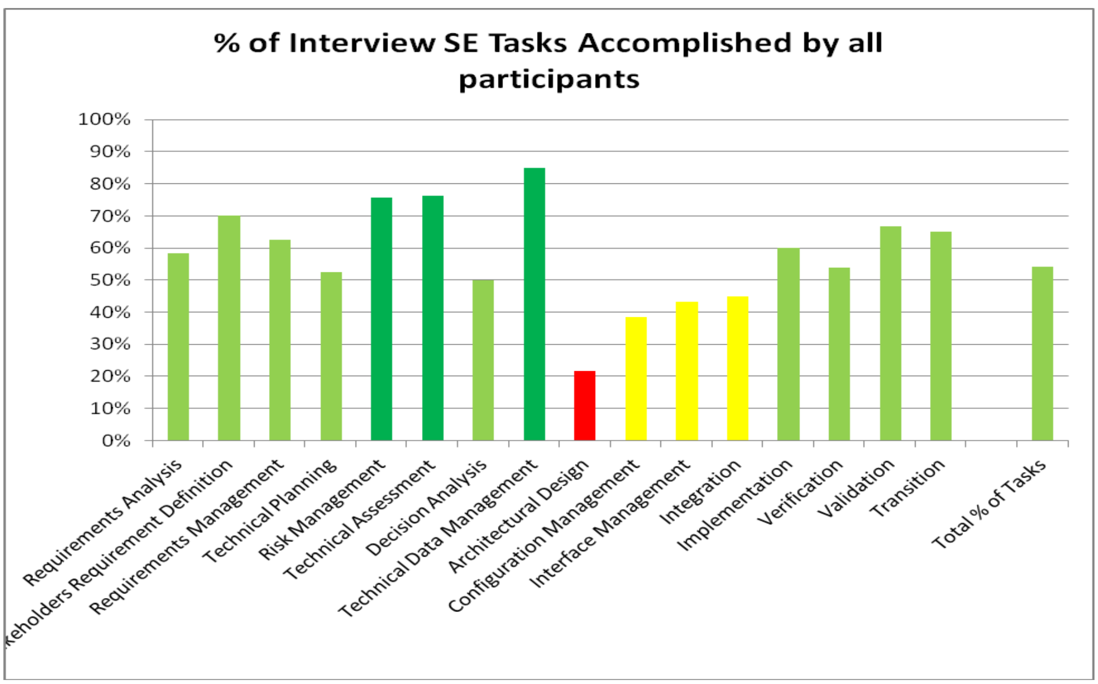

Figure 7: All Participant Results

Center Results

Results identified several weak areas with regards of implementation of AFRL SE tasks from identified in AFRL policy. This illustrates how SBIR is unique when compared to typical S & T projects within AFRL.

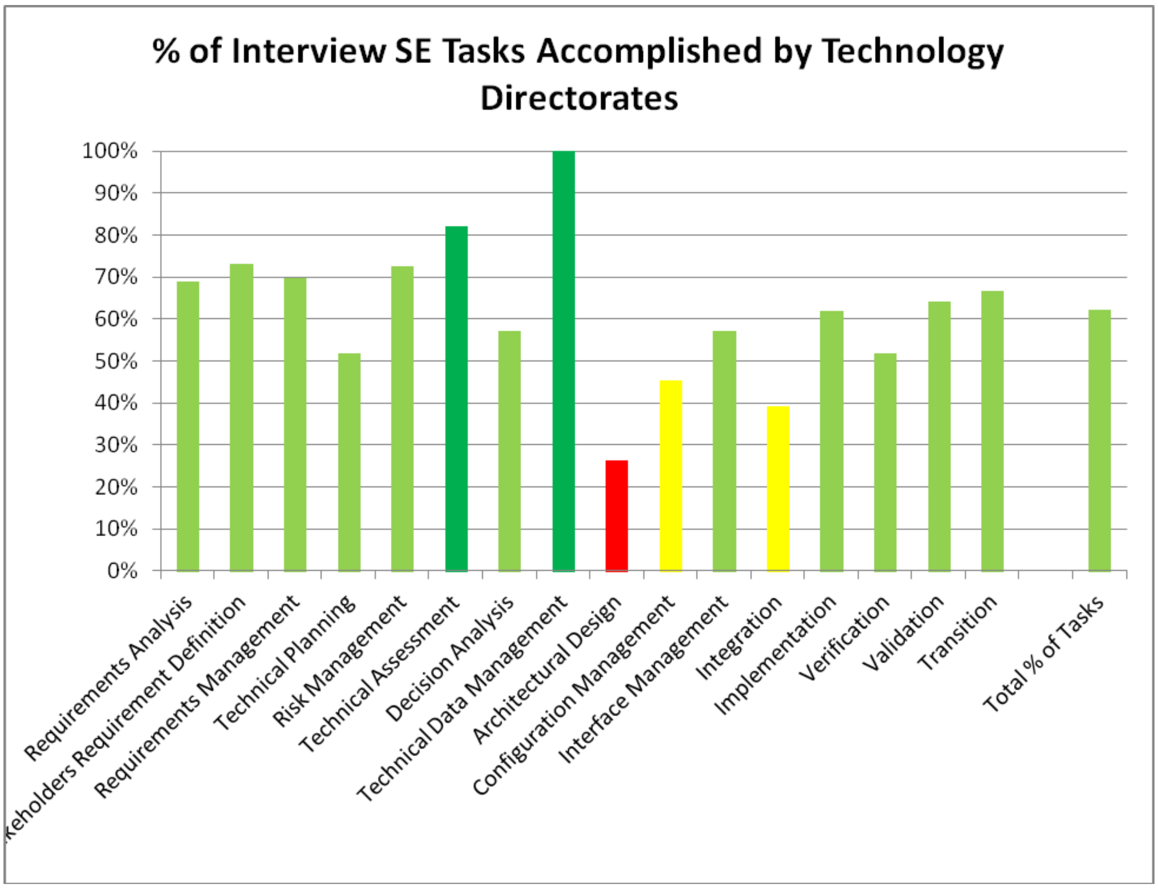

Figure 8: Technology Directorates Results

Test Center Results

Since the interview instrument was developed using AFRL policy some of the tasks were in AFRL language and participants did not identify with them. Data was gathered from a small participant size for Test Centers. Both of those factors must be considered when intrepreting results. Additional comments on how tasks were actually performed was captured in their comments that was previously noted for each area. Architectural Design, Decision Analysis and Interface Management identified no interview SE tasks as applicable from survey responses.

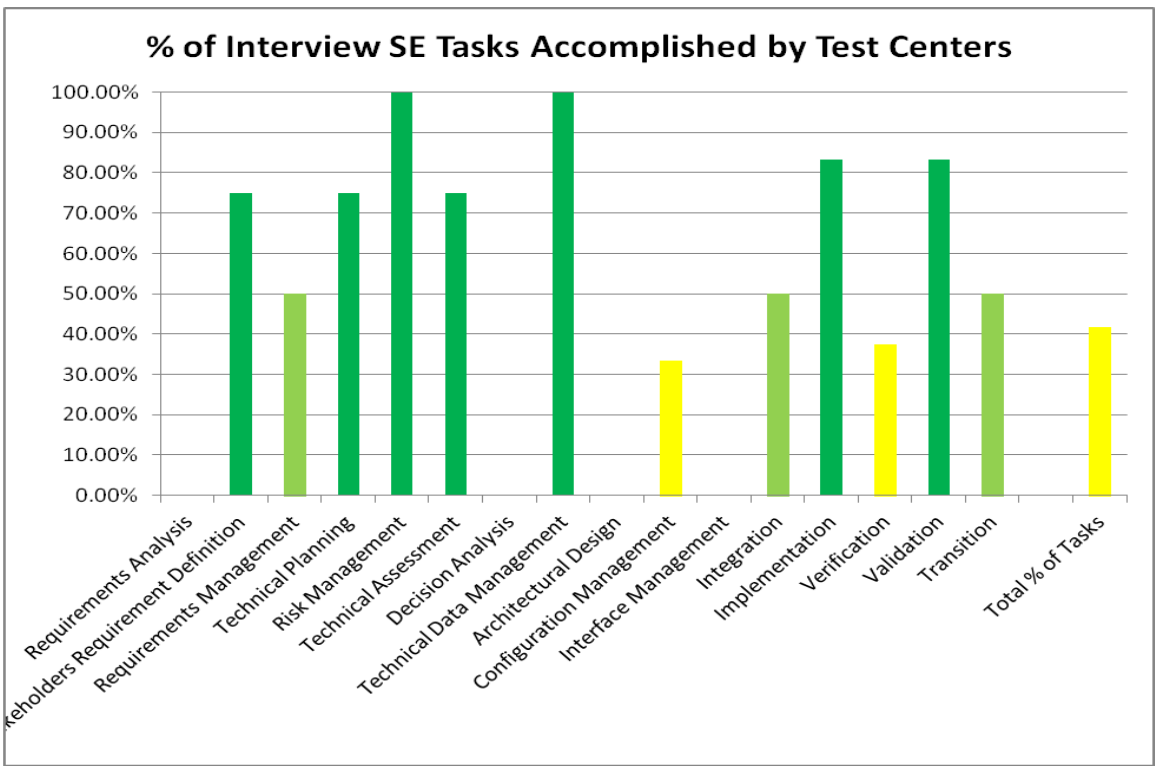

Figure 9: Test Centers Results

Air Logistics Center Results

Since the interview instrument was developed using AFRL policy some of the tasks were in AFRL language and participants did not identify with them. Data was gathered from a small participant size for ALC's. Both of those factors must be considered when intrepreting results. Additional comments on how tasks were actually performed was captured in their comments that was previously noted for each area.

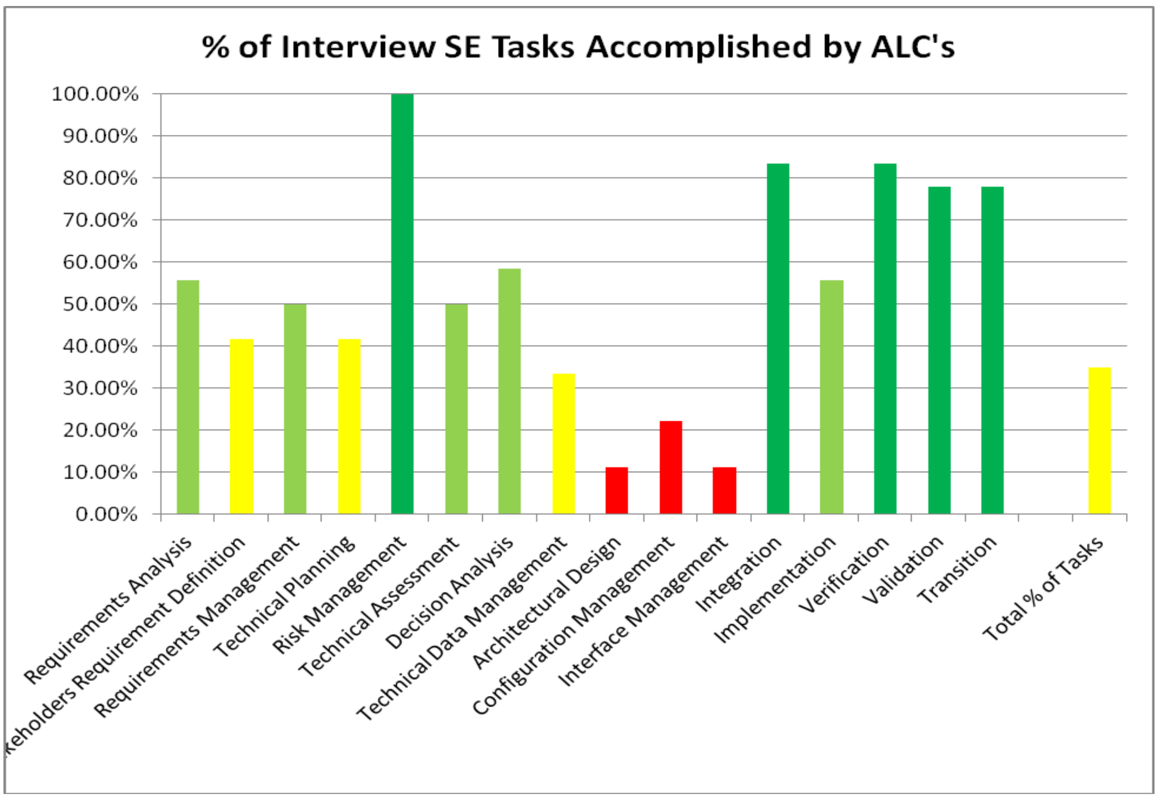

Figure 10: Air Logistics Centers Results

AFRL Eight Systems Engineering Key Questions

AFRL emphasizes the use of the Eight SE Key Questions identified in AFRLI 61-104. The questions are mapped back to the DAG SE processes. This below table illustrates the interview results mapped back to the questions. The majority of interview participants identified these questions to be useful to extremely useful. Each participant subjectively identified the most and least useful question illustrated in the below table.

Table 24: AFRL SE Key Questions Mapped to Interview Results

	Most useful	**Least Useful**	**Mapped to SE Process**
1. Who is your customer?	**5**	2	Requirements Management Requirements Definition
2. What are the customer's requirements?	**5**		Requirements Management Configuration, Data & Interface Management Requirements Development & Validation
3. How will you demonstrate you have met the requirements?	**5**	1	Technical Planning & Technical Assessment Decision Analysis Risk & Requirements Management Verification, Validation & Transition Configuration & Interface Management Integration Logical Analysis
4. What are the technology options?	1	2	Technical Planning & Implementation Logical Analysis
5. Which is the best approach?		1	Technical Assessment Decision Analysis & Implementation Integration Design Solution
6. What are the risks to developing the selected technology?	2	1	Technical Planning Risk Management Design Solution
7. How will you structure your program to meet requirements and mitigate risk?	2		Risk Management & Data Management Technical Planning & Requirements Definition Verification &Validation Implementation & Transition Logical Analysis & Design Solution Integration
8. What is your business-based transition plan that meets customer approval?		**4**	Configuration Management Data Management & Interface Management Transition

Though the majority of participant thought the questions were useful about 30% identified them as not being that useful. Several participants observed if you can't answer these you are not managing the project correctly. The first three seemed to be the most important. The least important question was identified as question # 8. This is likely because not all SBIR projects transition into larger projects.

The analysis of how these questions map back to the DAG processes suggests these questions must be answered to successfully manage a program. However different organizations manage SBIR projects which value and implement SE differently. The difference in opinion from participants on their value addresses a bigger issue of the different levels of understanding and appreciation of SE. In the author's experience two major factors are responsible. Either workers have not received good SE education and have not made the connection that good SE leads to good program management or they have been discouraged from their experience with mismanaged SE efforts. SE must be tailored to the appropriate level for a program or project to ensure it is value added. Historically the DoD had tried to standardize SE processes by mandating them. This one size fits all approach often leads to an increased work load without much value added to the program. One participant identified that the first seven questions are almost offensive since they must be known. The author is not surprised how an experienced project manager can see it this way however the management of SBIR projects varies from project managers new to the government to the very seasoned. This point is evident in the results above and the varying understanding of the questions.

AF SEAM Comparison

The author compared his results with AF SEAM to identify the applicable SE tasks for the SBIR community. AF SEAM and AFRL policy do not directly align since AFRL policy maps back to the DAG. Using the data gathered from this research the author reviewed each AF SEAM task with the data collected and translated those results into AF SEAM SE tasks. Results of this comparison are captured in Appendix 2.

This information will be very useful to the Air Force SBIR community when the current draft revision of 63-1201 is published since it is projected to align with Air Force SEAM. It can be used to explain what is applicable to the SBIR community from AF SEAM and also illustrates that AF SEAM is not tailored specific for the SBIR community. Only about 50% of the tasks from AF SEAM were found to be applicable for the SBIR community. Many of the tasks identified in AF SEAM are not applicable until later phases of a program.

These findings show that it would not be useful to implement AF SEAM within the SBIR community. In addition to only half the tasks being applicable, AF SEAM requires a large manpower effort to complete it due to its 190 SE tasks. Since SBIR projects do not have resources to support such a significant SE effort and it is not tailored for SBIR a more tailored approach is would be a much better use of resources.

Research Questions Answered

1. How well do SBIR projects currently implement Systems Engineering policy?

   Answer: The SBIR community does not believe all SE tasks in AFRL policy apply to their projects and does consistently implement SE tasks.

2. How are SE Policies implemented?

   Answer: The results identified a wide spectrum of interpretation that partially rests on the sponsoring organization type and the SBIR phase. Those results identified weak areas within the current policy.

3. How do DoD and Air Force SE processes apply to SBIR projects?

   Answer: DoD and Air Force SE processes do apply to SBIR projects. However they must be tailored for the scope of the project. Applicable SE tasks SBIR projects were identified in Chapter IV.

4. To what level of rigor does each SE process apply to SBIR projects?

   Answer: The number of tasks for each SE process area varies. Specific tasks for each area where captured in interview results and comparison of AF SEAM applicable tasks.

5. What is the best way to implement these processes?

   Answer: The best way to implement SE to a SBIR project is establish a tailored approach and follow the key steps outlined in policy. SE guidance for this is identified in the AFRL SE Guide. Project managers must have a good understanding of SE and tailor a solid approach for their project. Project officers can use results from this research as a guide to better understand what level of rigor typically applies to a SBIR project.

Summary

Results from the literature review indentified a number of SE processes that were applied effectively to AFRL projects. The interview data identified what SE tasks are being accomplished and to what level of rigor within the SBIR community. The results identified in many areas that the SE tasks defined in policy are either not applicable or are not being accomplished within the SBIR community. Better SE education will help project managers fully tailor SE to their projects and ensure applicable tasks are being incorporated. Tasks that are not applicable however should not be required. The results from the literature reviews and interviews identified those tasks and can be used to better tailor an organization s SE approach for SBIR projects to avoid wasting resources on non value added tasks. Overall these findings again illustrated the unique nature of SBIR projects.

V. Conclusions and Recommendations

Chapter IV identified the SE tasks that are applicable to the SBIR community. The case studies demonstrated successfully tailoring a SE approach for S&T projects. Interview results provided applicable SE tasks from AFRL policy for SBIR projects. The author translated those results with his SE expertise to identify what SE tasks are applicable for SBIR from Air Force SEAM in Appendix 2. Analysis of AFRL SE tasks and AF SEAM identified neither of them are specific enough for SBIR. Many of the tasks were not applicable during SBIR phase I and II projects due to the unique nature of SBIR which includes limited budget, short schedule and a limited scope. Projects also vary greatly across the Air Force and DoD. This study concludes that current policy does not fully define SE for the SBIR community and that SE is being implemented at various level amongst the different organizations that manage SBIR projects.

Results from this study also identified that overall the SBIR community was well educated and understood how certain SE processes applied to their projects. However the results also identified that they are very week in many areas. I believe there is a misconception within the community that some areas of SE do not apply to their projects. All areas of SE apply with different levels of rigor for any project. Leadership and project managers must ensure adequate levels of SE are being incorporated into their projects to improve their chance of success, limit cost and schedule overruns and meet performance goals. Failure to follow established SE processes in any one area can have significant negative consequences to the project.

SBIR SE Checklist

The following checklist will ensure adequate levels of SE are being incorporated for SBIR projects. This SBIR SE Checklist is a guide for project managers and engineers to ensure all SE areas are adequately addressed. This checklist was developed using the results derived from this research and align with the 10 AF SEAM SE processes areas.

- Represents general AF SE process tasks tailored for SBIR
- \- Represents specific SE tasks captured in analysis

Table 25: SBIR SE Checklist

Requirements	• Determine requirements to include stakeholder needs, expectations, constraints, and interface requirements. - Translate all stakeholder needs to technical requirements. - Requirements made quantifiable, have unique definitions, and specified thresholds and objectives. - Work with stakeholders to refine requirements. - Performance parameters and constraints allocated and derived technical requirements defined. - Maintain the traceability of all requirements from needs. - Document changes and record rationale of changes.
Project Planning	• Identify project milestones to include cost, schedule and technical milestones. - Define the scope of the tech effort required to achieve program technical goals. - Define exit criteria and products/deliverables which can be tracked with progress measured.
Risk Management	• Develop a risk management plan and identify, analyze, identify handling options, mitigate and track risk.
Decision Analysis	• Establish selection criteria, identify & evaluate alternatives and select solution. - Criteria selected for decision & methods to be used in conducting the analysis. - Identify analysis methods and conduct analysis of alternatives.
Design	• Establish the design and integration baseline. - Incorporate the lower-level system elements into a higher-level system element in the physical architecture. - Indentify constraints & interfaces that will result in derived technical requirements.

Technical Management & Control	• Establish and maintain the project environment, integrated product teams (IPT), measurements approach and monitor technical reviews, work products, project data, corrective actions and technical milestones. - Measure technical progress, technology maturity and the effectiveness of plans and requirements. - Demonstrate and confirm completion of required accomplishments and project exit criteria.
Configuration Management	• Establish the technical baseline, track and document changes. - Maintain record of all configurations to include hardware, software and test set up and document changes. - Define internal and external interfaces. - Project data managed through the Defense Technical Information Center (DTIC).
Verification & Validation	• Establish and maintain the overall verification strategy and plan to include verification and validation criteria and an integrated testing approach when applicable. Verify and Validate that the project has meets the required parameters. - Confirm project meets design specifications. - Test the system elements against their defined requirements. - Test the performance of the technology against the original program goals.
Transition, Fielding, & Sustainment	• Indentify future transition, fielding, & sustainment requirements as needed to proceed to the next phase of the project. - Needs of follow-on phases considered early in the program and included in all of the technical management processes. - Yield the fundamental capability of the program.
Manufacturing	• Identify and maintain documentation relevant to the future production of the project. - Develop supporting documentation for the system.

Project Managers using this checklist will begin to accomplish some of these tasks in Phase 1 with the emphasis of demonstrating the project is feasible, identifying stakeholders and defining requirements. By the end of Phase 2 all of the above tasks should have been tailored and accomplished for the project. Projects that enter Phase 2.5 will emphasize on further defining and documenting information and demonstrating the technology with the hopes to aid in the future transition of the project to the Phase III. Phase III is the commercialization phase.

Significance of Research

This research identified the SE policy gap in the SBIR community and defined the applicable SE tasks. This highlights a huge risk as millions of dollars are spent within the DoD each year on SBIR projects. Failure to implement good SE principles can and will lead to cost overruns, schedule slips and performance short falls. Findings from this research should be used to tailor a SE approach for SBIR projects to ensure SE practices are being implemented in a best practice manner.

Recommendations for Action

1. **Organizational policy needs to be tailored for SBIR.** The SBIR community should use the identified SBIR SE applicable tasks from this study to develop adequate policy and SE tasks for their SBIR projects. SE experience varies greatly amongst the SBIR project manager within the DoD. You may have a project manager with 30 years of experience or a newly commissioned officer managing the project. There for it is critical to have adequate SE policy and guidance in place to ensure that critical tasks are being accomplished.

2. **The SBIR community should incorporate a tailored SE approach for their projects.** The approach should be consistent with the Streamline SE Approach for the S&T community outlined in the draft AFRL SE Guide. The case study review for this research identified the benefits of using such an approach.

3. **The SBIR community should ensure the project managers receive adequate SE education to enable them to tailor SE to their projects.** As the scope of SBIR projects can vary greatly it can be challenging for project managers to understand how all areas of SE apply to their projects. Results from the interviews also identified weak areas in the community as well as misconceptions that some areas don't apply to them. That is why good SE education is critical for project managers to truly make the connection of how SE applies to their projects. The Air Force and DoD have many good resources to provide SE education to the work force such as DAU and AFIT. Supervisors should ensure they are requiring their folks to take advantage of these opportunities and are continuing to develop their project manager skills.

Recommendation for Future Research

The research reveled several opportunities for future work that was not within the scope of the research.

1. Good SE practices are often hard to measure. Further data could be collected from each of the SBIR organization managing projects to identify the successful transition rate of their projects and the SE rigor being implemented within the organizations. This would likely illustrate the impact of implementing good SE practices into the SBIR community. Transition data was not available for this research project.

Appendix 1 – SBIR SE Interview

Small Business Innovative Research (SBIR) Technical Management Processes Interview

Date:

Survey Directions: Please answer each question in regards to the SBIR projects you have managed.

Experience Questions

1. What is your current job title? (Circle one)

   Program Manager   Project Engineer. Chief Engineer   Other_______________

2. What AFRL Directorate do you work for? (Circle one)

RX	RY	RZ	RB	RH	RD
RV	RW	711 HPW	AFOSR	Other____	

3. How are you employed? (Circle one)

   Military   Civilian   Contractor
   Other_______________

4. How many years of experience do you have in your job? (Circle one)

   1-2   3-5   5-10   10+

5. What level of APDP certification have you accomplished? (Circle one)

   1   2   3   none

6. In what APDP area? (Circle one)

   PM   SPRDE   Other________________

7. What phase of SBIR projects and how many have you managed?

   Phase I ___   Phase II ___   Other________________

8. What kinds of Stakeholders Requirements Definition do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o All inputs from relevant stakeholders translated into technical requirements.
    - o Requirements made quantifiable, have unique definitions, and specified thresholds and objectives.
    - o Work with the user to establish and refine goals, attributes, performance parameters, and financial and schedule constraints, and then ensure that all relevant requirements are addressed during the science and technology effort.
    - o Translate the "customer needs" into S&T program and system requirements.
    - o Other ____

9. What kinds of Requirements Analysis do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Obtain sets of logical solutions to improve understanding of the defined requirements and the relationships among the requirements (e.g. functional, behavioral, temporal).
    - o Performance parameters and constraints allocated and derived technical requirements defined.
    - o Partition the technical problem into self-contained, cohesive, logical groupings of elements and, where appropriate, defined the key interfaces.
    - o Other ____

10. What kinds of Requirements Management do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Maintain the traceability of all requirements from needs
    - o Document all changes to those requirements
    - o Record the rationale for those changes.
    - o Traceable to some current or potential future military capability need.
    - o Other ____

11. What kinds of Decision Analysis do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Criteria selected for decision and methods to be used in conducting the analysis.
    - o Analysis conducted to help choose among alternatives to achieve a balanced, supportable, robust, and cost effective program.
    - o Analysis methods include some of the following: trade studies, modeling and simulation, cost/benefit analysis, and the analytic hierarchy process (AHP).
    - o Studies are augmented with virtual and/or physical prototypes, where applicable, prior to making decisions on best alternative.
    - o Other ____

12. What kinds of Technical Planning do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Technical Planning made to ensure that the technical activities were conducted properly throughout the system's life cycle.
    - o Define the scope of the technical effort required to achieve program technical goals which includes exit criteria and products/deliverables which can be tracked with progress measured.
    - o Indentify constraints and interfaces that will result in derived technical requirements.
    - o Contribute input to the Systems Engineering Plan, which is owned and maintained by the acquisition activity.
    - o Other ____

13. What kinds of Technical Assessment do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Measure technical progress, technology maturity, and the effectiveness of plans and requirements. Activities include: Technical Performance Measurement, Technology Readiness Assessment, and the conduct of technical reviews.
    - o Demonstrate and confirm completion of required accomplishments and S&T exit criteria.
    - o Discover deficiencies or anomalies that may result in the application of corrective action and may have formed the technical portion of a continuous process improvement process when used to evaluate application of SE IAW paragraph 2.5.5.2.
    - o Technical assessment inputs used in support of the Laboratory Management Review process.
    - o Technical assessment activities conducted in concert with existing reviews where possible to minimize disruption to the research project.
    - o Other ____

14. What kinds of Technical Data Management do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Project data managed through the Defense Technical Information Center (DTIC)
    - o Or similar data base.
    - o Other ____

15. What kinds of Risk Management do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Develop risk management plan and performed the following:
    - o Identified risk
    - o Analyze risk and define probably and likelihood.
    - o Identify handling options
    - o Mitigate risk
    - o Track risk
    - o ____

16. What kinds of Configuration Management do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Ensure the repeatability of experimental results to include data by knowing and keeping a record of the laboratory set-up as well as tracking changes to it.
    - o Keep a record of laboratory experimental hardware configuration when measurements are gathered including such things as calibration status, environmental conditions, software version and modifications used, and documentation (data) resulting from the experiment/demonstration?
    - o A complete audit trail of decisions affecting laboratory equipment/software design modifications maintained.
    - o Other ____

17. What kinds of Interface Management do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Ensure interface definition and compliance among the elements that compose the laboratory system (internal interfaces), as well as with other systems with which the operational system or system elements might interact (external interfaces).
    - o Ensure that all internal and external interface requirement changes are properly documented in accordance with the configuration management plan and communicated to all affected elements of the program.
    - o All interfaces defined in sufficient detail to facilitate necessary communication/interaction among system, subsystem, and components.
    - o Other ____

18. What kinds of Architectural Design do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Translate the outputs of the Stakeholder Requirements Definition and Requirements Analysis processes into alternative technical solutions and selects a final technical path to explore.
    - o Iterate Stakeholder Requirements Definition, Requirements Analysis, and with the technical management processes to identify and select the best solution by first developing a high-level view of the system architecture capable of meeting stakeholder needs.
    - o Output the design functional or physical architecture sufficiently detailed to allow upward and downward traceability of requirements.
    - o Generate some of the following: AV-1, SV-1, OV-1 or additional DODAF 2.0 views
    - o Other ____

19. What kinds of Implementation do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Yield the fundamental capability of the program.
    - o Include some testing of the individual elements before they passed to Integration.
    - o Develop supporting documentation for the system; such as the as-built configuration, or discovered limitations of the concept; is also a part of the implementation process.
    - o Other ____

20. What kinds of Integration do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Incorporate the lower-level system elements into a higher-level system element in the physical architecture.
    - o Define the plan or strategy for the Integration process, including the assembly sequence, that may have imposed constraints on the design solution
    - o Other ____

21. What kinds of Verification do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Confirm that the laboratory/experimental system element meets design specifications.
    - o Test the system elements against their defined requirements (predicted versus experimental results).
    - o Design solutions at all levels of the physical architecture were verified through a cost-effective combination of analysis, examination, demonstration, and testing, all of which can be aided by modeling and simulation.
    - o Answer the verification question “Did we build the thing right?”.
    - o Other ____

22. What kinds of Validation do you accomplish on average for your SBIR projects? Check all that are accomplished:

    - o Test the performance of the technology against the original program goals.
    - o Capture any testing results/data so that they are available for further development/research/maturation efforts.
    - o Answer the validation question “Did we build the right thing?”.
    - o Other ____

23. What steps do you take, or tasks do you perform, to help with the possible future Transition of your SBIR projects? Check all that are accomplished:

    - o Deliver a supportable technology project capable of being put in the hands of the warfighter.
    - o The transition process applied in a step-by-step manner to move the technology to the next level in the developmental cycle.
    - o Needs of follow-on phases considered early in the program and included in all of the technical management processes.
    - o Other ____

Current Practices Questions

24. Do you use the 8 Systems Engineering key questions identified in AFRLI 61-104, and listed below, to support the management of your SBIR project?

    Yes or No

25. Did you know they existed prior to this survey? Yes or No

    If no skip to question 28.

26. On a scale from 1 to 7 overall do you find the AFRL 8 Systems Engineering key questions indentified in AFRLI 61-104 to be value added for managing your SBIR projects?

1	2	3	4	5	6	7
not useful	a little useful	somewhat useful	moderately useful	useful	very useful	extremely useful

    Please explain in short detail:

27. How useful do you find each of the 8 SE key questions for management of your SBIR projects? Please score each question below using the scale provided. (Circle one)

1	2	3	4	5	6	7
not useful	a little useful	somewhat useful	moderately useful	useful	very useful	extremely useful

	Score
9. Who is your customer?	______
10. What are the customer's requirements?	______
11. How will you demonstrate you have met the requirements?	______
12. What are the technology options?	______
13. Which is the best approach?	______
14. What are the risks to developing the selected technology?	______
15. How will you structure your program to meet requirements and mitigate risk?	______
16. What is your business-based transition plan that meets customer approval?	______

28. Which of the AFRL 8 SE key questions are most useful?

    Please explain in short detail:

29. Which of the AFRL 8 SE key questions are least useful?

    Please explain in short detail:

30. Is there a Technical Management Process Area that is not addressed in the 8 key questions that you feel should be incorporated? Yes or No

    If so, please explain in short detail:

31. On a scale from 1 to 7 in your overall opinion how much Systems Engineering rigor should be applied to SBIR projects?

1	2	3	4	5	6	7
none	very little	moderate detail	in good detail	well documented	very detailed	extreme detail

    Please explain in short detail:

32. Is there anything else you would like to add for his survey?

Appendix 2: SBIR AF SEAM and AFRL Policy SE Tasks

The below table captures the applicable SE tasks from AF SEAM. It illustrates that many tasks from AF SEAM apply to SBIR however many do not. Approximately only 50% of AF SEAM tasks were found to be either applicable in most cases or sometimes applicable by the author. The author was able to translate the interview results and comments using his expertise as a SE instructor to identify the applicable AF SEAM tasks for the SBIR community

In the table below, “Applicable” tasks represent that 50% or greater of participants identified it as a valid SBIR task. “May be applicable” tasks represent that 25% to 50 % of participants identified it as a valid SBIR task. “Typically not applicable” tasks represent less 25% of participants identified it as a valid SBIR task.

Results identified a limited number of SE tasks performed in the SBIR community for Configuration Management. Reviewing SEAM it was evident that most of the SEAM tasks are for a mature acquisition program and not the SBIR environment.

Table 25: AF SEAM SE Tasks for SBIR Projects

AF SEAM		
Configuration Management (CM)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
CMG1	*The approach for technical baseline management is defined and documented.*	Applicable
CMG1P1	Identify accountability for the disposition of, access to, release of and control of the technical baselines.	Typically not applicable
CMG1P2	Establish and maintain plans for managing the configuration of the product.	Typically not applicable
CMG2	*Establish and maintain technical baselines while managing change*	Applicable
CMG2P1	Identify the configuration items and related work products that will be placed under configuration management.	Typically not applicable
CMG2P2	Establish and maintain configuration and change management systems.	Typically not applicable
CMG2P3	Create or release technical baselines.	Typically not applicable
CMG2P4	Track and control changes.	Applicable
CMG3	*Integrity of baselines is established and maintained*	Applicable
CMG3P1	Establish and maintain records describing configuration items	May be applicable
CMG3P2	Perform configuration audits to maintain integrity of the configuration baselines	Typically not applicable

Results identified several SE tasks performed in the SBIR community that translated well with Air Force SEAM. Those tasks included selecting criteria to be used, methods to be used and conducting analysis of alternatives.

Decision Analysis (DA)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
DAG1	*Base decisions on an evaluation of alternatives using established criteria*	Applicable
DAG1P1	Establish and maintain guidelines to determine which issues are subject to a formal evaluation process	May be applicable
DAG1P2	Establish and maintain the criteria for evaluating alternatives, the relative ranking of these criteria, and select the evaluation methods	Applicable
DAG1P3	Identify alternative solutions to address issues	Applicable
DAG1P4	Evaluate alternative solutions using the established criteria and methods	Applicable
DAG1P5	Select the solution(s) from the alternatives and document decisions based on the evaluation	Applicable

Results identified a limited number of SE tasks performed in the SBIR community for Design. Design from AFRL policy included Architecture, Interface Management and Integration Tasks. Results from the interview identified a low percentage of SE tasks in these areas being completed.

Design (D)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
DG1	*The design is based upon a documented architecture, traceable to requirements, and optimized for the set of requirements and constraints*	Typically not applicable
DG1P1	Establish and maintain the architectural design baseline	Typically not applicable
DG1P2	Establish and maintain interface designs	Typically not applicable
DG1P3	Establish and maintain design artifacts that describe the conditions, functions, operating modes, and operating states specific to the components of the architecture	Typically not applicable
DG1P4	Develop potential product-component solutions, alternatives, and selection criteria	Typically not applicable
DG1P5	Analyze and select product-component solutions that best satisfy the established criteria	Typically not applicable
DG2	*Develop and document a detailed design and implementation strategy*	Typically not applicable
DG2P1	Establish initial product-component designs and development strategies	Typically not applicable
DG2P2	Evaluate whether the product-components should be developed, purchased, or reused based on established criteria	Typically not applicable
DG2P3	Establish detailed designs for the product-component	Typically not applicable
DG2P4	Establish and maintain a technical data package	Typically not applicable
DG3	*Assemble the design/development prototype(s) in accordance with the detailed design and integration strategy*	May be applicable
DG3P1	Establish and maintain the product integration approach	May be applicable
DG3P2	Establish and maintain procedures and criteria for integration of the product-components	May be applicable
DG3P3	Manage internal and external interface definitions, designs, and changes for products and product-components	May be applicable
DG3P4	Conduct, prior to assembly product-component verification	May be applicable
DG3P5	Assemble product-components according to the product integration sequence and established procedures	Typically not applicable

Results identified several Implementation SE tasks performed in the SBIR community. Implementation is captured under Manufacturing in AF SEAM. However those tasks identified by AF SEAM do not identify with the SBIR community as seen below since little from the AFRL Tasks could be translated into SEAM tasks as seen below.

Manufacturing (M)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
MG1	*Prepare for manufacturing*	May be applicable
MG1P1	Establish and maintain strategy and plans for manufacturing	Typically not applicable
MG1P2	Perform concurrent design and manufacturing engineering	May be applicable
MG1P3	Establish and maintain manufacturing technical data	Typically not applicable
MG2	*Transition from development to repeatable and economical production at desired rate*	Typically not applicable
MG2P1	Establish and maintain plans for transition to production	May be applicable
MG2P2	Qualify/proof manufacturing processes, special tools and test equipment	Typically not applicable
MG2P3	Ensure readiness for manufacturing	Typically not applicable
MG3	*Manufacture the product in accordance with plans and specifications*	Typically not applicable
MG3P1	Ensure that production at desired rates is conducted according to the plan	Typically not applicable
MG3P2	Establish and maintain inventory and supplier management/control	Typically not applicable
MG3P3	Complete First Article Inspection (FAI)	Typically not applicable
MG4	*Product and process quality is assessed and improved*	Typically not applicable
MG4P1	Establish and maintain piece part control and perform manufacturing screening	Typically not applicable
MG4P2	Establish and maintain a quality management system	Typically not applicable
MG4P3	Establish and maintain defect control	Typically not applicable

Results for Technical Planning identified several tasks performed in the SBIR community that translate to the SE tasks captured under Project Planning in AF SEAM. Most are applicable or may be applicable in the SBIR community as illustrated below.

Project Planning (PP)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
PPG1	*Establish and maintain estimates of project* planning parameters	Applicable
PPG1P1	Define the project life cycle phases, milestones, and key decision points	Applicable
PPG1P2	Establish a work breakdown structure (WBS) to organize the effort	May be applicable
PPG1P3	Establish and maintain the scope of the work products and tasks that describe the project cost and schedule	Applicable
PPG1P4	Establish, validate, and maintain estimates for cost and schedule	Applicable
PPG2	*Establish and maintain integrated plans*	May be applicable
PPG2P1	Assign responsibility for acquisition and sustainment management, support, and product enhancement	Typically not applicable
PPG2P2	Establish and maintain engineering plans to accomplish project	Applicable
PPG2P3	Plan for the management of project data	Applicable
PPG2P4	Plan for necessary resources, including personnel knowledge and skills, to perform the project tasks	Applicable
PPG2P5	Plan the involvement of identified stakeholders	Applicable
PPG2P6	Establish and maintain the technology development strategy	Applicable
PPG2P7	Plan for product Reliability, Availability, and Maintainability (RAM)	May be applicable
PPG2P8	Establish and maintain an Integrated Master Plan and Integrated Master Schedule (IMP/IMS)	May be applicable
PPG3	*Establish and maintain commitment to the technical plan*	Applicable
PPG3P1	Review all plans to understand commitments and ensure the technical plans and overall plans are integrated and consistent	May be applicable
PPG3P2	Reconcile the technical plans to reflect available and estimated resources	Applicable
PPG3P3	Obtain commitment from relevant stakeholders responsible for performing and supporting execution	Applicable

Results for Requirements Definition, Analysis and Management identified tasks performed in the SBIR community that translate to the SE tasks captured under Requirements in AF SEAM. Most tasks were applicable but some did not apply for SBIR projects as illustrated below.

Requirements (R)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
RG1	*Stakeholder needs, expectations, constraints, and interface requirements are collected and translated into a definition of needed product capabilities/characteristics for all phases of the life cycle*	Applicable
RG1P1	Elicit stakeholder needs, expectations, constraints, and interfaces	Applicable
RG1P2	Establish and maintain concepts of operations and support that define the operational capability required	Applicable
RG1P3	Transform stakeholder needs, expectations, constraints, and interfaces into a prioritized requirements baseline	Applicable
RG1P4	Establish and maintain a requirements/decision data archive to document requirements and related technical decisions	Applicable
RG2	*Requirements are refined, elaborated, and allocated to support design or service(s)*	May be applicable
RG2P1	Establish and maintain design mission reference profiles that define the product characteristics required in engineering terms and document the interaction of the product with the environment, other systems and operational users	Typically not applicable
RG2P2	Allocate the requirements to each product-component	Applicable
RG3	*Iteratively analyze and validate operational and derived requirements throughout the product life cycle*	Applicable
RG3P1	Analyze requirements to ensure that they are necessary and sufficient	Applicable
RG3P2	Analyze requirements to balance stakeholder needs and constraints	Applicable
RG3P3	Validate requirements to ensure the evolving product will perform as intended in the operational environment	Applicable
RG4	*Requirements are managed and controlled, and inconsistencies with technical plans and work products are identified*	Typically not applicable
RG4P1	Use a disciplined process for accepting, vetting, approving, and providing requirements and changes to the suppliers	Typically not applicable
RG4P2	Establish and maintain commitment to the requirements	Applicable
RG4P3	Establish and maintain bidirectional traceability between requirements and work products	Applicable
RG4P4	Identify and resolve inconsistencies between requirements, project plans, and work products	Applicable

Results identified all AF SEAM SE tasks apply to the SBIR community for Risk Management.

Risk Management (RM)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
RMG1	*Prepare for Risk Management*	Applicable
RMG1P1	Determine risk sources and categories	Applicable
RMG1P2	Define the parameters used to analyze and categorize risks, and the parameters used to control the risk management effort	Applicable
RMG1P3	Establish and maintain the strategy and plans to be used for risk management	Applicable
RMG2	*Identify and analyze risks to determine their relative importance*	Applicable
RMG2P1	Identify and document the technical risks	Applicable
RMG2P2	Evaluate and categorize each identified risk using the defined risk categories and parameters, and determine its relative priority	Applicable
RMG3	*Perform risk handling to manage adverse impacts on the project*	Applicable
RMG3P1	Establish and maintain plans for mitigating each of the important risks to the project	Applicable
RMG3P2	Monitor and assess risk handling activities	Applicable

Results identified several SE tasks applicable for Transition in the SBIR Community. However none of these tasks translate to AF SEAM SE tasks for Transition, Fielding, & Sustainment. All of these tasks become relevant in later stages of technology development and not during SBIR Phase I & II.

Transition, Fielding, & Sustainment (S)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
SG1	*Prepare to support operations, maintenance, repair, and disposal of the product*	Typically not applicable
TFSG1P1	Establish and maintain plans for logistics support of the product	Typically not applicable
TFSG1P2	Establish and maintain the strategy and plan(s) for transitioning acquired products into operational use and support	Typically not applicable
TFSG1P3	Establish and maintain plan(s) for the disposal of the product	Typically not applicable
SG2	*Ensure the resources, capacity and capability to support the operations, maintenance, repair, and disposal of the product are ready prior to need*	Typically not applicable
TFSG2P1	Establish and maintain budgets for sustainment activities	Typically not applicable
TFSG2P2	Establish and maintain processes and procedures for repair, overhaul, or modification	Typically not applicable
TFSG2P3	Ensure readiness for fielding and transition to operations and support	Typically not applicable
TFSG2P4	Ensure product support is maintained during transition	Typically not applicable
TFSG2P5	Establish and maintain the required facilities, manpower, tooling and test equipment for repair, overhaul, or modification	Typically not applicable
SG3	*Repair, overhaul, or modify the product*	Typically not applicable
TFSG3P1	Repair, overhaul or modify the product in accordance with established procedures and processes	Typically not applicable
TFSG3P2	Establish and maintain inventory and supplier management/control to execute the repair, overhaul or modification	Typically not applicable
SG4	*Maintain Operational Safety, Suitability, and Effectiveness (OSS&E)*	Typically not applicable
TFSG4P1	Establish and maintain OSS&E baseline(s)	Typically not applicable
TFSG4P2	Identify and monitor safety critical items	Typically not applicable
TFSG4P3	Identify and mitigate hazards	Typically not applicable
TFSG4P4	Identify and monitor operations and maintenance data	Typically not applicable
TFSG4P5	Execute (as required) the plan for decommissioning and disposal of the product	Typically not applicable

Results for Technical Assessment identified tasks performed in the SBIR community that translate to the SE tasks captured under Technical Management & Control in AF SEAM. Most tasks were applicable except executing supplier agreements since this does not take place during SBIR Phase I & II but would be relevant after the project transitions.

Technical Management & Control (TMC)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
TMCG1	*Prepare for Integrated Management*	Applicable
TMCG1P1	Establish and maintain the project environment	Applicable
TMCG1P2	Establish and maintain supplier agreements	Typically not applicable
TMCG1P3	Establish and maintain integrated product teams (IPT)	May be applicable
TMCG1P4	Establish and maintain measurement approach	Applicable
TMCG2	*Perform Integrated Management*	Applicable
TMCG2P1	Monitor and control the project in accordance with project commitments	Applicable
TMCG2P2	Monitor & control coordination and collaboration	Applicable
TMCG2P3	Execute Supplier Agreements	Typically not applicable
TMCG2P4	Obtain and analyze specified measurement data	Applicable
TMCG2P5	Monitor the development and delivery of project data	Applicable
TMCG3	*Monitor & Control Technical Progress*	Applicable
TMCG3P1	Technical reviews and audits are conducted when all the key entry criteria are met and closed when the exit criteria are met	Applicable
TMCG3P2	Assess results of technical reviews to support key milestone decisions, higher level reporting, and project re-planning as required	Applicable
TMCG3P3	Manage project work products and data	Applicable
TMCG4	*Monitor & Control Corrective Actions*	Applicable
TMCG4P1	Collect and analyze the project issues to determine and track corrective actions	Applicable
TMCG4P2	Establish and maintain a deficiency reporting system	Applicable
TMCG4P3	Manage corrective actions to closure	Applicable

Results for Verification and Validation identified tasks performed in the SBIR community that translate to the SE tasks captured under Verification and Validation in AF SEAM. Most tasks were applicable but some did not apply for SBIR projects since a limited amount of testing in performed during SBIR Phase I & II. Additional testing will take place when the project transitions and those tasks will be applicable then.

Verification and Validation (V)		
SG ID	**AF SEAM Specific Goal (SG) Title**	
VG1	*Prepare for verification*	Applicable
VG1P1	Establish and maintain the overall verification strategy and plan, including integrated testing approach	Applicable
VG1P2	Identify the work products to be verified and the verification methods that will be used	Applicable
VG1P3	Establish and maintain the environment and resources needed to support verification	Applicable
VG1P4	Establish verification procedures and criteria	Applicable
VG2	*Peer reviews are performed*	May be applicable
VG2P1	Prepare for peer reviews of selected work products	May be Applicable
VG2P2	Conduct peer reviews on selected work products and identify issues resulting from the peer review	May be Applicable
VG3	*Work products are verified*	Applicable
VG3P1	Perform verification on the selected work products	Applicable
VG3P2	Analyze and document the results of all verification activities	Applicable
VG3P3	Initiate and document corrective actions	Applicable
VG4	*Prepare for validation*	Applicable
VG4P1	Develop a product validation strategy and identify work products for validation	Applicable
VG4P2	Establish and maintain validation criteria, methods and procedures	Applicable
VG4P3	Establish and maintain the environment and resources needed to support validation	Applicable
VG4P4	Ensure appropriate certifications & accreditations have been completed	Typically not applicable
VG4P5	Establish and maintain a documented plan for validation	Applicable
VG5	*Validate product to ensure that it will be safe, suitable and effective in the intended operating environment*	Typically not applicable
VG5P1	Perform validation on the selected products and product-components	May be applicable
VG5P2	Analyze and document the results of the validation activities	Applicable

Appendix 3: SBIR SETT Tool Output

Research of past work on this topic identified a prior AFIT thesis titled “A Tailored Systems Engineering Framework for Science and Technology Projects” from March 2009. This thesis built a tool for identifying what Systems Engineering principals should by applied to a particular program in AFRL based on inputting the following parameters identified in the example below:

Parameters inputted into tool:

Welcome to the Systems Engineering Tailoring tool for Science & Technology Projects (SETT-

Please select the following project discriminants that apply. Hover on a selection to see a description.
(To select a discriminant place a "1" in the cell next to the domain value. Leave all other domain values mark

RDT&E Category	
6.1 (Basic Research)	1
6.2 (Applied Research)	0
6.3 (Advanced Technology Development)	0

Technology Readiness Level	
1-2	1
3-4	0
5-6	0
7-9	0

Project Budget	
<$500K	1
$500K - $2M	0
>$2M	0

Integration Level	
Subsystem	1
System	0
Mission	0

Core Process	
CP-1 (Far Term)	0
CP-2 (Medium Term)	1
CP-3 (Urgent User Needs)	0

Requirements Maturity	
Technology Push	1
Requirements Pull	0

After selecting your project discriminant click on the worksheet tab "Tailored SE Activities" below.
Drill down into lower level SE activities by using the "+" marks on the left of that worksheet.

Inputted parameters above would fit some SBIR programs. Below is the output for the tool for those parameters:

SE Activity	Source	Tools	SE Rigor
TP-1 (Requirements Development)			25% - 100%
Establish Communications with Stakeholders	DAG Sec 4.2.4.1		25% - 100%
Identify Project Constraints	DAG Sec 4.2.4.1		30% - 100%
Determine Required Capabilities	DAG Sec 4.2.4.1		25% - 80%
Determine Desired Performance	DAG Sec 4.2.4.1		30% - 100%
TP-2 (Logical Analysis)			0% - 100%
Analysis Preparation	DAG Sec 4.2.4.2.		100% - 100%
Perform Functional Analysis	DAG Sec 4.2.4.2.	DoDAF OV-5, SV-5	60% - 100%
Perform Behavioral Analysis	DAG Sec 4.2.4.2.	DoDAF OV-6(a,b,c), SV-10(a,b,c)	80% - 100%
Perform Environmental Analysis	DAG Sec 4.2.4.2.		10% - 100%
Design Factors Analysis	INCOSE Pg 4.6		0% - 100%
Develop Functional Architecture	DAG Sec 4.2.4.2.		30% - 100%
TP-3 (Design Solution)			10% - 100%
Define Design Problem	Buede Pg 31, 39		20% - 100%
Generate Alternative Design Solutions	Buede Pg 31, 39		10% - 100%
Evaluate Design Alternatives	DAG Sec 4.2.4.3		20% - 80%
TP-4 (Implementation)			5% - 100%
Generate Implementation Strategy	INCOSE Pg 4.10		30% - 100%
Fabricate Hardware	DAG Sec 4.2.4.4.		30% - 80%
Code Software	DAG Sec 4.2.4.4.		30% - 100%
Conduct Unit Testing	INCOSE Pg 4.10		30% - 100%
Conduct Training	INCOSE Pg 4.10		5% - 5%
Prepare for Integration	DAG Sec 4.2.4.4.		30% - 80%
TP-5 (Integration)			10% - 100%
Determine Integration Process	Buede Pg 310		80% - 80%
Conduct Assembly / Integration of System	INCOSE Pg 4.12		10% - 100%
Relevant Environment	DAG Sec 4.2.4.5.		10% - 10%
TP-6 (Verification)			30% - 100%
Plan Verification	Buede Pg 314		30% - 100%
Execute Verification	INCOSE Pg 4.14		30% - 100%
TP-7 (Validation)			30% - 100%
Plan Validation	Buede Pg 314		30% - 100%
Execute Validation	Buede Pg 51; INCOSE Pg 4.17		30% - 100%

SE Activity	Source	Tools	SE Rigor
TP-8 (Transition)			0% - 100%
Identify Transition Opportunities	INCOSE Pg 3.2		50% - 100%
Qualify Production Item	Buede Pg 314		0% - 0%
Execute Transition	INCOSE 4.15		30% - 100%
TMP-1 (Decision Analysis)			100% - 100%
Identify Strategy for Making Decision	INCOSE Pg 5.8		100% - 100%
Execute Decision Making Strategy	DAG 4.2.3.1		100% - 100%
TMP-2 (Technical Planning)			0% - 100%
Plan Systems Engineering	DAG Sec 4.2.3.2.		0% - 100%
Implement Technical Plan	INCOSE Pg 8.1-13	Integrated Master Plan	30% - 100%
Evaluate Plan to Address Needs	INCOSE Pg 3.8-9		0% - 0%
TMP-3 (Technical Assessment)			70% - 100%
Prepare for Technical Assessment	DAG Sec 4.2.3.3.		80% - 100%
Perform Technical Assessment	INCOSE Pg 5.5		70% - 100%
TMP-4 (Requirements Management)			5% - 100%
Determine Roles/Responsibilities During Reqs Generation Process	Buede Pg 129		75% - 100%
Define System Capabilities and Performance Objectives	INCOSE Pg 7.6-12		30% - 100%
Validate Requirements Development Process	Buede Pg 41		25% - 25%
Ensure Requirements Feasibility and Validity	Buede Pg 40		5% - 95%
Document Requirements	INCOSE Pg 4.3, 4.4		25% - 100%
Ensure Traceability of Requirements	DAG Sec 4.2.3.4.; Buede Pg 158; INCOSE Pg 3.10		25% - 100%
Establish Process for Requirements Changes	Buede Pg 129		25% - 80%

SE Activity	Source	Tools	SE Rigor
TMP-5 (Risk Management)			10% - 100%
Risk Planning	DAG Sec 4.2.3.5	Risk Management Framework	0%
Risk Identification	DAG Sec 4.2.3.5.; Buede Pg 314; INCOSE Pg 5.10-5.11	Documentation Reviews; Information Gathering (Brainstorming, Delphi Technique, Interviews, SWOT (Strength-Weakness-Opportunity-Threat) Analysis)	30% - 100%
Risk Analysis (Qualitative & Quantitative)	DAG Sec 4.2.3.5.; Buede Pg 382	ARENA, CORE, MATLAB State Flow Modeler, Crystal Ball (Excel add-in)	100% - 100%
Risk Handling	DAG Sec 4.2.3.5.; INCOSE Pg 5.11		100% - 100%
Risk Monitoring	DAG Sec 4.2.3.5.		80% - 100%
Risk Documentation	DAG Sec 4.2.3.5.; INCOSE Pg 5.10		10% - 100%
TMP-6 (Configuration Management)			30% - 100%
Develop Configuration Baselines	DAG Sec 4.2.3.6.; INCOSE Pg 4.17 INCOSE Pg 5.12		30% - 100%
Establish Configuration Change Control Plan (Establish configuration control cycle that incorporates evaluation, approval, validation, and verification of change requests)	DAG Sec 4.2.3.6.; INCOSE Pg 5.13		30% - 30%
Develop and Maintain Configuration Control Documentation	INCOSE Pg 4.6 & 5.13		30% - 30%
Maintain Configuration Baselines	DAG Sec 4.2.3.6.; INCOSE Pg 4.12 & 5.13		30% - 100%

SE Activity	Source	Tools	SE Rigor
TMP-7 (Technical Data Management)			10% - 100%
Develop Data Management Plan	DAG Sec 4.2.3.7.; INCOSE Pg 5.15	Core Architecture Data Model	30% - 100%
Determine / Define System Relevant Information	INCOSE Pg 5.15		100% - 100%
Identify System Data to Purchase	DAG Sec 4.2.3.7.1.		100% - 100%
Determine Data Protection Requirements	DAG Sec 4.2.3.7.2.		100% - 100%
Address Long-term Data Storage Requirements	DAG Sec 4.2.3.7.3.		50% - 50%
Record Program Data	INCOSE Pg 4.10		10% - 100%
Make Project Data Available	INCOSE Pg 5.15		50% - 100%
TMP-8 (Interface Management)			10% - 100%
Define Interface Requirements and Control Methods	Buede Pg 294; INCOSE Pg 4.8		100% - 100%
Develop System Interface Control Methods	DAG Sec 4.2.4.1. DAG Sec 4.2.3.8.; Buede Pg 50; INCOSE Pg 4.7		30% - 100%
Generate Interface Control Documentation	DAG Sec 4.2.3.8. DAG Sec 4.2.4.5.	DoDAF SV-1, Interface Control Document	60% - 100%
Utilize Interface Controls	DAG Sec 4.2.3.8.; Buede Pg 39		10% - 100%
Fundamental Principles (Applicable to ALL PROCESSES)			100% - 100%
Utilize Enterprise Capabilities	INCOSE Pg 4.12-13		100% - 100%

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Vita

Captain Phillip O'Connell graduated from the University of Florida with a bachelor's degree in Aerospace Engineering in 2002, and from Embry Riddle University with a Masters of Aeronautical Science in Space Systems in 2007. He has spent 9 years in the United States Air Force as an acquisitions officer. His experience includes Air Logistics Center, Space Launch, Air Force Institute of Technology Systems Engineering continuous learning instruction and Human Systems Division acquisitions.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)* 01-09-2012	**2. REPORT TYPE** Master's Thesis	**3. DATES COVERED** *(From – To)* Mar 2011 – Sept 2012

4. TITLE AND SUBTITLE Systems Engineering applications for Small Business Innovative Research (SBIR) Projects	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) O'Connell, Phillip J., Captain, USAF	**5d. PROJECT NUMBER** JON 11V515 **5e. TASK NUMBER** **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S) Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way, Building 640 WPAFB OH 45433-8865	**8. PERFORMING ORGANIZATION REPORT NUMBER** AFIT/GSE/ENV/12-S01
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory/XP 2275 D Street B016 Attn: Dr. James Malas WPAFB OH 45433 Email: JAMES.MALAS@WPAFB.AF.MIL Phone: 937 656-6272	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A.; APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This research defined Systems Engineering applications for Small Business Innovative Research (SBIR) projects and answered five research questions addressing the essential elements and application of SE processes within the SBIR community. The research identified that current DoD and Air Force SE Policy do not specifically address SBIR projects. This research identified the need to tailor a SE approach for SBIR projects as overarching policy is not applicable in all cases. The culmination of this effort defined the current SE tasks applicable for the SBIR community.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** Joseph Wirthlin, Lt Col, USAF
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*
U	U	U	UU	119	(937) 255-3636, ext 4650 (emailname@afit.edu)

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18