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Supply Chain Resilience: Assessing USAF Weapon System Life Cycle

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SUPPLY CHAIN RESILIENCE: ASSESSING USAF WEAPON SYSTEM LIFE CYCLE

THESIS

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Abstract

The Air Force Global Logistics Support Center (AFGLSC) is responsible for the United States Air Force's supply chain. One of the AFGLSC's responsibilities is to improve AF supply chain processes. This thesis investigates the subject of supply chain resilience and its potential impact for improving supply chain management. Through literature a supply chain resilience framework and measurement tool was identified for potential benefit to Air Force supply chain management. Air Force weapon systems were identified and segmented into two phases of the weapon system life cycle. This research analyzes data collected on supply chain resilience factors, vulnerabilities and capabilities, for each individual weapon system to determine if differences exist as weapon systems progress through the weapon system life cycle. The results indicate that the supply chain resilience framework and measurement tool provides Air Force leadership with beneficial information to improve and assist in the strategic management of their supply chain.

To my wife and kids who gave me their love and support.

To my parents who instilled in me the importance of education.

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SUPPLY CHAIN RESILIENCE: ASSESSING USAF WEAPON SYSTEM LIFE CYCLE

I. Introduction

> The Air Force supply chain is one of the largest and most complex supply chains in the world, involving millions of parts, thousands of business and production processes, and hundreds of information systems. There are significant opportunities to improve the Air Force supply chain in terms of performance and cost that are both effective and efficient. This requires a revolution in thinking and action. (Air Force Global Logistics Support Center, 2008:1)

The purpose of this paper is to expand the research in the field of supply chain resilience, specifically in a United States Air Force (USAF) setting. First, this chapter will begin with a background of logistics and more recently supply chain management in the United States military and specifically in the Air Force. This is followed by problem statement definition, research objectives and concludes with the research focus.

Background

Beginning in the 1960's the commercial sector was lagging behind the military in the field of logistics. This was evident due to the commercial sector bench-marking concepts and practices that the military had developed for their operations (Russell, 2007). Figure 1 illustrates the US military's progression from the leader of logistics in the 1950s and 1960s until 2003 and beyond where the military is now implementing the commercial sector's best practices by pursuing the concepts, practices, and technologies of supply chain management (Russell, 2007).

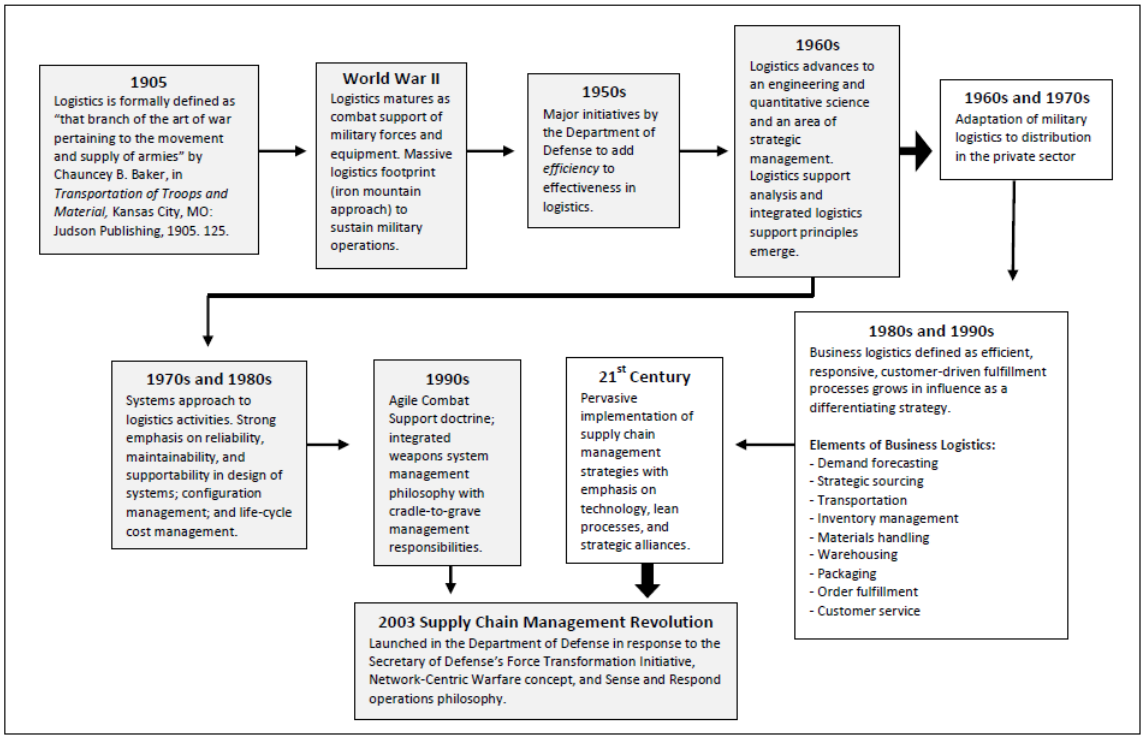

Figure 1: Evolution of Logistics Thought and Practice
(Adapted from Russell, 2007)

The Department of Defense (DoD), in 2003, directed the implementation of modern supply chain practices for all DoD components with the release of the DoD Supply Chain Material Management Regulation (DoD 4140.1-R, 2003). This regulation mandates the framework and guiding principles for many aspects of supply chain management and requires all DoD components to measure total supply chain performance (DoD 4140.1-R, 2003; Russell, 2007). Under this guidance, the USAF created the Air Force Global Logistics Support Center (AFGLSC). Air Force Materiel Command (AFMC) provisionally stood up the AFGLSC on 7 May 2007 and officially on 28 March 2008. The USAF also has a long history of supply chain management. Figure 2 details the progression of the USAF's supply chain management. Prior to 1998 the focus was limited to each air force base individually. Then in 2000, the focus shifted

from the individual base to each major command. In 2006, the focus shifted again from the major commands to a weapon system focus and finally with the creation of the AFGLSC the focus shifted to the USAF enterprise.

Figure 2: AFGLSC Evolution (AFGLSC, 2009)

Since the AFGLSC creation in 2007 it is the agency in charge of the USAF's supply chain. It was designed to be the single face to the warfighter for all supply chain issues and improvements.

AFGLSC's vision:

> *Recognized and respected as a premier Supply Chain Management organization through trusted support, continuous innovation and a professional, highly skilled workforce.*

AFGLSC's mission statement:

> *Execute the Air Force Supply Chain by integrating Enterprise-wide planning and strategy with Global command and control as the Single Focal Point to the Warfighter.*

In a 15 May 2009 briefing presented by Major General Gary T. McCoy, AFGLSC Commander, he identified the AFGLSC's six top focus areas to improve the USAF's supply chain. The AFGLSC's six focus areas include:

1) Optimize support to the warfighter
2) Exercise enterprise supply chain command and control
3) Establish single Air Force supply chain owner
4) Improve Air Force supply chain processes
5) Pursue and implement enabling technology
6) Develop professional, highly skilled workforce (AFGLSC, 2009)

Problem Statement

The list above identified AFGLSC's fourth top focus area as improving Air Force supply chain processes. Imbedded in this focus area is the requirement to define and deploy a supply chain risk management program. Supply chain resilience has been identified as a method of enhancing traditional risk management associated with commercial supply chains both in recent literature and research. This leads to the problem statement:

> ***Does recent literature and research provide AFGLSC a method to enhance current supply chain risk management with supply chain resilience?***

Research Objective

The objective of this research is to provide AFGLSC with a method to improve supply chain management, specifically with the processes involved in supply chain risk management.

This research investigates literature and studies on supply chain resilience. Supply chain resilience has been a topic of research since the globalization of the supply chain and some major unanticipated disruptions, such as the terrorist attacks on the United States on 11 September 2001. This research will focus on the Supply Chain Resilience Assessment and Management (SCRAM™) tool (Pettit, 2008). The SCRAM™ tool is used to measure current supply chain vulnerabilities and capabilities, provide recommendations for improvements, and provide information to better prepare supply chain leadership with managing products, processes, and relationships.

Research Focus

This research focuses on the AFGLSC's fourth top focus area, to improve Air Force supply chain processes. This research investigates the use of the SCRAM™ tool, which was developed by Pettit (2008), in conjunction with the Center for Resilience and the Fisher College of Business at The Ohio State University. The SCRAM™ tool was created to measure the vulnerabilities and capabilities within an organization's supply chain and was validated within the commercial sector. To date, research conducted utilizing the SCRAM™ tool to measure vulnerabilities and capabilities of a supply chain has not been utilized on a military supply chain. This indicates the opportunity for the following research question to be investigated:

Research Question: Is the SCRAM™ tool able to measure supply chain vulnerabilities and capabilities within the USAF's weapon system product life cycle and provide useful feedback?

To answer the research question the following investigative questions will be addressed:

Question 1: Will the SCRAM™ tool identify an overage of capabilities compared to vulnerabilities in selected weapon system at a current point in time in the weapon system life cycle?

Question 2: Will the SCRAM™ tool identify an underage of capabilities compared to vulnerabilities in selected weapon system at a current point in time in the weapon system life cycle?

Question 3: Do supply chain vulnerabilities and capabilities vary across the separate weapon system life cycle phases?

Methodology

This research will use a survey based methodology to address the research and investigative questions. USAF weapon system program offices will be self-assessed using the SCRAM™ tool to identify vulnerabilities and capabilities within the individual weapon system's supply chain. The weapon systems will be organized into two groups based on their current position within the weapon system life cycle. Phase I is identified as weapon systems from conception through production and Phase II is identified as weapon systems from post production through disposal. Figure 3 depicts a basic view of the weapon system life cycle and its division into phases used for this research.

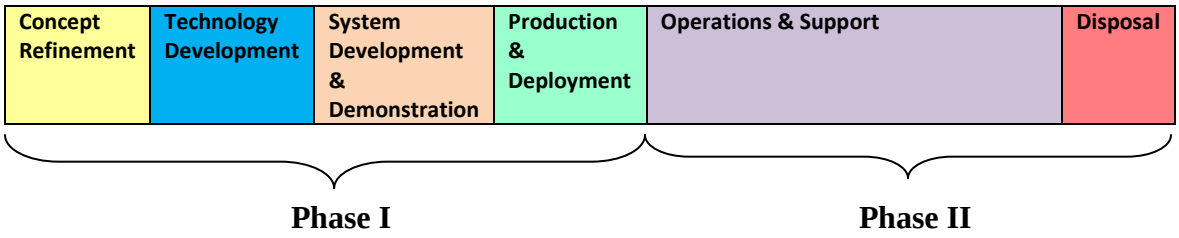

Figure 3: Lifecycle Framework with Project Phases
(Adapted from Defense Acquisition University, 2009)

To answer the investigative questions the individual weapon system assessments will be analyzed by statistical methods to identify if the SCRAM™ tool will measure an overage and an underage of capabilities verses vulnerabilities. Additionally, the complete set of weapon system assessments divided into the two phases (Phase I and Phase II) will be statistically compared to identify if differences exist between life cycle phases. The intent of this research is to assist USAF leadership with supply chain management for weapon systems as they mature and progress throughout the weapon system life cycle. Specifically to enable leadership to proactively identify and mitigate weapon systems risks for real-time business continuity and long-term sustainability.

Scope and Limitations

Given the vast amount of weapon systems currently within the USAF's weapon system life cycle, this research will be limited to addressing supply chain resilience of eleven weapon systems identified in conjunction with the researcher, principal investigator and sponsoring organization. Due to the complexity of the weapon systems throughout the life cycle and the varying methods used to manage the individual weapon system supply chains, this may impose limitations on the generalizability of the results.

Summary

This section began with an introduction and background of military and USAF supply chain management progression. Introduction of the AFGLSC followed with a discussion of its top focus areas to improve USAF supply chain management. This paper is concentrated on improving AF supply chain processes, specifically supply chain risk management through resilience. Additionally, the problem statement, the research objective, research focus with investigative questions, and methodology were presented to frame the research. The organization of the rest of this paper is as follows. Literature review is presented in Chapter II, followed by methodology in Chapter III. Results and analysis of the research are discussed in Chapter IV. The research concludes in Chapter V with managerial implications, research limitations, and future research recommendations.

II. Literature Review

Introduction

This chapter begins with a detailed explanation of the weapon system life cycle and the definition of supply chain, as used for this research. The rest of the chapter discusses traditional risk management, resilience, why resilience is important, resilience framework and how to measure resilience.

Weapon System Life Cycle

In Chapter I, Figure 3 displayed a simplified pictorial view of the weapon system life cycle. Figure 4, shows the complete Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System (Defense Acquisition University, 2009). This image is intended for a 2'x3' poster and in this size is added to emphasize the complexity of the system. This system is structured by DoDI 5000.02 into discrete phases separated by major decision points, called milestones or decision reviews, with a number of key activities to provide the basis for comprehensive management and informed decision making. Life Cycle Logistics (LCL) is included in this system as the planning, development, implementation, and management of a comprehensive, affordable, and effective systems support strategy within the total life cycle systems management. LCL encompasses the entire weapon system's life cycle including acquisition (design, develop, test, produce, and deploy), sustainment (operations and support), and disposal. A key goal or objective of USAF logistics is to maintain and improve readiness, improve affordability, and minimize the overall footprint of the weapon system and its required support (DoDI 5000.02). As discussed in Chapter I, this research will separate the weapon system life cycle into two phases, Phase I and Phase II. Phase I includes weapon

systems from conception through production and Phase II includes weapon systems from post production through disposal

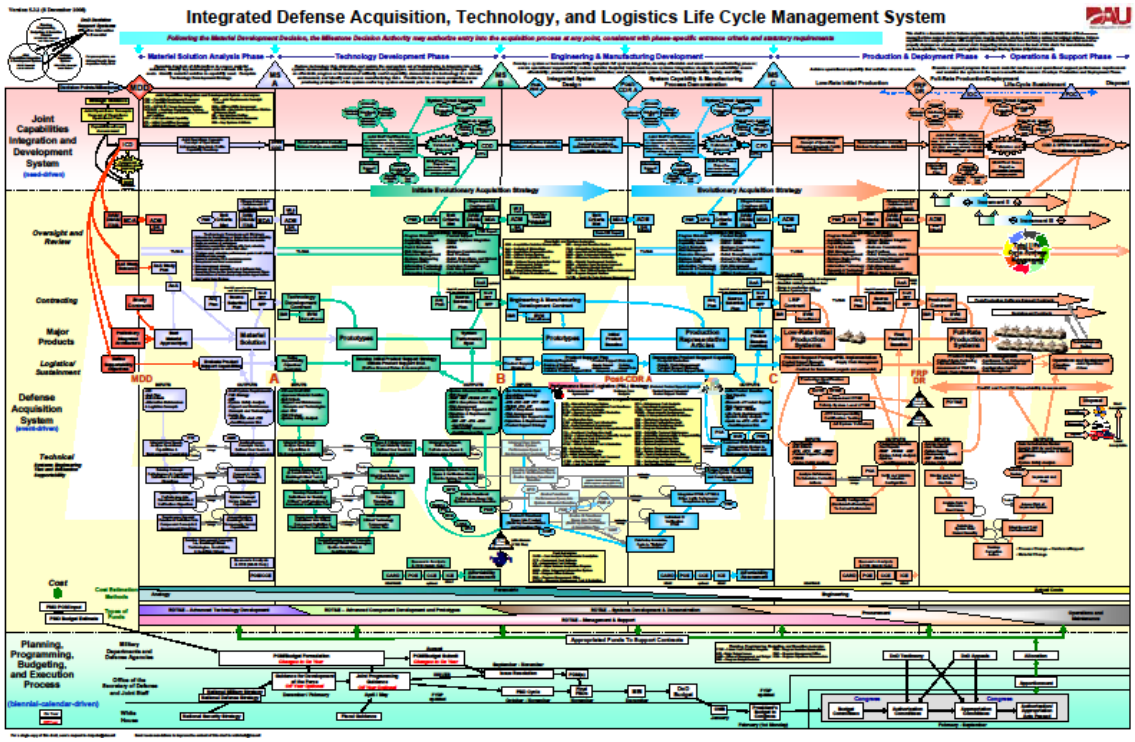

Figure 4: Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System (Defense Acquisition University, 2009)

Definition of Supply Chain

There are many different definitions of a supply chain in literature. Stock and Boyer noted 173 individual definitions of supply chain management in journals and books (2009). For the purpose of this research, the supply chain is defined as the network of organizations involved in the upstream and downstream flows of products, services, finances and information from the initial supplier to the ultimate customer (Christopher, 1992; Mentzer et al., 2001; Lambert, Garcia-Dastugue, Croxton, 2005 and Pettit, 2008).

This definition is important to the research of resilience; it must have a wide view across the supply chain to capture the dynamics of turbulence and complexity (Pettit, 2008).

Risk Management

Traditional risk management involves risk analysis which includes assessing each risk in terms of its likelihood of occurrence (probability), and the estimated impact (severity) should the risk occur (VanderBok, et. al, 2007). A typical step by step explanation of the risk management process is shown Figure 5, illustrating a continuous circle of risk identifying, assessing, analyzing, controlling, implementing and reviewing (Manuele, 2005). Today's supply chains are much more complex and more susceptible to disruptions due to the globalized supply chains, specialized factories, centralized distribution, increased outsourcing, reduced supplier base, increased volatility of demand, and technological innovations (Cranfield University, 2002). Recent literature identifies the greatest weakness of risk management is its inability to adequately characterize low-probability, high-consequence events (Kunreuther, 2006). Pettit noted that "traditional assessment approach cannot deal with unforeseeable events" (2008:16).

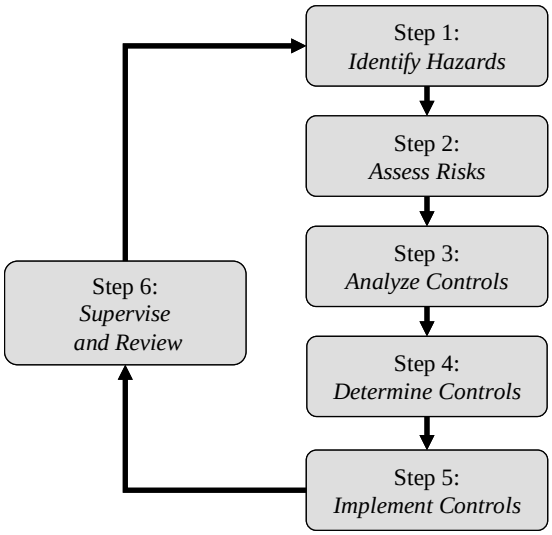

Figure 5: Operational Risk Management Process
(Adapted from: Manuele, 2005)

Resilience

What is resilience? A respected dictionary defines resilience as "the tendency of a material to return to its original shape after the removal of a stress that has produced elastic strain" (Merriam-Webster, 2007:1340). Resilience has been identified as an important concept in other fields of study, such as ecology, psychology, leadership, and the supply chain (Folke et al., 2004; Gorman et al., 2005; Stoltz, 2004; Rice and Caniato, 2003; Sheffi, 2005; Christopher and Peck, 2004; Fiksel, 2006; and Ponomarov and Holcomb, 2009). Definitions of resilience from the fields of study listed above are summarized in Table 1.

Table 1: Definitions of Resilience
(Adapted from Pettit, 2008)

Source	Definition	Field of study
Merriam-Webster (2007)	Capability of a body to ***recover its size and shape*** after deformation	Engineering
Folke et al. (2004)	***Ability to rebound*** from a disturbance while maintaining diversity, integrity and ecological processes	Ecology
Gorman et al. (2005)	***Ability to bounce back*** from adversity	Psychology
Stoltz (2004)	***Ability to bounce back*** from adversity and ***move forward*** stronger than ever	Leadership
Rice and Caniato (2003)	***Ability to react*** to an unexpected disruption and ***restore normal operations***	Supply chain
Sheffi (2005)	***Containment of disruption*** and ***recovery*** from it	Supply chain
Christopher and Peck (2004)	Ability of a system to ***return to its original state*** or ***move to a new, more desirable state*** after being disturbed	Supply chain
Fiksel (2006)	Capacity for complex industrial systems to ***survive, adapt and grow*** in the face of turbulent change	Supply chain
Ponomarov and Holcomb (2009)	Capability to prepare for unexpected events, ***respond*** to disruptions, and ***recover by maintaining continuity of operations*** at the desired level of connectedness and control	Supply chain

Why Resilience?

"Supply chain resilience no longer implies merely the ability to manage risk. It now assumes that the ability to manage risk means being better positioned than competitors to deal with–and even gain advantage from–disruptions" (Sheffi, 2005:1). Why the interest in supply chain resilience? According to Christopher and Peck, "in an age of lengthening supply chains serving globe-spanning operations, there are frequent reminders that we live in an unpredictable and changing world 2004:1). Fiksel added, "the old methods of risk management are no longer effective in a global economy that is

tightly connected and unpredictable" (The Ohio State University, 2008:1). Fiksel also stated "companies must cope with a continuous stream of surprises, ranging from industrial accidents to economic shocks to natural catastrophes" and "resilience is about configuring company assets, including both human and economic capital, in a way that maximizes the capacity of the enterprise to survive, adapt and grow in the face of turbulent change" (The Ohio State University, 2008:1).

The study of supply chain resilience was spurred by the disruptions in the United Kingdom's (UK) transportation network due to fuel protests in 2000 and to UK's beef market due to the outbreak of Foot and Mouth Disease in 2001 (Peck, 2005). Additionally, there are many examples of disruptions that demonstrate the importance of resilience. For example, a lightning bolt that, in March 2000, struck a Philips semiconductor plant in Albuquerque, New Mexico, created a 10-minute blaze that contaminated millions of chips and subsequently delayed deliveries to its two largest customers: Finland's Nokia and Sweden's Ericsson. The fire contributed to Ericsson to leaving the mobile phone business due to the losses it sustained, but Nokia prevailed because the company recognized the magnitude of the disruption and took action because it was resilient (Sheffi, 2005). Also, the 2002 longshoreman union lockout at the Los Angeles/Long Beach port interrupted transshipments and deliveries to many US-based firms. Port operations and schedules did not return to normal until six months after the strike ended. This 10-day strike did not interrupt Dell Computer's operations like it did for many of the other country's retailers and manufacturers. Dell was aware that its lean, high-speed business model left it vulnerable. Dick Hunter, in charge of Dell's United States supply chain, stated " when a labor problem or an earthquake or a SARS epidemic

breaks out, we've got to react quicker than anyone else" (Breen, 2004:86). Dell recognized its vulnerabilities and took steps to make sure they, as a firm, are resilient. The following is an excerpt taken from Pettit's research that provides another view why businesses and organizations should be interested in and pursuing resiliency.

> *In a world of turbulent change, resilience is a key competency, since even the most carefully designed supply chain is susceptible to unforeseen factors. Businesses must be prepared to cope with a continuous stream of challenges, ranging from human errors to technological failures to natural disasters* (Pettit, 2008:191)

Pettit argues that the ability to manage the risk of uncertainty is a challenge and that businesses are always changing and change introduces risk, and this requires resilience (2008). Sheffi stated, "Some organizations cope far better than others with both the prospect and the manifestation of unquantifiable risk. They don't have in common a secret formula or even many of the same processes for dealing with risk, but they share a critical trait: resilience" (2005:1).

Resilience Framework

Since the UK's fuel protests in 2000 and the many other major disruptions around the globe and in the U.S. there has been many who have investigated supply chain resilience to define its characteristics. A review of extant literature identified vulnerabilities as one of the characteristics of supply chain resilience (Peck, 2005; Sheffi, 2005b; Pettit, 2008; Ponomarov and Holcomb, 2009). Pettit defined supply chain vulnerabilities as "fundamental factors that make an enterprise susceptible to disruptions" (2008:191). Table 2 lists and defines the vulnerability factors that Pettit identified during his research and lists the sub-factors identified for each factor.

Table 2: Vulnerability Factors
(Adapted from Pettit, Fiksel and Croxton, 2010)

Vulnerability Factor	Definition	Sub-Factors
Turbulence	Environment characterized by frequent changes in external factors beyond your control	Natural disasters, Geopolitical disruptions, Unpredictability of demand, Fluctuations in currencies and prices, Technology failures, Pandemic
Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism/sabotage, Labor disputes, Espionage, Special interest groups, Product liability
External pressures	Influences, not specifically targeting the firm, that create business constraints or barriers	Competitive innovation, Social/Cultural change, Political/Regulatory change, Price pressures, Corporate responsibility, Environmental change
Resource limits	Constraints on output based on availability of the factors of production	Supplier, Production and Distribution capacity, Raw material and Utilities availability, Human resources
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity, Product purity, Restricted materials, Fragility, Reliability of equipment, Safety hazards, Visibility to stakeholders, Symbolic profile of brand, Concentration of capacity
Connectivity	Degree of interdependence and reliance on outside entities	Scale of network, Reliance upon information, Degree of outsourcing, Import and Export channels, Reliance upon specialty sources
Supplier/Customer disruptions	Susceptibility of suppliers and customers to external forces or disruptions	Supplier reliability, Customer disruptions

The vulnerability factors are discussed throughout the literature on the subject of supply chain resilience. Many researchers identified vulnerabilities as the potential for disruptions. Table 3 presents supply chain vulnerability taxonomy and matches it with a small sample from supply chain resilience literature.

Table 3: Supply Chain Resilience Framework – Vulnerabilities
(Adapted from Pettit, Fiksel and Croxton, 2010)

Main Factors of Vulnerability	Descriptors	Christopher, Rutherford (2004)	Peck (2005)	Sheffi (2005)	Ponamarov, Holcomb (2009)	Pettit, Fiksel, Croxton (2010)
Turbulence	Natural disasters	X	X	X	X	X
	Exposure to geopolitical disruptions		X	X		X
	Unpredictability of demand		X	X		X
	Fluctuations in currencies & prices					X
	Unforeseen technology failures					X
	Pandemic					X
Deliberate threats	Piracy & theft	X	X	X		X
	Terrorism & sabotage		X	X	X	X
	Labor disputes		X	X		X
	Industrial espionage					X
	Special interest groups					X
	Product liability					X
External pressures	Innovation (competition)		X			X
	Social/Cultural changes		X			X
	Political/Regulatory changes		X			X
	Price pressures (competition)					X
	Corporate responsibility					X
	Environmental changes					X
Resource limits	Supplier capacity					X
	Production capacity					X
	Distribution capacity					X
	Raw material availability					X
	Utilities availability					X
	Human resources					X
Sensitivity	Complexity	X	X	X	X	X
	Product purity					X
	Restricted materials					X
	Fragility					X
	Reliability of equipment		X			X
	Potential safety hazards					X
	Visibility of disruption to stakeholders					X
	Symbolic profile of brand					X
	Concentration of capacity					X
Connectivity	Scale/Extent of supply network		X	X	X	X
	Reliance upon information flow		X	X		X
	Degree of outsourcing		X	X	X	X
	Import/Export channels					X
	Reliance upon specialty sources					X
Supplier/Customer disruptions	Supplier trust, loyalty, relations, reliability		X	X	X	X
	Customer disruptions					X

The other characteristic that literature identified in supply chain resilience is capabilities (Cranfield, 2002; Fiksel, 2006, Peck, 2005; Sheffi, 2005; Pettit, Fiksel and Croxton, 2010; Ponomarov and Holcomb, 2009). Pettit, Fiksel and Croxton defined supply chain capabilities as the "attributes that enable an enterprise to anticipate and overcome disruptions" (2010:191). Table 4 lists and defines the capability factors identified and list the sub-factors identified (Pettit, Fiksel and Croxton, 2010).

Table 4: Capability Factors
(Adapted from Pettit, Fiksel and Croxton, 2010)

Capability Factor	Definition	Sub-Factors
Flexibility in sourcing	Ability to quickly change inputs or the mode of receiving inputs	Part commonality, Modular product design, Multiple uses, Supplier contract flexibility, Multiple sources
Flexibility in order fulfillment	Ability to quickly change outputs or the mode of delivering outputs	Alternate distribution channels, Risk pooling/sharing, Multi-sourcing, Delayed commitment/Production postponement, Inventory management, Re-routing of requirements
Capacity	Availability of assets to enable sustained production levels	Reserve capacity, Redundancy, Backup energy sources and communications
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination, Labor productivity, Asset utilization, Product variability reduction, Failure prevention
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering, Information technology, Product, equipment and people visibility, Information exchange
Adaptability	Ability to modify operations in response to challenges or opportunities	Fast re-routing of requirements, Lead time reduction, Strategic gaming and simulation, Seizing advantage from disruptions, Alternative technology development, Learning from experience
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals, Forecasting, Deviation and near-miss analysis, Risk management, Business continuity/preparedness planning, Recognition of opportunities
Recovery	Ability to return to normal operational state rapidly	Crisis management, Resource mobilization, Communications strategy, Consequence mitigation
Dispersion	Broad distribution or decentralization of assets	Distributed decision-making and Assets, Decentralization of key resources, Location-specific empowerment, Dispersion of markets
Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative forecasting, Customer management, Communications, Postponement of orders, Product life cycle management, Risk sharing with partners
Organization	Human resource structures, policies, skills and culture	Accountability, Creative problem solving, Cross-training, Substitute leadership/empowerment, Learning/benchmarking, Culture of caring
Market position	Status of a company or its products in specific markets	Product differentiation, Customer loyalty/retention Market share, Brand equity, Customer relationships, Customer communications
Security	Defense against deliberate intrusion or attack	Layered defenses, Access restrictions, Employee involvement, Collaboration with governments, Cyber-security, Personnel security
Financial strength	Capacity to absorb fluctuations in cash flow	Insurance, Portfolio diversification, Financial reserves and liquidity, Price margin

Just as the vulnerability factors are discussed throughout the literature, capabilities have been investigated in literature within the subject of supply chain resilience. Researchers have identified capabilities as management's ability to anticipate and overcome disruptions (Pettit, Fiksel and Croxton, 2010). Table 5 presents capability taxonomy and matches it with a small sample from supply chain resilience literature.

Table 5: Supply Chain Resilience Framework — Capabilities
(Adapted from Pettit, Fiksel and Croxton, 2010)

Main Factors of Capability	Descriptors	Cranfield (2002, 2003)	Rice and Caniato (2003)	Fiksel (2003)	Peck (2005)	Sheffi (2005)	Ponomarov And Holcomb (2009)	Pettit, Fiksel and Croxton (2010)
Flexibility-sourcing	Commonality (facilities, processes)					X	X	X
	Product commonality (modularity, interchangeability)		X			X		X
	Multiple uses for supplies		X			X		X
	Supplier contract flexibility	X	X	X	X	X		X
	Multiple sources	X	X	X	X	X		X
Flexibility-fulfillment	Alternate distribution channels		X		X			X
	Risk pooling/sharing					X	X	X
	Multi-sourcing (peak vs. base)							X
	Delayed commitment, Production postponement					X	X	X
	Inventory management						X	X
	Fast re-routing of requirements							X
Capacity	Reserve capacity (materials, assets, labor, inventory)	X	X		X	X	X	X
	Redundancy (assets, labor)	X	X			X	X	X
	Backup energy sources/communications					X	X	X
Efficiency	Waste elimination	X		X		X		X
	Labor productivity						X	X
	Asset utilization						X	X
	Product variability reduction							X
	Failure prevention							X
Visibility	Business intelligence gathering	X				X	X	X
	Information technology	X	X		X		X	X
	Products, Assets, People visibility	X	X		X			X
	Collaborative information exchange						X	X

Table 5 continued.

Main Factors of Capability	Descriptors	Cranfield (2002, 2003)	Rice and Caniato (2003)	Fiksel (2003)	Peck (2005)	Sheffi (2005)	Ponomarov And Holcomb (2009)	Pettit, Fiksel and Croxton (2010)
Adaptability	Fast re-routing of requirements		X			X	X	X
	Process Improvement, Lead time reduction	X	X	X	X	X	X	X
	Strategic gaming & simulation			X	X	X		X
	Seizing advantage from disruptions					X	X	X
	Alternative technology development			X	X			X
	Learning from experience, Reengineering				X	X	X	X
Anticipation	Monitoring early warning signals		X		X	X	X	X
	Forecasting	X			X	X		X
	Deviation, Near-miss analysis				X	X		X
	Contingency planning, Preparedness (Training/Drill/Exercise plans)		X			X	X	X
	Risk management, Business continuity planning	X	X	X		X	X	X
	Recognition of opportunities					X		X
Recovery	Crisis management	X	X			X		X
	Resource mobilization							X
	Communications strategy						X	X
	Consequence mitigation							X
Dispersion	Distributed decision-making			X		X		X
	Distributed capacity & assets	X	X	X		X		X
	Decentralization of key resources (including data)			X		X		X
	Location-specific empowerment							X
	Geographic dispersion of markets							X
Collaboration	Collaborative forecasting, Customer relationship management	X	X	X	X	X	X	X
	Communications - internal, external	X		X	X	X	X	X
	Postponement of orders						X	X
	Product life cycle management							X
	Risk sharing with partners						X	X

Table 5 continued.

Main Factors of Capability	Descriptors	Cranfield (2002, 2003)	Rice and Caniato (2003)	Fiksel (2003)	Peck (2005)	Sheffi (2005)	Ponomarov And Holcomb (2009)	Pettit, Fiksel and Croxton (2010)
Organization	Learning, Benchmarking, Feedback		X					X
	Responsibility, Accountability & Empowerment	X						X
	Teamwork, Creative problem solving	X				X	X	X
	Training, Cross-train workers		X			X		X
	Substitute leadership capacity							X
	Culture of caring for employees							X
Market position	Product differentiation							X
	Customer loyalty/retention							X
	Market share							X
	Brand equity							X
	Customer relationships						X	X
	Customer communications						X	X
Security	Layered defenses	X	*		X	X		X
	Access restriction	X				X		X
	Employee involvement in security					X		X
	Collaboration with governments	X			X	X		X
	Cyber-security					X		X
	Personnel security							X
Financial strength	Insurance		X					X
	Portfolio diversification			X				X
	Financial reserves & liquidity			X				X
	Price margin							X

* NOTE: Authors specifically describe security as separate from resilience.

How to Measure Resilience

Many scholars agree that supply chain resilience is essential in today's global environment (Christopher and Peck, 2004; Sheffi, 2005; Ponomarov and Holcomb, 2009; Pettit, Fiksel, and Croxton 2010). However, the ability to measure supply chain resilience without using traditional risk management techniques had been lacking in

literature. Based on the framework that Pettit, Fiksel and Croxton developed, Pettit with the Center for Resilience and the Fisher College of Business at The Ohio State University created the Supply Chain Resilience Assessment and Management (SCRAM™) tool (Pettit, 2008).

The resilience framework that Pettit, Fiksel and Croxton developed was based on two postulates and three propositions (2010).

Postulate 1: Forces of change create supply chain vulnerabilities.

Postulate 2: Management controls create supply chain capabilities.

Proposition 1: Supply chain resilience increases as capabilities increase and vulnerabilities decrease

Proposition 2: Linkages exist between each vulnerability and a specific set of capabilities that can directly improve balanced resilience.

Proposition 3A: Excessive vulnerabilities relative to capabilities will result in excessive risk.

Proposition 3B: Excessive capabilities relative to vulnerabilities will erode profitability.

Proposition 3C: Supply chain performance improves when capabilities and vulnerabilities are more balanced.

Pettit, Fiksel and Croxton built their resilience framework using tenets of Grounded Theroy (2010). The first phase created the taxonomies of both capabilities and vulnerabilities based on extant literature and then refined and validated this list with supply chain managers from a large retailer with a complex global supply chain. The second phase of the validation used focus groups from the large retailer using a detailed interview protocol to discuss recent supply chain disruptions in order to identify the

vulnerabilities and capabilities (Pettit, Fiksel and Croxton, 2010). Figure 6 is a pictorial view of the Pettit's framework.

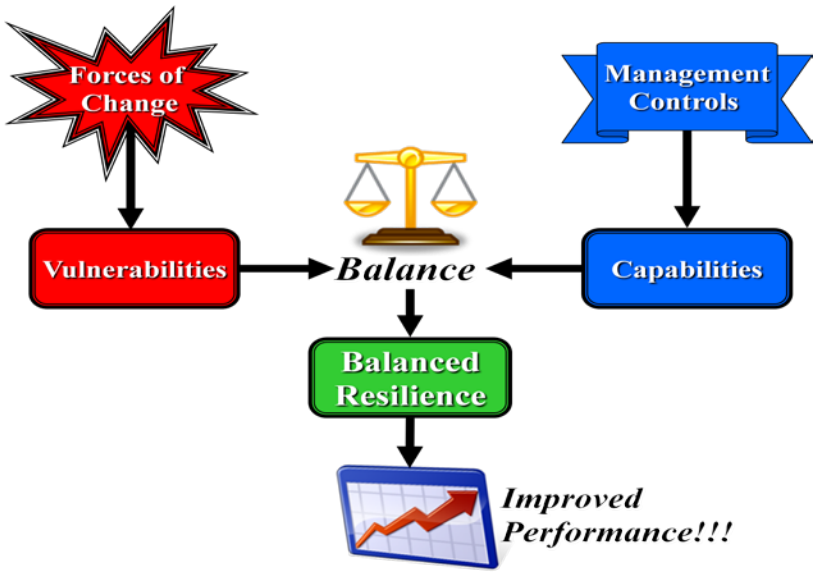

Figure 6: Supply Chain Resilience Framework
(Pettit, Fiksel and Croxton, 2010)

Pettit, Fiksel and Croxton believed that through the measurement of vulnerabilities and capabilities they could provide an evaluation of a supply chain's current level of resilience and from this developed the supply chain resilience assessment and management (SCRAM™) tool to direct supply chain improvements (2010). The tool is designed to subjectively measure the vulnerability and capability factors and their respective sub-factors. The target population for SCRAM™ included all business organizations, both for-profit and not-for-profit, global companies and privately owned small businesses, as well as corporations and governmental agencies (Pettit, 2008). It is a web-based survey instrument that measures responses in ordinal form in a Likert Scale

"Disagree/Agree," ranging from 1 to 5. Due to the large number of factors and sub-factors (21 and 111, respectively) Pettit controlled the number of questions in order to maintain a reasonable survey length (Dillman, 2000; Pettit 2008).

Pettit, Fiksel and Croxton proposed that the assessment of the 21 factors, listed in Tables 2 and 4, respectively, can be used to evaluate an organization's current state of resilience within its supply chain, and therefore, through a strategic review of the organization's resilience suggest recommendations for improvements that can be prioritized to meet strategic goals. The recommendations are designed to lead an organization to a state of "balanced resilience". Figure 7 graphically presents this state of "balanced resilience" and shows that an overage in capabilities relative to vulnerabilities erodes profits and the overage of vulnerabilities relative to capabilities exposes an organization to risk (Pettit, Fiksel and Croxton, 2010).

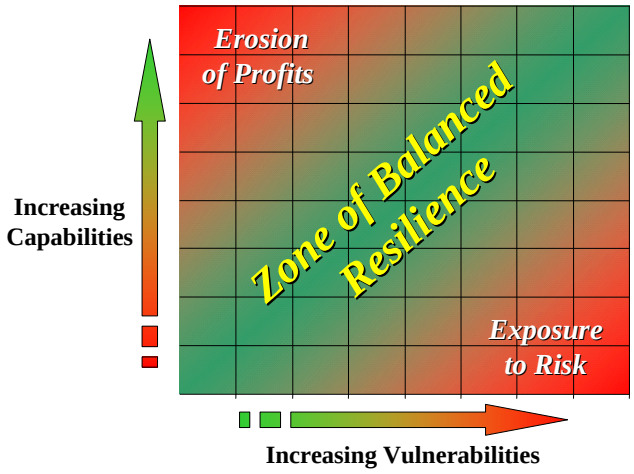

Figure 7: Zone of Balanced Resilience (Pettit, 2008)

Pettit's research indicated that the SCRAM™ tool is a viable method of evaluating the levels of vulnerabilities and capabilities of a firm's supply chain.

Presentation of his results to corporate sponsors provided excellent feedback as to the breadth of the supply chain resilience framework and the ability of the SCRAM™ tool to accurately measure the sources of change facing the firm as well as the firm's strengths and weaknesses (Pettit, 2008).

Summary

The literature review provided an overview of the USAF weapon system life cycle, the definition of resilience used in this research, risk management processes, resilience, why resilience is important to organizations, resilience framework, and how to measure resilience. Additionally, the results of Pettit's research provide an opportunity for further research utilizing the SCRAM™ tool. This research plans to validate the SCRAM™ tool on USAF weapon systems throughout the weapon system life cycle. The following chapter covers the research methods that are intended to be used to complete this research paper.

III. Research Methodology

Introduction

This research employs a web-based survey instrument to collect the data necessary to answer the research question and the three investigative questions. This chapter begins by stating the research and investigative questions. The chapter continues with the research assumptions and limitations, the selection of the weapon systems and their respective respondents, and the SCRAM™ tool with modifications necessary for a military application and the administration of the SCRAM™. The chapter concludes with a discussion of the analysis plan followed by a summary.

Research and Investigative Questions

To date, the SCRAM™ tool has not been utilized on a military supply chain. This indicates the opportunity for the following research question to be investigated:

Research Question: Is the SCRAM™ tool able to measure supply chain vulnerabilities and capabilities within the USAF's weapon system life cycle and provide useful feedback?

To answer the research question the following investigative questions will be addressed:

Question 1: Will the SCRAM™ tool identify an overage of capabilities compared to vulnerabilities in selected weapon system at the current point in time in the weapon system life cycle?

Question 2: Will the SCRAM™ tool identify an underage of capabilities compared to vulnerabilities in selected weapon system at the current point in time in the weapon system life cycle?

Question 3: Do supply chain vulnerabilities and capabilities vary across the separate weapon system life cycle phases?

Assumptions and Limitations

The following assumptions are stated for this research:

1. The weapon system samples participating in this research represent the population of weapon systems in the Air Force.

2. The respondents are subject matter experts in their functional role.

3. The respondents hold top-level positions within the organization, providing a strategic perspective.

4. The respondents are knowledgeable with the supply chain their organization operates in regardless if organically or contactor managed.

5. The respondents took the appropriate amount of time to read, understand and answer each question properly.

6. That the weapon system life cycle phases (Phase I and Phase II) for this research do not overlap.

The following are limitations of this research project:

1. The sample size of this research may provide less than robust results.

2. The weapon system's leadership decision to select only one from each functional role may introduce single-respondent bias.

3. Due to the complexity of the weapon systems throughout the life cycle and the varying methods used to manage the individual weapon system supply chains, this may impose limitations on the generalizability of the results.

Research Sample

The target sample population for this study is USAF weapon system program offices that are actively managing weapon systems. The type of weapon systems targeted included man and unmanned from the attack, bomber, cargo, fighter, multi-mission, special electronic installation, and tanker type of systems. There were 21 weapon systems identified in a collaboration effort between the researcher, principal investigator and the research sponsoring organization. A request letter (Appendix A) was distributed

to the leadership of the 21 different weapon systems. Following the request letter, follow up contact was made and 11 weapons systems agreed to participate in the project, representing a 52% response rate.

Each weapon system's leadership was asked to identify a cross-functional team of top-level personnel from their organization. The cross-functional team should include, but not limited to, such functional roles as engineering, acquisition, sustainment, program management, research and development, logistics, financial management, and contracting. Each team was to include a minimum of five members, with no maximum stated. The minimum number of five participants was arbitrarily chosen to get a varied sample of top-level cross-functional participants. The request for top-level cross-functional participants was reiterated in all follow up contact, leaving the final selection of participants to the weapon system's leadership. Table 6, displays the number of each functional role represented per weapon system with the total number of participants for each weapon system and the overall total of all participants.

Table 6: Functional Roles by Weapon System

Weapon System Designator	Functional Role: Acquisition	Engineering	Budgeting / Finance	Logisitics	Manufacturing	Procurement / Contracting	Sustainment	Program Management	**Number of Participants**
w/s 1	1	1	1				1	1	**5**
w/s 2		1		1		1		2	**5**
w/s 3							5		**5**
w/s 4		1		1		1		2	**5**
w/s 5	2	1		1				2	**6**
w/s 6				3					**3**
w/s 7		1		1		1	1	1	**5**
w/s 8	1				1		1	2	**5**
w/s 9	1	2				1		1	**5**
w/s 10	1	1	1	1		1			**5**
w/s 11	1	1	1	1		1			**5**
								Total	**54**

Additionally, each weapon system's leadership was asked to provide a point of contact or a list of individuals for which the researcher would electronically send the survey link. If the organization only provided a point of contact for the researcher to send the assessment link, the point of contact was asked to provide the number of respondents and functional roles of the assigned to take the assessment to assist the researcher in tracking the organization's completion.

The SCRAM™ tool includes a total of 152 questions. Each participant was informed, as a guide, the assessment will take on average approximately 30 minutes to complete. Of the 54 participants, the longest time to complete the assessment was 87 minutes and the shortest time to complete the assessment was approximately 4.5 minutes.

Respondents with low completion times, less than 15 minutes, may bring concern of the reliability of the data due to the number of questions. All samples were kept with the assumption that the weapon systems leadership tasked their most qualified person(s) in that functional role. Table 7 includes an average of assessment completion times of the participants by weapon system and the number of respondents in each of the functional role and the organization timeframe categories. With 29 of the 54 (53%) respondents having more than 10 years of experience in their functional role lends credit to the assumption that the respondents are subject matter experts. A note of interest is the number of respondents that have less than five years in their current organization. Of the 54 respondents 44 (81%) have less than five years.

Table 7: Assessment Completion Times with Timeframe in Role and Organization

			The number of Respondents Time in current Functional Role				**The number of Respondents Time in current Organization**			
Weapon System #	Min/Max completion time (min/max)	Average Completion time (mm:ss)	0- <1 Year	1-< 5 Years	5-10 Years	More than 10 Years	0- <1 Year	1-< 5 Years	5-10 Years	More than 10 Years
1	4:19/30:59	16:00	1	1	1	2	1	3	1	
2	20:58/44:30	36:47		3		2	1	4		
3	6:54/53:23	17:30	1	2		2	1	2		2
4	12:57/54:19	24:33		1	1	3		3	2	
5	24:53/59:18	46:30	1			5	1	4		1
6	18:37/55:39	39:10		1	1	1	2	1		
7	7:04/35:37	18:50		1	2	2		3	1	1
8	13:19/87:00	38:03	1		2	2	3		2	
9	7:18/29:25	18:38	1	2		2	5			
10	6:14/50:40	27:12				5	3	2		
11	6:14/50:40	17:33		2		3	2	3		
Total average time		27:21								
Total # of respondents per time frame			5	13	7	29	19	25	6	4

Supply Chain Assessment and Management (SCRAM™) tool

As discussed in Chapter II, the SCRAM™ tool was developed by Pettit, in conjunction with the Center for Resilience and the Fisher College of Business at The Ohio State University (Pettit, 2008). SCRAM™ is a web-based instrument that firms are administered to self-assess the supply chain their organization is operating within. Web-based or internet surveys are a low cost method compared to traditional research methods, such as telephone, mail, and fax surveys (Griffis, Goldsby and Cooper, 2003; Maronick, 2009). The web-based instrument was appropriate for this research since all participants have access to the internet. The survey instrument was reviewed and approved by Air Force Institute of Technology's Institutional Review Board.

The SCRAM™ tool in Pettit's research has been improved with further research and this study will use the latest version of the tool, SCRAM™ 2.0. In SCRAM™ 2.0 the vulnerability factors have been reduced by one; therefore, there are only six. The vulnerability factor removed was supply/customer disruptions. In a personal interview, Pettit discussed the broadness of the supply/customer disruption factor and the reason for removing the factor from the vulnerability list. His reasoning was that a firm's strategic suppliers and customers would complete the SCRAM™ from their perspective and consolidated into a multi-aspect view of the supply chain's resilience (Pettit, 2010b). The SCRAM™ 2.0 vulnerability factors and the sub-factors are listed in Table 8.

Furthermore, the capability factors have also been modified since Pettit's initial research. In Pettit's (2008) study he identified 14 capabilities, but further research expanded this list to 16 factors. The two capabilities factors that were added include; flexibility in manufacturing and product stewardship. In a personal interview, Pettit

discussed the reasoning for expanding the list. Flexibility in manufacturing was added as an individual factor from flexibility in order fulfillment due to scope of manufacturing complexities. The second factor added was product stewardship due to the importance of sustainable business practices required by government regulations and the public's desire for responsible firms protecting the environment (Pettit, 2010b). Table 9 lists the SCRAM™ capability factors and sub-factors

Table 8 SCRAM™ 2.0 Vulnerability Factors
(Pettit, Fiksel, and Croxton, 2010)

Vulnerability Factor	Definition	Sub-Factors
Turbulence	Environment characterized by frequent changes in external factors beyond your control	Natural disasters, Geopolitical disruptions, Unpredictability of demand, Fluctuations in currencies and prices, Technology failures, Pandemic
Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism/sabotage, Labor disputes, Espionage, Special interest groups
External pressures	Influences, not specifically targeting the firm, that create business constraints or barriers	Competitive innovation, Social/Cultural change, Political/Regulatory change, Budget constraints, Corporate responsibility, Environmental, Health and Safety Concern
Resource limits	Constraints on output based on availability of the factors of production	Supplier, Production and Distribution capacity, Raw material and Utilities availability, Human resources
Sensitivity	Importance of carefully controlled conditions for product and process integrity	Complexity, Product purity, Restricted materials, Fragility, Reliability of equipment, Safety hazards, Visibility to stakeholders, Symbolic profile of brand, Concentration of capacity
Connectivity	Degree of interdependence and reliance on outside entities	Scale of network, Reliance upon information, Degree of outsourcing, Import and Export channels, Reliance upon specialty sources

Table 9: SCRAM™ 2.0 Capability Factors
(Pettit, Fiksel, and Croxton, 2010)

Capability Factor	Definition	Sub-Factors
Flexibility in sourcing	Ability to quickly change inputs or the mode of receiving inputs	Part commonality, Multiple uses, Supplier contract flexibility, Multiple sources
Flexibility in Manufacturing	Ability to quickly and efficiently change the quantity and type of outputs	Modular product design, Delayed commitment/ Production postponement, Small batch sizes, Equipment change over speed
Flexibility in order fulfillment	Ability to quickly change outputs or the mode of delivering outputs	Alternate distribution channels, Risk pooling/sharing, Multi-sourcing, Inventory management, Re-routing of requirements
Capacity	Availability of assets to enable sustained production levels	Reserve capacity, Redundancy, Backup energy sources and communications
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination, Labor productivity, Asset utilization, Product variability reduction, Failure prevention
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering, Information technology, Product, equipment and people visibility, Information exchange
Adaptability	Ability to modify operations in response to challenges or opportunities	Fast re-routing of requirements, Lead time reduction, Strategic gaming and simulation, Seizing advantage from disruptions, Alternative technology development, Learning from experience
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals, Forecasting, Deviation and near-miss analysis, Risk management, Business continuity/preparedness planning, Recognition of opportunities
Recovery	Ability to return to normal operational state rapidly	Crisis management, Resource mobilization, Communications strategy, Consequence mitigation
Dispersion	Broad distribution or decentralization of assets	Distributed decision-making and Assets, Decentralization of key resources, Location-specific empowerment, Dispersion of markets
Collaboration	Ability to work effectively with other entities for mutual benefit	Collaborative forecasting, Customer management, Communications, Postponement of orders, Product life cycle management, Risk sharing with partners
Organization	Human resource structures, policies, skills and culture	Accountability, Creative problem solving, Cross-training, Substitute leadership/empowerment, Learning/benchmarking, Culture of caring
Market position	Status of a company or its products in specific markets	Product differentiation, Customer loyalty/retention Market share, Brand equity, Customer relationships, Customer communications

Table 9: Continued

Security	Defense against deliberate intrusion or attack	Layered defenses, Access restrictions, Employee involvement, Collaboration with governments, Cyber-security, Personnel security
Financial strength	Capacity to absorb fluctuations in cash flow	Insurance, Portfolio diversification, Financial reserves and liquidity, Price margin
Product Stewardship	Assurance of sustainable business practices throughout product life cycle	Monitor environmental, health and safety, Communicate sustainability with Suppliers, Communicate disposal requirements with Customers

Pettit validated SCRAM™ by assessing seven commercial firms with global supply chains. This validation occurred through a series of focus groups within each firm using a multiple case study methodology (Pettit, 2008; Yin, 2003). Pettit administrated the SCRAM™ to the seven firms to evaluate several recent disruptions within each firm to validate the tool (Pettit, 2008). Additionally, Pettit's (2008) research included the methods he used to address construct validity, internal validity, external validity and reliability.

Construct validity was controlled by using multiple respondents from each firms varying functional areas, a secure database back-up, and followed up by a final presentation to the firm's leadership (Pettit, 2008). Therefore, to ensure construct validity, Pettit used multiple data sources to combine expert perceptions with historical performance (2008).

For internal validity, Pettit conducted a pre-test by academics and practitioners, and a large pilot test of the SCRAM™ tool prior to administering the assessment to his research sample (2008). Additionally, he used Cronbach's alpha as an unbiased estimator of internal consistency. Pettit noted that in literature well-developed scales will have a Cronbach's alpha of 0.7 or greater, but using a lower limit of 0.5 is acceptable in

exploratory research (2008). Table 10 compares Pettit's Cronbach's alpha scores of his main sample to the Cronbach's alpha of this research's population sample. The difference between SCRAM™ 1.0, which Pettit used in his research, and SCRAM™ 2.0, which is used for this research are noted in Table 8. The Cronbach's alpha values are consistent except for a decrease in factors V3, V4, and C14, and an increase in factor C1. V3 – External pressures alpha of 0.487, fell below the 0.5 threshold that Pettit (2008) set for his exploratory study. This may be explained by the sample size of the current study (N=54). V4 – Resource limits alpha of 0.405 also fell below the 0.5 threshold. Again the sample size may have an impact and the number of questions for this factor was reduced from six in Pettit's study to three in this research. C14 – Financial Strength alpha dropped dramatically from 0.682 in Pettit's study to 0.069 in this research. This factor was reduced to two questions for the current research and the wording modified to match government terminology. This alpha may be unacceptable and should be investigated in further studies. C1 – Flexibility in sourcing experienced a significant increase in its Cronbach's alpha. Pettit's original study recorded an alpha of 0.288 and the current research recorded an alpha of 0.719. This may be attributed to the change from SCRAM™ 1.0 to SCRAM™ 2.0. In SCRAM™ 2.0 an additional factor was created out of SCRAM™ 1.0 C1 and C2 factors, flexibility in manufacturing. The purpose of this research was to use SCRAM™ 2.0 with minor changes to terminology and removal of any sub-factors that do not relate to the military's supply chain management practices.

Table 10: Internal Reliability of Factor Measures
(Adapted from Pettit, 2008)

Baseline SCRAM™ 1.0	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**V7**
Number of Items	6	6	6	6	9	5	2
Cronbach's Alpha (Pettit, 2008)	0.651	0.756	0.746	0.730	0.704	0.745	0.756
Sample size*	138	134	142	105	102	130	142
Equivilent SCRAM™ 2.0	**V1**	**V2**	**V3**	**V4**	**V5**	**V6**	**X**
Number of Items	7	5	6	3	9	5	X
Cronbach's Alpha (Current sample)	0.709	0.754	0.487	0.405	0.785	0.554	X
Sample size*	54	48	53	49	53	52	X

Baseline SCRAM™ 1.0	**C1**	**X**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Number of Items	5	X	6	3	5	4	6	6
Cronbach's Alpha (Pettit, 2008)	0.288	X	0.677	0.515	0.701	0.813	0.708	0.803
Sample size*	75	X	90	96	108	123	91	99
Equivilent SCRAM™ 2.0	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
Number of Items	5	9	6	5	6	8	5	10
Cronbach's Alpha (Current sample)	0.719	0.645	0.719	0.601	0.848	0.856	0.872	0.934
Sample size*	52	49	40	39	44	41	41	46

Baseline SCRAM™ 1.0	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**X**
Number of Items	4	5	5	6	6	6	4	X
Cronbach's Alpha (Pettit, 2008)	0.682	0.461	0.615	0.779	0.763	0.896	0.682	X
Sample size*	136	115	89	158	141	87	136	X
Equivilent SCRAM™ 2.0	**C9**	**C10**	**C11**	**C12**	**X**	**C13**	**C14**	**C15**
Number of Items	5	6	11	7	X	6	2	5
Cronbach's Alpha (Current sample)	0.859	0.413	0.907	0.930	X	0.933	0.069	0.864
Sample size*	44	46	47	40	X	35	46	39

* Sample size due to listwise deletion of missing or "Don't Know" responses: Pettit's (2008) Sample N=170, Current Sample N=54.

X Indicates the factor was not part of either Pettit's (2008) or the current research

To ensure external validity, Pettit designed into his study a sample of firms that are representative from the spectrum of markets (Pettit, 2008). Furthermore, Pettit noted that the generalizability of the assessment tool was further improved because it was created using a broad set of extant literature and presented to eight focus groups within a firm that produces a wide variety of products (Pettit, 2008; Pettit, Fiksel and Croxton, 2010).

To ensure reliability, Pettit was the single researcher that facilitated each of the focus groups. Pettit conducted a pre-test and pilot test for the assessment tool. The early tests were used to correct interpretation issues related to the format and content of the assessment tool (Pettit, 2008). Additionally, Pettit used hold-out samples for the case studies. The hold-out sample was administered a subset of the questions in order to evaluate the reliability of the focus group's ability to uncover salient points and his research concluded that the focus groups performed well in extracting the necessary salient points (Pettit, 2008).

Current Research

This research uses SCRAM™ 2.0 and assessed military organizations, specifically USAF weapon system acquisition and sustainment organizations that are managing weapon systems in one of the two different phases of the weapon system life cycle. The weapon system life cycle is divided into two different phases, Phase I includes weapon systems from conception through production and Phase II includes weapon systems from post production through disposal. Figure 8, depicts a description of weapon system life cycle framework and how the life cycle is divided into two phases for this research.

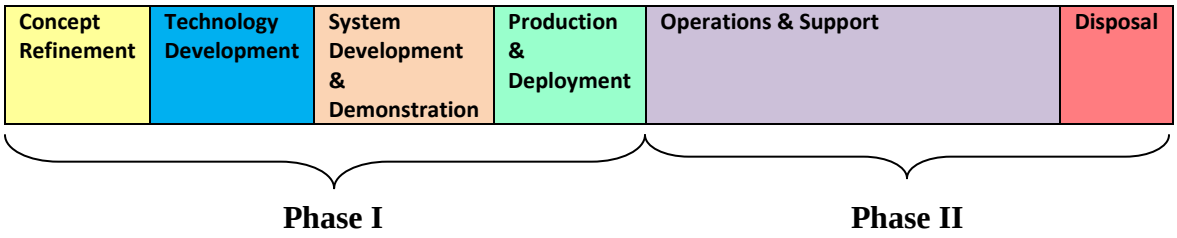

Figure 8: Lifecycle Framework with Project Phases
(Adapted from Defense Acquisition University, 2009)

The SCRAM™ tool required minor modification prior to assessing military units. First, the capability factor "market position" was removed from the assessment, it was determined that this capability was not appropriate for this assessment due to the military is not concerned with market share or brand equity. Additionally, each individual question was reviewed and modified if the wording was not consistent with government terminology. For example, the word *product* was replaced with the words *weapon system* throughout the tool. Refer to Appendix B for the modified SCRAM™ 2.0 used for this research.

Administration of SCRAM™

The SCRAM™ tool was built onto Air Force Institute of Technology's server utilizing Snap Survey software. When participants completed the assessment their responses were collected in Air Force of Institute's web survey-information retrieval system (WebSIRS), which is a database that is common access card secured and only the researcher could access.

All weapon system point of contacts or individual respondents were electronically sent an e-mail with a brief set of instructions and a hyperlink to access the SCRAM™ tool.

The instructions included with the assessment link are as follows:

1. The assessment should take approximately 30 minutes to complete.

2. Do not close the assessment prior to completion due to the server will not save the assessment if not fully completed.

3. During the assessment you can use your browser's back button to go back to questions/screens you have previously answered/viewed.

4. This assessment of your weapon system is not a collaboration effort. Only answer for your functional expertise. If there are questions you do not have expertise in, use the "Don't Know" answer button.

5. Do not share the assessment link with others.

Once the individual respondents accessed the assessment tool on-line, additional directions were provided. See Appendix B, Modified SCRAM™ Assessment Tool**,** for the additional directions presented to the assessment respondents.

The initial e-mail with the assessment link was sent out on 12 December 2009. Weapon systems were given updates on the number of completed assessments beginning on 8 January 2010 and approximately every two weeks for a total of three e-mails with updates. It was decided to only send three updates spread apart by two weeks to not bias the respondents.

Analysis Method

The data collected from each weapon systems self-assessment from the SCRAM™ tool is used for the analysis of this research. Two separate methods were used to answer each investigative question and the overall research question.

To answer investigative questions 1 and 2, which are listed at the beginning of this chapter, the data collected from each individual weapon system was used to calculate

a small-sample confidence interval for the sample population mean (McClave, Benson and Sincich, 2008). Due to the small sample size, three to six respondents, both parametric and nonparametric methods were explored. The researcher decided for this set of investigative questions to use the parametric method, since 94% of all samples can be assumed to come from a normal distribution at the 95% confidence level according to the statistical program JMP8. The nonparametric method was not an option due to the small sample size, the reference chart for the parametric method in Rice's book should not be used below n=5 (Rice, 1995).

To answer investigative question number 3, the weapon systems' SCRAM™ results were grouped into the two phases, Phase I and Phase II. Again, due to the small sample size, Phase I with a sample size of N=5 and Phase II with a sample size of N=6, both parametric and nonparametric statistical methods were explored. The research opted to use the nonparametric method, Wilcoxon rank sum test, due to the results being more conservative than the parametric method.

Summary

This chapter discussed the laid the foundation for the research methodology. The chapter began with the research question and investigative questions, then a review of the research approach. The next chapter will present the analysis of the data collected from the SCRAM™ assessment tool.

IV. Analysis and Results

Introduction

This chapter will present the data and the results of the analysis used to answer the research question and investigative questions.

Research and Investigative Questions

Research Question: Is the SCRAM™ tool able to measure supply chain vulnerabilities and capabilities within the USAF's weapon system life cycle and provide useful feedback?

To answer the research question the following investigative questions will be addressed:

Question 1: Will the SCRAM™ tool identify an overage of capabilities compared to vulnerabilities in selected weapon system at the current point in time in the weapon system life cycle?

Question 2: Will the SCRAM™ tool identify an underage of capabilities compared to vulnerabilities in selected weapon system at the current point in time in the weapon system life cycle?

Question 3: Do supply chain vulnerabilities and capabilities vary across the separate weapon system life cycle phases?

Weapon System Assessments

Each weapon system identified for this research the individual respondents were administered a SCRAM™ web-based assessment. The results from the individual assessments were used to answer the investigative questions and the research question for this study.

The data from each respondent's self-assessment using the SCRAM™ tool was analyzed using a Microsoft Excel program that Pettit (2008) developed. The SCRAM™ analyzer calculates an aggregated resilience assessment score from the individual respondent's subjective assessment of the organization's supply chain. Additionally,

resilience gaps, an imbalance of vulnerabilities verses capabilities, are calculated between linked vulnerabilities and capabilities (Pettit, 2008). Figure 9 is the resilience assessment score for Phase I and Phase II weapon systems. Table 11 and Table 12 are charts of Phase I and Phase II resilience gaps, respectively.

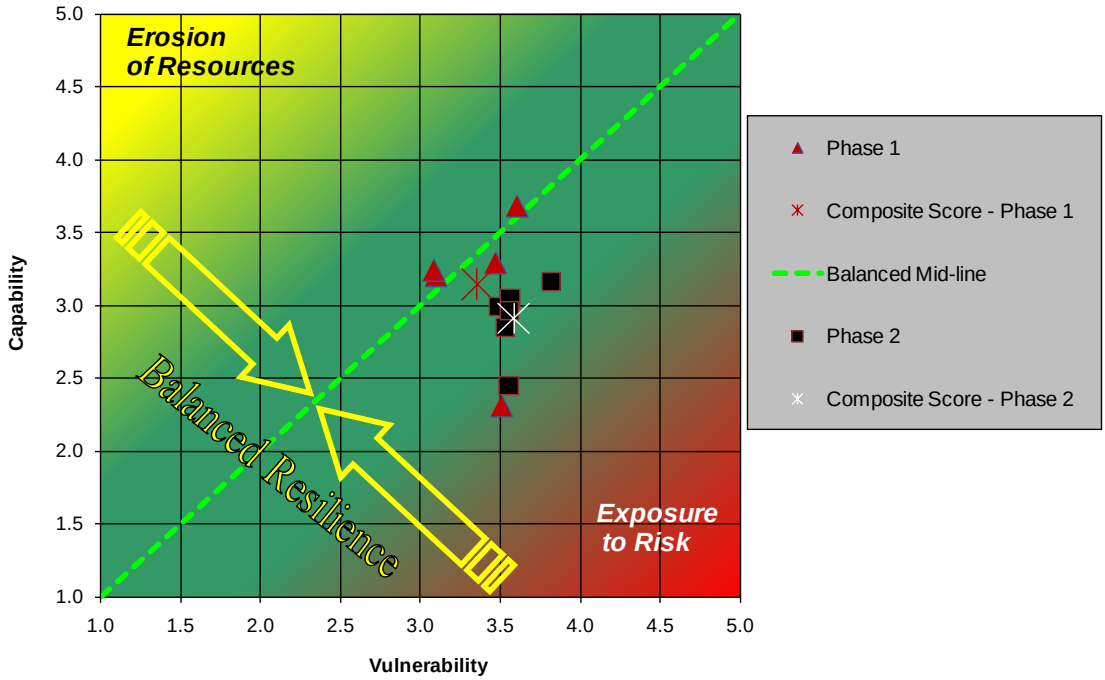

Figure 9: Phase Comparison Resilience Assessment

Table 11: Phase I Resilience Gaps

Phase I		Turbulence	Deliberate Threats	External Pressures	Resource Limits	Sensitivity	Connectivity
		V1	V2	V3	V4	V5	V6
Flexibility in Sourcing	C1	-18.5%	0.7%		-6.4%	12.4%	8.4%
Flexibility in Manufacturing	C2	-11.6%		-16.0%		-0.9%	
exibility in Order Fulfillment	C3	5.6%				4.5%	
Capacity	C4	-10.0%	-24.2%	-0.2%	2.6%	3.5%	-23.2%
Efficiency	C5	-3.3%		-8.6%	4.8%	12.5%	-14.6%
Visibility	C6	-4.9%	3.0%			21.8%	-16.1%
Adaptability	C7	1.7%	9.1%	2.8%		10.8%	2.4%
Anticipation	C8	1.5%	4.0%	0.0%	6.9%	20.7%	-2.9%
Recovery	C9	10.6%	9.8%		1.2%	5.2%	-0.3%
Dispersion	C10	8.4%	15.3%			46.2%	1.4%
Collaboration	C11	-0.1%	3.6%			19.5%	-6.9%
Organization	C12	6.3%			0.0%	27.8%	
Security	C13		-21.6%				-30.0%
Financial Strength	C14	9.6%	-6.6%			-4.7%	
Product Stewardship	C15		5.3%	4.4%	10.6%	12.0%	1.5%

* Upper gap limit 5%
* Lower gap limit -5%

Table 12: Phase II Resilience Gaps

Phase II		Turbulence	Deliberate Threats	External Pressures	Resource Limits	Sensitivity	Connectivity
		V1	V2	V3	V4	V5	V6
Flexibility in Sourcing	C1	-25.8%	-3.5%		-20.2%	6.0%	2.4%
Flexibility in Manufacturing	C2	-15.5%		-17.9%		-2.0%	
exibility in Order Fulfillment	C3	1.0%				-3.3%	
Capacity	C4	-12.8%	-26.7%	-4.8%	-6.2%	-0.5%	-27.8%
Efficiency	C5	-14.5%		-20.0%	-11.0%	0.7%	-26.8%
Visibility	C6	-7.1%	7.3%			16.3%	-22.3%
Adaptability	C7	-8.3%	3.3%	2.0%		1.0%	-3.6%
Anticipation	C8	-10.6%	-8.9%	-19.5%	-8.3%	8.8%	-16.9%
Recovery	C9	0.7%	-1.1%		-12.9%	-5.7%	-11.0%
Dispersion	C10	3.4%	11.0%			32.1%	-3.3%
Collaboration	C11	-10.5%	-9.0%			10.0%	-16.2%
Organization	C12	-3.2%			-12.0%	17.2%	
Security	C13		-21.9%				-27.3%
Financial Strength	C14	3.2%	0.6%			-12.4%	
Product Stewardship	C15		-0.8%	-4.9%	1.7%	3.2%	-7.1%

* Upper gap limit 5%
* Lower gap limit -5%

Each weapon system that participated in this study the organization's leadership was provided the results of their individual organization's assessment with recommendations.

Investigative Questions 1 and 2

The SCRAM™ tool was administered to 11 weapon systems with an average of five respondents per weapon system; see Table 6, in Chapter III, for a breakdown of respondents per weapon system. To test for an overage/underage of capabilities compared to vulnerabilities each weapon system's individual results were used to calculate a resilience score. The resilience score (R) is calculated from each weapon system's individual respondent's assessment answers, using a Likert scale of 1 to 5, by a formula that uses an single vulnerability (V) score and calculates with each of the individual capability (C) score, C1 through C15. For example, the result of the formula ((4-V1+C1)/8-0.5) would equal the value of R1.1. The R score for all respondents was then averaged to get the mean R score and standard deviation. The critical t-statistic values were obtained from TABLE V in Appendix B of McClave, Benson and Sincich's statistical book (2008). Using the values stated above the confidence intervals were calculated using Microsoft Excel with average and standard deviation functions embedded in Excel and the formula $\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$, where x-bar is the mean, t is the test statistic, s is the standard deviation, and n is the sample size. Prior to calculating the confidence interval all R scores (R1.1 through R1.15 for each Vulnerability (1 through 6)) the data was checked for a normal distribution in JMP 8. Of the 90 groups checked, 94% with a 95% confidence level appeared to be from a normal distribution. From this information it was determined to use the parametric small-sample confidence interval for

a population mean from McClave, Benson and Sincich's book (2008). Table 13 displays the results from weapon system #10's V6 with the results from V1 through V6 in Appendix C.

Table 13: Confidence Interval for WS10; Vulnerability 6

V6	Resilience Score														
Respondents	R6.1	R6.2	R6.3	R6.4	R6.5	R6.6	R6.7	R6.8	R6.9	R6.10	R6.11	R6.12	R6.13	R6.14	R6.15
A	0.125	0.095833	0.16875	0.033333	0.075		0.1375	0.2	0.1375	-0.075	0.047222	-0.025	0.0125	-0.05	0.1375
B															
C	0	-0.15833	-0.05417	-0.23125	-0.05417	-0.09286	-0.15833	-0.15	-0.0125	-0.075	-0.09063	-0.075	0.05	-0.075	-0.11667
D	-0.11667	-0.15104	-0.04167	-0.16667	-0.04167	-0.07738	-0.06667	-0.04167	-0.11667	-0.16667	-0.06439	-0.04167	-0.02083	-0.04167	-0.04167
E	0.025	0	0.041667	0.025	0.041667	-0.09375	0.041667	-0.04167	0.125	-0.025	0.034091	0.089286	0.125	0	0.075
Mean	0.008333	-0.05339	0.028646	-0.0849	0.005208	-0.088	-0.01146	-0.00833	0.033333	-0.08542	-0.01843	-0.0131	0.041667	-0.04167	0.013542
Std Dev	0.099303	0.123379	0.102633	0.134364	0.063042	0.009204	0.128622	0.14798	0.120905	0.059073	0.069266	0.071349	0.062639	0.03118	0.114229
$t_{\alpha/2}$	2.353	2.353	2.353	2.353	2.353	2.92	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353
Count	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4
Confidence Level(90.0%)															
+ Conf. Interval	0.125163	0.09177	0.149393	0.073184	0.079377	-0.07248	0.139866	0.165765	0.175578	-0.01592	0.063065	0.070847	0.115361	-0.00498	0.147932
- Conf. Interval	-0.1085	-0.19854	-0.0921	-0.24298	-0.06896	-0.10351	-0.16278	-0.18243	-0.10891	-0.15492	-0.09992	-0.09704	-0.03203	-0.07835	-0.12085
Overage of Capabilities	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Underage of Capabilities	**0**	**0**	**0**	**0**	**0**	**1****	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Balanced Resilience	**27**														
Overage of Capability	**0**														
Underage of Capability	**2**														

** 99% Confidence Level

The results from the small-sample confidence interval of weapon system #10's SCRAM™ assessment results identified two positive resilience gaps, an overage of capabilities verses vulnerabilities, at a confidence level of 90%, with V1 - R1.14 at a 95% confidence level. Additionally, as shown above in Table 13, three negative resilience gaps, an underage of capabilities verses vulnerabilities, are identified at a confidence level of 90%, with R6.6 at a 99% confidence level. The low numbers of confidence intervals that do not include the resilience mean score of zero, five out of 90, may be attributed to many different variables. For example, the small sample size, the weapon systems supply chain resilience may be balanced, or the subjective answers of the selected respondents.

Investigative Question 3

The results of the SCRAM™ were next used to compare Phase I versus Phase II of the weapon system life cycle to answer Investigative question 3. As stated in Chapter III, the researcher used a nonparametric method to compare the distributions of Phase I against Phase II to indicate differences in the phases as weapon systems mature from Phase I to Phase II in the life cycle. The nonparametric method used was the Wilcoxon rank sum test. This method does not specify the shape or type of probability distribution, but does require two conditions for a valid test (McClave, Benson and Sincich, 2008)

1. The two samples are random and independent
2. The two probability distributions from which the samples are drawn are continuous.

The Wilcoxon rank sum test was calculated using two different methods, first the data was entered into JMP 8, statistical software program, and the results are presented in

Table 14. The second method to calculate the Wilcoxon rank sum test used the formula in Rice's (1995) Mathematical Statistics and Data Analysis book. The results of this method are presented in Table 15. The results of both methods are similar with the Wilcoxon rank sum test calculated by the method in Rice's (1995:402) book being more conservative. The test identified one of the six vulnerability factors varied between Phase I and Phase II at a confidence level of 90%, and six of the 15 capability factors varied between Phase I and Phase II also at a confidence level of 90%. Table 16, identifies the factors and the direction of the change.

Table 14: Wilcoxon rank sum test, JMP8

	V1	V2	V3	V4	V5	V6
2-Sample Test, Normal Approx.	0.0828	1.0000	0.0277	0.1207	0.2353	0.4642
1-Way Test, ChiSquare	0.0679	1.0000	0.0219	0.1003	0.2012	0.4102
Reject/Fail to Reject	Reject		Reject			

	C1	C2	C3	C4	C5	C6	C7
2-Sample Test, Normal Approx.	0.2353	0.0552	0.2353	0.4632	0.0225	0.2002	0.0225
1-Way Test, ChiSquare	0.2012	0.0446	0.2012	0.4092	0.0176	0.1699	0.0176
Reject/Fail to Reject		Reject			Reject		Reject

	C8	C9	C10	C11	C12	C13	C14	C15
2-Sample Test, Normal Approx.	0.0222	0.0358	0.4113	0.0358	0.4113	0.7837	0.1207	0.1709
ChiSquare Approx.	0.0174	0.0285	0.3613	0.0285	0.3613	0.7144	0.1003	0.1441
Reject/Fail to Reject	Reject	Reject		Reject				

Null Hyp: Phase I = Phase II
Alt Hyp: Phase I ≠ Phase II

Table 15: Wilcoxon rank sum test (Rice, 1995)

		V1	V2	V3	V4	V5	V6	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
W/S & Phase																						
5	1	2.74	2.90	3.50	3.39	3.83	3.93	3.10	2.88	3.57	3.44	3.82	3.83	3.51	3.67	3.92	3.82	3.75	3.79	3.70	3.42	4.03
6	1	2.48	3.07	3.17	2.89	3.74	3.27	3.00	2.96	3.17	2.64	2.72	2.63	3.05	3.24	3.80	3.67	3.27	2.89	4.17	4.00	3.83
8	1	2.44	3.50	3.50	3.00	4.49	4.13	1.94	2.29	2.50	2.63	2.74	3.27	2.55	2.73	3.50	3.83	2.88	2.84	4.17	2.13	3.72
10	1	3.11	3.28	3.29	2.79	3.38	3.58	3.30	2.98	3.50	2.91	3.25	3.16	3.47	3.51	3.43	3.10	3.52	3.64	3.63	3.25	3.53
11	1	2.95	3.25	3.68	3.07	3.67	3.42	3.64	2.99	3.51	2.55	3.42	3.14	3.29	3.33	3.45	2.96	3.31	3.30	3.79	3.18	3.42
1	2	3.38	3.28	3.68	3.93	3.76	3.87	3.13	2.85	3.78	2.67	2.56	3.00	2.78	2.92	3.73	2.75	3.28	3.50	4.00	2.25	3.81
2	2	2.59	2.70	3.63	3.57	3.77	4.02	2.24	2.28	3.01	2.08	2.93	2.70	2.66	2.58	3.08	3.71	2.80	2.88	3.60	2.60	3.32
3	2	2.90	3.60	3.70	3.27	4.40	3.56	2.64	2.76	2.93	2.67	2.65	2.95	2.50	2.97	2.64	2.98	2.86	3.03	4.38	2.70	3.89
4	2	3.28	3.25	3.87	3.75	4.04	4.04	2.48	2.73	2.38	2.63	2.14	2.63	2.54	2.18	2.25	3.44	2.25	2.24	3.25	2.67	3.12
7	2	3.37	2.80	3.69	3.92	3.92	3.93	2.30	2.12	2.49	2.50	2.50	2.87	2.35	2.58	2.98	3.54	2.94	3.07	4.25	3.00	3.37
9	2	3.18	3.40	3.59	2.67	3.93	3.75	2.92	2.64	3.03	2.71	2.16	3.22	2.07	2.36	2.81	3.58	2.66	3.08	3.22	2.30	3.08
	R	20.00	30.00	17.50	21.00	23.00	25.50	37.00	41.00	37.00	34.50	43.00	37.50	43.00	43.00	42.00	35.00	42.00	35.00	32.00	39.00	38.00
	R'	40	30	42.5	39	37	34.5	23	19	23	25.5	17	22.5	17	17	18	25	18	25	28	21	22
	R*	20.00	30.00	17.50	21.00	23.00	25.50	23.00	19.00	23.00	25.50	17.00	22.50	17.00	17.00	18.00	25.00	18.00	25.00	28.00	21.00	22.00
	α= 0.10			Reject					Reject			Reject		Reject	Reject	Reject		Reject				

Critical Value of Smaller Rank Sum for the Wilcoxon Test is 20 (N1-5 and N2-6 for two-tailed test at .10)

Null Hyp: Phase I = Phase II

Alt Hyp: Phase I ≠ Phase II

Table 16: Difference between Phases

Factor	Phase I to Phase II	Factor	Phase I to Phase II	Factor	Phase I to Phase II
V1		C1		C8	Decreased
V2		C2		C9	Decreased
V3	Increased	C3		C10	
V4		C4		C11	Decreased
V5		C5	Decreased	C12	
V6		C6		C13	
		C7	Decreased	C14	
				C15	

Indicates no significant difference

Summary

The data collected from the SCRAM™ 2.0 assessment of 11 weapon systems was presented. The following chapter, Chapter V, will present the conclusions formulated for answering the investigative questions and the overall research question. The researcher will also present conclusions inferred from the results. Furthermore, managerial implications and future research recommendations are also presented.

V. Conclusions and Recommendations

Introduction

Previous research presented opportunities for improvement with the Air Force's supply chain management processes. This research investigated literature in the field of supply chain resilience and identified the Supply Chain Resilience Assessment and Management (SCRAM™) tool as an avenue for potential improvement with Air Force supply chain risk management processes. Based on the results of this study's SCRAM™ assessment of 11 weapon systems within the two defined phases of the weapon system life cycle, the researcher provides an answer to the overall research question (*Is the SCRAM™ tool able to measure supply chain vulnerabilities and capabilities within the USAF's weapon system life cycle and provide useful feedback?).* Following the answer to the research question, the chapter continues with managerial implications, lessons learned, and areas of future research.

Research Question

The information from Chapters II-IV provided the basis for answering the three investigative questions and the overall research question. The researcher interpreted from the analysis and results that the SCRAM™ demonstrated the ability to measure vulnerabilities and capabilities within the defined weapon system life cycle phases and the information obtained can provide beneficial information to guide those that manage Air Force weapon systems as their weapon system matures and progress throughout the life cycle. Though, these results are not without limitations, the results show promise for the utility of supply chain resilience to enhance current Air Force risk management processes.

Managerial Implications

The SCRAM™ tool assessment results have show in previous research that the assessment tool can identify an organization's current level of resilience by measuring the organization's supply chain vulnerabilities and capabilities (Pettit, 2008). The results from this research obtained the same conclusions. Additionally, the analysis and results in Chapter IV demonstrate that the SCRAM™ tool can target an imbalance of specific vulnerabilities and capabilities. This information can provide weapon system leadership the ability to further investigate and apply corrective measures if deemed appropriate.

The results from comparing the defined phases of the weapon system life cycle produced promising results that there are changes in vulnerabilities and capabilities as weapon systems progress throughout the weapon system life cycle. This information can be very beneficial to weapon system managers in providing the necessary information for strategic decisions as they plan for the next 5, 10, 15, 20 years and beyond. Furthermore, since the AFGLSC is the organization responsible for the Air Force's supply chain. This information may be beneficial for instituting policy on supply chain management.

Future Research

The researcher tried to be as thorough as possible in this study, but realizes that there are many opportunities for improvement and future research. A more targeted study of one or two weapon systems with a larger sample size would be beneficial to the research of supply chain resilience within the USAF's weapon system life cycle. Additionally, this researcher believes the research could be expanded by dividing the weapon system life cycle into more distinct phases to identify more differences as weapon systems mature through the life cycle. This research only focused on the weapon

system's supply chain resilience from the perspective of personnel in that weapon system. Future research could explore the supply chain from not only the weapon system perspective, but also the suppliers and customers up and down the supply chain. Furthermore, the opportunity to conduct cost analysis studies of supply chain resilience would be beneficial to assist with future implementation within the USAF weapon system life cycle.

Appendix A: Assessment Support Request Letter

DEPARTMENT OF THE AIR FORCE
AIR FORCE MATERIEL COMMAND
AIR FORCE GLOBAL LOGISTICS SUPPORT CENTER

MEMORANDUM FOR SEE DISTRIBUTION LIST

FROM AFGLSC/CA

SUBJECT: Supply Chain Resilience - Assessing the USAF Weapon System Product Life Cycle

1. Improving the Air Force supply chain management processes is a top priority of the AFGLSC. I request your organization's support of a research project that AFGLSC is funding through the Air Force Institute of Technology (AFIT). This supply chain resilience research project will enable the Air Force to better understand the concept of resilience and will assist your organization to increase its ability to be more responsive to change and disruption. Analysis of the information collected will enable your organization to identify current supply chain management issues that require an increase in capabilities to overcome vulnerabilities or a decrease in capabilities to reduce waste. Additionally, the project will provide insight to direct planned adaptation as your weapon system matures.

2. To accomplish this goal, I have selected a sample of representative weapon systems that will best support this project (Attachment 1). I request you identify a small cross-functional team of top-level personnel in your organization (e.g. engineering, acquisition, sustainment, operations), that are familiar with these systems. This team should consist of at least five personnel (no maximum). Each selected individual will be asked to complete a 30-minute on-line self assessment, with the potential of you, the senior leader, participating in a one-hour interview. All data will be kept strictly confidential by the AFIT research team. In return, you will be provided a final report of the supply chain capabilities and vulnerabilities identified within your organization, along with recommended areas for improvement.

3. Please contact SMSgt Brian Tobin, AFIT project officer, with a point of contact from your office to begin the assessment process. SMSgt Tobin's contact information: DSN 785-3636 x6003 or e-mail: brian.tobin@afit.edu. Thank you in advance for your support.

LORNA B. ESTEP
Executive Director

Note: Distribution list not included in this document

Appendix B: Modified SCRAM™ 2.0

Survey Control Number: AF 09-13

Privacy Notice

The following information is provided as required by the Privacy Act of 1974:

Purpose: You have received a special invitation to participate in a unique questionnaire designed to assess the resilience of your weapon system's supply chain.

Our Goal: To strengthen the resilience of the weapon system throughout its life cycle, giving the enterprise greater ability to cope with a turbulent business environment thus creating a competitive advantage.

Participation: Your participation is **COMPLETELY VOLUNTARY**. Your decision to not participate or to withdrawal at any time from participation will not jeopardize your relationship with the Air Force Institute of Technology, the U.S. Air Force, or the Department of Defense. Thank you for participating in this project.

Confidentiality: Your responses to this assessment will be kept strictly confidential by the research team at the Air Force Institute of Technology. Your honest and accurate assessment is important for gaining meaningful insights into supply chain resilience.

Completion of the assessment requires approximately 30 minutes.

Project Overview:

a. Definition: For the purpose of this project the supply chain is defined as the network of organizations involved in the upstream and downstream flows of products, services, finances and information from the initial supplier to the ultimate customer (*Christopher 1992; Mentzer et al. 2001; Lambert, Garcia-Dastugue, Croxton 2005 and Pettiti 2008*).

b. **The Problem:** The environment is becoming more and more turbulent. Supply chain disruptions, whether an accident, natural disaster, security breach, competitive threat, or shift in demand, can be costly in the short term and may have lasting adverse impacts. It is essential for organizations with complex supply chains to develop a clear understanding of their supply chain vulnerabilities then to proactively strengthen their capabilities to anticipate, respond and adapt.

c. **The Solution:** Based on research in management, economics, ecology and sociology, the concept of resilience has emerged as a critical characteristic of complex, dynamic systems such as business enterprises. In the business context, resilience is defined as the capacity for an enterprise to survive, adapt and grow in the face of change and uncertainty.

   Change not only presents threats to business continuity, but can also create opportunities for business value creation. When disruptions change the competitive landscape, a resilient organization can often take advantage by introducing innovations. Reducing costs and improving mission effectiveness.

d. **The Framework:** In order to analyze the myriad of issues that contribute to enterprise resilience, The Center for Resilience at The Ohio State has developed a structured framework, which captures the fundamental factors that make an enterprise susceptible to disruptions -- Vulnerabilities -- and compares them with attributes that enable an enterprise to anticipate and overcome disruptions -- Capabilities.

Your contribution today is a first step on the journey toward enhanced resilience!

Informed Consent:

1. **Nature and Purpose**: You have been asked to volunteer to assess the current state of supply chain resilience of your organization. This will take approximately 30 minutes.
2. **Experimental Procedures:** You will be asked a series of questions relating to your experience within the organization, assessing the organization's risks and strengths in many areas.
3. **Benefits:** Your organization's leadership will be presented with a consolidated report of assessment results, along with recommendations for improvement.
4. **Confidentiality:**
   a. Records of your participation in this study will not be disclosed.
   b. Your decision to participate in this research is also confidential.

   If you decide to participate, your individual responses will be kept strictly confidential by the research team.
5. **Questions:** If you have any questions or concerns prior to beginning this assessment, please contact **SMSgt Brian Tobin** at **(937) 255-3636 x6003**, or e-mail **brian.tobin@afit.edu**.

I wish to participate in this study.	I elect NOT to participate.
⊙	○

Start Survey

Functional Role:

Please select the weapon system you currently represent:

Weapon Systems Blocked for Anonymity

Please select the function that best represents your role:

Acquisition	Engineering	Budgeting/Finance	Logistics
○	○	○	○

Maintenance/Overhaul	Manufacturing	Contracting	Planning/Scheduling
○	○	○	○

Research and Development	Sustainment	Program Management	Other
○	○	○	○

Please select the time frame that best represents the amount of time in your current function:

0-1 year	1-5 years	5-10 years	› 10 years
○	○	○	○

Please select the time frame that best represents the amount of time in your current organization:

0-1 year	1-5 years	5-10 years	› 10 years
○	○	○	○

Continue

Section I: Vulnerabilities

First, you will be asked to assess the vulnerabilities that currently challenge your operations. Each vulnerability will begin with an overall definition, followed by a question for each factor.

Using the scale provided, for each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Vulnerability #1 –– Turbulence: "Environment characterized by frequent changes in external factors beyond your control."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	The weapon system is subject to unpredictable demand shifts.	○	○	○	○	○	○
2	Our supply chain depends on weapon systems that experience severe currency or price fluctuations.	○	○	○	○	○	○
3	Our supply chain imports are subject to disruptions due to geopolitical turmoil.	○	○	○	○	○	○
4	Our supply chain exports to Foreign Military Sales and/or Allied Partners who are subject to disruptions due to geopolitical turmoil.	○	○	○	○	○	○
5	Facilities throughout our supply chain are exposed to severe natural disasters.	○	○	○	○	○	○
6	Operations within our supply chain have the potential for unforeseen technology failures.	○	○	○	○	○	○
7	Our supply chain operations are susceptible to a potential health pandemic.	○	○	○	○	○	○
8	Comments						

Vulnerability #2 --- Deliberate Threats: "Intentional attacks aimed at disrupting operations or causing human or financial harm."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain facilities or personnel may be targets of terrorism or sabotage.	○	○	○	○	○	○
2	Our weapon systems and components are likely to be stolen or vandalized.	○	○	○	○	○	○
3	Our supply chain depends on unionized labor, which may be hostile to the firm.	○	○	○	○	○	○
4	Our supply chain operations may be affected by Special Interest Groups.	○	○	○	○	○	○
5	Our weapon system or technologies may be compromised by industrial espionage.	○	○	○	○	○	○
6	Comments						

Section I: Vulnerabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Vulnerability #3 --- External Pressures: "Influences, not specifically targeting the organization, that create business constraints or barriers."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our weapon system design is threatened by frequent changes due to innovations.	○	○	○	○	○	○
2 Our supply chain operations and/or weapon system is subject to stringent and/or changing government regulations.	○	○	○	○	○	○
3 Our weapon system program faces strong budget constraints.	○	○	○	○	○	○
4 Stakeholders have high expectations for us to behave in a socially responsible and ethical manner.	○	○	○	○	○	○
5 Social or cultural issues can significantly impact our ability to serve our customers.	○	○	○	○	○	○
6 Environmental concerns influence how we design our weapon system and/or conduct our operations.	○	○	○	○	○	○
7 Comments						

Vulnerability #4 --- Resource Limits: "Constraints on output based on availability of the factors of production."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Raw materials for our weapon system are scarce or in high demand.	○	○	○	○	○	○
2 We and/or our supply chain members have difficulty recruiting and retaining highly skilled workers.	○	○	○	○	○	○
3 Our weapon system is dependent on non-renewable or scarce natural resources or fragile ecosystems.	○	○	○	○	○	○
4 Comments						

Continue

Section I: Vulnerabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Vulnerability #5 --- Sensitivity: "Importance of carefully controlled conditions for weapon system and process integrity."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our weapon system requires or emits toxic, hazardous, or restricted substances.	○	○	○	○	○	○
2	The quality of our weapon system is highly dependent on the quality of our supply chains inputs/supplies.	○	○	○	○	○	○
3	Our supply chain operations require stringent tolerances during production to ensure weapon system quality.	○	○	○	○	○	○
4	Our weapon system requires strict storage or handling controls to maintain its purity and/or integrity.	○	○	○	○	○	○
5	Our supply chain production operations are very complex.	○	○	○	○	○	○
6	Some of our supply chain's equipment is delicate.	○	○	○	○	○	○
7	Our supply chain workers sometimes operate in extreme or hazardous conditions.	○	○	○	○	○	○
8	Errors or deficiencies in our supply chain operations are highly visible to stakeholders.	○	○	○	○	○	○
9	Our customers have stringent quality standards for our weapon system.	○	○	○	○	○	○
10	Comments						

Vulnerability #6 --- Connectivity: "Degree of interdependence and reliance on outside entities."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain has a large number of members.	○	○	○	○	○	○
2	Our supply chain imports a significant portion of our supplies.	○	○	○	○	○	○
3	Our supply chain exports a significant portion of our weapon system or components.	○	○	○	○	○	○
4	For some items in our supply chain, it can be a difficult or lengthy process to certify new suppliers.	○	○	○	○	○	○
5	Continuous information flow is critical to regular operations.	○	○	○	○	○	○
6	Comments						

Section II: Capabilities

Next, you will be asked to assess the capabilities that enable your organization to anticipate and overcome disruptions, as well as seize opportunities for competitive advantage.

Using the scale provided, for each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your organization, operations and weapon system. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #1 --- Flexibility in Sourcing: "Ability to quickly change inputs or the mode of receiving inputs."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our supply chain uses supplies that are used in multiple weapon systems.	○	○	○	○	○	○
2 Our supply contracts can be easily modified to change specifications, quantities and terms.	○	○	○	○	○	○
3 Our existing supplier-base can quickly respond to meet sudden surges in our orders.	○	○	○	○	○	○
4 Our suppliers will expedite our orders in emergency situations.	○	○	○	○	○	○
5 Our supply chain has many alternate sources for key inputs.	○	○	○	○	○	○
6 Comments						

Capability #2 --- Flexibility in Manufacturing: "Ability to quickly and efficiently change the quantity and type of outputs."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our weapon systems use modular designs.	○	○	○	○	○	○
2	Our weapon system can be made by a variety of machines and workers.	○	○	○	○	○	○
3	Our supply chain facilities are able to delay final production in order to be more responsive to demand.	○	○	○	○	○	○
4	Our supply chain facilities utilize equipment that have very short change-over time.	○	○	○	○	○	○
5	Our supply chain operations run very small batch sizes.	○	○	○	○	○	○
6	Our supply chain production operations can process expedited orders to meet urgent needs.	○	○	○	○	○	○
7	Our supply chain production equipment can be quickly reconfigured to produce a new weapon system variant.	○	○	○	○	○	○
8	Our supply chain can quickly increase the throughput of production operations.	○	○	○	○	○	○
9	Our supply chain can quickly decrease the throughput of production operations.	○	○	○	○	○	○
10	Comments						

Continue

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #3--- Flexibility in Order Fulfillment: "Ability to quickly change the mode of delivering outputs/inventories."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our supply chain stores inventory for a wide variety of customers at centralized locations.	○	○	○	○	○	○
2 Our supply chain has a sophisticated inventory management system that regularly computes both safety stock and cycle stock at all storage and maintenance locations.	○	○	○	○	○	○
3 Our supply chain can quickly change the routing and the mode of transportation for inventory shipments.	○	○	○	○	○	○
4 Our supply chain is able to service customers from alternate locations with minimal impact on delivery time.	○	○	○	○	○	○
5 Our supply chain's existing transportation network can quickly respond to sudden increases in volume.	○	○	○	○	○	○
6 Our supply chain's transportation network has the ability to expedite out-bound inventory orders to meet our customers' emergency orders.	○	○	○	○	○	○
7 Comments						

Capability #4 --- Capacity: "Availability of assets to enable required production levels."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain facilities have reliable back-up utilities (e.g. electricity, water, communications, etc).	○	○	○	○	○	○
2	Our supply chain has sufficient stores of raw materials to meet potential surges in production.	○	○	○	○	○	○
3	Our supply chain has sufficient excess production capacity.	○	○	○	○	○	○
4	Our supply chain is able to quickly expand workforce to boost output.	○	○	○	○	○	○
5	Our supply chain facilities are in regions with plentiful natural resources and available ecosystem services, including water, agricultural land, and fuel.	○	○	○	○	○	○
6	Comments						

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #5 --- Efficiency: "Capability to produce outputs with minimum resource requirements."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our supply chain labor productivity is very high.	○	○	○	○	○	○
2 Our supply chain assets are effectively utilized with no limiting bottlenecks.	○	○	○	○	○	○
3 Our supply chain consistently produces high quality weapon systems with little waste.	○	○	○	○	○	○
4 Our supply chain has effective preventive maintenance programs.	○	○	○	○	○	○
5 Our supply chain processes are standardized and require minimal learning.	○	○	○	○	○	○
6 Our supply chain processes are efficient in utilization of materials and energy.	○	○	○	○	○	○
7 Comments						

Capability #6 --- Visibility: "Knowledge of the status of operating assets and the environment."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain has information systems that accurately track all operations.	○	○	○	○	○	○
2	Our supply chain information systems report the current status of all inventories.	○	○	○	○	○	○
3	Our supply chain information systems report the current status of all weapon systems.	○	○	○	○	○	○
4	Our supply chain information systems report the current status of all personnel.	○	○	○	○	○	○
5	Our supply chain exchanges accurate and timely information with suppliers.	○	○	○	○	○	○
6	Our supply chain exchanges accurate and timely information with customers.	○	○	○	○	○	○
7	Our supply chain exchanges accurate and timely information with transportation carriers.	○	○	○	○	○	○
8	Our supply chain accurately monitors external conditions that influence operations (e.g. weather).	○	○	○	○	○	○
9	Comments						

Continue

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #7 --- Adaptability: "Ability to modify operations in response to challenges or opportunities."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain excels at seizing advantages from changes in the industry.	○	○	○	○	○	○
2	Our supply chain develops innovative technologies to improve operations.	○	○	○	○	○	○
3	Our supply chain effectively employs continuous improvement programs.	○	○	○	○	○	○
4	Our supply chain uses strategic gaming and simulations to design more adaptable processes.	○	○	○	○	○	○
5	Our supply chain is progressive in adoption of sustainable business practices, including greenhouse gas and waste reduction.	○	○	○	○	○	○
6	Comments						

Capability #8 --- Anticipation: "Ability to discern potential future events or situations."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain effectively uses demand forecasting methods.	○	○	○	○	○	○
2	Our supply chain has a formal risk identification and prioritization processes.	○	○	○	○	○	○
3	Our supply chain closely monitors deviations to normal operations, including near misses	○	○	○	○	○	○
4	Our supply chain quickly recognizes early warning signals of possible disruptions.	○	○	○	○	○	○
5	Our supply chain has detailed business continuity plans that cover probable situations.	○	○	○	○	○	○
6	Our supply chain regularly conducts emergency preparedness exercises and readiness evaluations.	○	○	○	○	○	○
7	Our supply chain recognizes new business opportunities early and take immediate steps to capitalize on them.	○	○	○	○	○	○
8	Our supply chain has effective intelligence gathering programs.	○	○	○	○	○	○
9	Our supply chain works with other government agencies to anticipate and influence changes in policies and regulations.	○	○	○	○	○	○
10	Our supply chain monitors climate change and other emerging sustainability issues that may affect our operations.	○	○	○	○	○	○
11	Comments						

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #9 --- Recovery: "Ability to return to normal operational state rapidly."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain can quickly repair faulty equipment to minimize downtime.	○	○	○	○	○	○
2	In the event of a crisis, our supply chain can quickly organize a formal response team of key personnel, both on-site and at the corporate level.	○	○	○	○	○	○
3	Our supply chain has an effective strategy for communications in a variety of extraordinary situations.	○	○	○	○	○	○
4	Our supply chain is very effective at dealing with crises (e.g. protection of people, property and reputation).	○	○	○	○	○	○
5	Our supply chain takes immediate action to mitigate the effects of disruptions, and quickly restore normal operations.	○	○	○	○	○	○
6	Comments						

Capability #10 --- Dispersion: "Broad distribution or decentralization of assets."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Key materials for our weapon system are sourced from a geographically distributed network of suppliers.	○	○	○	○	○	○
2	Our supply chain production facilities are geographically distributed.	○	○	○	○	○	○
3	Our supply chain storage facilities and transportation resources are geographically distributed.	○	○	○	○	○	○
4	Our supply chain's senior leaders are based at a variety of different locations.	○	○	○	○	○	○
5	Our supply chain organization empowers on-site experts to make key decisions, regardless of level of authority.	○	○	○	○	○	○
6	Our weapon system is sold to customers in a variety of geographic locations.	○	○	○	○	○	○
7	Comments						

Continue

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #11 --- Collaboration: "Ability to work effectively with other entities for mutual benefit."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain effectively employs collaborative demand forecasting techniques using shared data.	○	○	○	○	○	○
2	Our supply chain is able to effectively communicate with supply chain members during crises.	○	○	○	○	○	○
3	Supply chain members collaborate effectively with other supply chain members to make key decisions.	○	○	○	○	○	○
4	Supply chain members solicit feedback and work with their suppliers to improve products and supply chain performance.	○	○	○	○	○	○
5	Supply chain members solicit feedback and work with their customers to improve products and supply chain performance.	○	○	○	○	○	○
6	Customers are willing to delay orders when production capacity is hampered.	○	○	○	○	○	○
7	Our supply chain has proactive product life-cycle management programs that strive to reduce both costs and risks across the supply chain.	○	○	○	○	○	○
8	Our supply chain members work very closely with their key suppliers to quickly respond when there is a problem.	○	○	○	○	○	○
9	Our supply chain members work very closely with their key customers to quickly respond when there is a problem.	○	○	○	○	○	○
10	Our supply chain members invest in facilities and equipment at their suppliers' plants and are prepared to share the risks and rewards.	○	○	○	○	○	○
11	Our supply chain members invest in facilities and equipment at their customers' locations and are prepared to share risks and rewards.	○	○	○	○	○	○
12	Comments						

Capability #12 --- Organization: "Human resource structures, policies, skills and culture."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain encourages creative problem solving.	○	○	○	○	○	○
2	Our supply chain enforces individual accountability for performance.	○	○	○	○	○	○
3	Our supply chain trains employees in a wide variety of skills.	○	○	○	○	○	○
4	Our supply chain is capable of filling leadership voids quickly.	○	○	○	○	○	○
5	Our supply chain members promote a learning environment, regularly using feedback and benchmarking tools.	○	○	○	○	○	○
6	Our supply chain has a culture of caring for employees.	○	○	○	○	○	○
7	Our supply chain has the ability to quickly increase and decrease the number of workers.	○	○	○	○	○	○
8	Comments						

Continue

Section II: Capabilities (Continued)

For each statement, indicate the extent of your agreement or disagreement based on your personal knowledge of your products, organization and operations. If you do not have personal knowledge of the subject, select "Don't Know".

Capability #13 --- Security: "Defense against deliberate intrusion or attack."

		Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
		0	1	2	3	4	5
1	Our supply chain employs layered defenses and does not depend on a single type of security measure.	○	○	○	○	○	○
2	Our supply chain uses stringent restrictions for access to facilities and equipment.	○	○	○	○	○	○
3	Our supply chain has active security awareness programs that involve all personnel.	○	○	○	○	○	○
4	Our supply chain effectively collaborates with other government agencies to improve security.	○	○	○	○	○	○
5	Our supply chain has a high level of information systems security.	○	○	○	○	○	○
6	Our supply chain uses a variety of personnel security programs such as awareness briefings, travel restrictions, and threat assessments.	○	○	○	○	○	○
7	Comments						

Capability #14 --- Financial strength: "Capacity to absorb fluctuations in cash flow."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our organization has sufficient budget to cover most potential needs.	○	○	○	○	○	○
2 Our supply chain partners have very diverse product portfolios.	○	○	○	○	○	○
3 Comments						

Capability #15 --- Product Stewardship: "Assurance of sustainable business practices throughout the weapon system life cycle."

	Don't Know	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	0	1	2	3	4	5
1 Our supply chain designs weapon systems to minimize potential environmental, health and safety problems.	○	○	○	○	○	○
2 Our supply chain strives to minimize the resource consumption footprint of our weapon system, components and supporting equipment.	○	○	○	○	○	○
3 Our supply chain regularly audits operations and keeps track of environmental, health and safety performance.	○	○	○	○	○	○
4 Our supply chain members communicate sustainability expectations to their suppliers and verify conformance.	○	○	○	○	○	○
5 Our supply chain members work with their customers to assure safe and responsible use and disposal of components and/or weapon systems.	○	○	○	○	○	○
6 Comments						

Next Section

Section III: Importance

Finally, all of the vulnerabilities and capabilities presented in Parts 1 and 2 will be summarized, and you will be asked to rate the relative level of importance for each factor. Response choices are scaled from 'Minor Importance' through 'Critical'. Choose the number that best represents the level of importance. If you do not have personal knowledge of the subject, select 'Don't Know'.

Vulnerabilities:

Please rate the relative level of importance for each factor.	Don't Know	Minor Importance	⇒	⇒	⇒	Critical
	0	1	2	3	4	5
1 Turbulence	○	○	○	○	○	○
2 Deliberate Threats	○	○	○	○	○	○
3 External Pressures	○	○	○	○	○	○
4 Resource Limits	○	○	○	○	○	○
5 Sensitivity	○	○	○	○	○	○
6 Connectivity	○	○	○	○	○	○
7 Comments						

Capabilities:

Please rate the relative level of importance for each factor.	Don't Know	Minor Importance	⇒	⇒	⇒	Critical
	0	1	2	3	4	5
1 Flexibility in Sourcing	○	○	○	○	○	○
2 Flexibility in Manufacturing	○	○	○	○	○	○
3 Flexibility in Order Fulfillment	○	○	○	○	○	○
4 Capacity	○	○	○	○	○	○
5 Efficiency	○	○	○	○	○	○
6 Visibility	○	○	○	○	○	○
7 Adaptability	○	○	○	○	○	○
8 Anticipation	○	○	○	○	○	○
9 Recovery	○	○	○	○	○	○
10 Dispersion	○	○	○	○	○	○
11 Collaboration	○	○	○	○	○	○
12 Organization	○	○	○	○	○	○
13 Security	○	○	○	○	○	○
14 Financial Strength	○	○	○	○	○	○
15 Product Stewardship	○	○	○	○	○	○
16 Comments						

Appendix C: Confidence Interval for Weapon System #10; V1-V6

V1	Resilience Score														
Resondents	R1.1	R1.2	R1.3	R1.4	R1.5	R1.6	R1.7	R1.8	R1.9	R1.10	R1.11	R1.12	R1.13	R1.14	R1.15
A	0.216667	0.1875	0.260417	0.125	0.166667		0.229167	0.291667	0.229167	0.016667	0.138889	0.066667	0.104167	0.041667	0.229167
B	0.15	0.025	-0.01667		0.025	0.025	0.05625	0.0625	-0.125	0.025	0.025	-0.02857	0.05625	0.025	0.025
C	-0.05	-0.20833	-0.10417	-0.28125	-0.10417	-0.14286	-0.20833	-0.2	-0.0625	-0.125	-0.14063	-0.125	0	-0.125	-0.16667
D	0.067857	0.033482	0.142857	0.017857	0.142857	0.107143	0.117857	0.142857	0.067857	0.017857	0.12013	0.142857	0.16369	0.142857	0.142857
E	0.096429	0.071429	0.113095	0.096429	0.113095	-0.02232	0.113095	0.029762	0.196429	0.046429	0.105519	0.160714	0.196429	0.071429	0.146429
Mean	0.09619	0.021815	0.079107	-0.01049	0.06869	-0.00826	0.061607	0.065357	0.06119	-0.00381	0.049783	0.043333	0.104107	0.03119	0.075357
Std Dev	0.099479	0.144073	0.142174	0.186104	0.110522	0.104464	0.163392	0.179521	0.155335	0.068793	0.114961	0.12014	0.079376	0.098275	0.153603
tα/2	2.132	2.132	2.132	2.353	2.132	2.353	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132
Count	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5
Confidence Level(90.0%)															
+ Conf. Interval	0.19104	0.159183	0.214665	0.20846	0.174069	0.114643	0.217395	0.236524	0.209296	0.061781	0.159394	0.157882	0.179789	0.124892	0.221812
- Conf. Interval	0.001341	-0.11555	-0.05645	-0.22944	-0.03669	-0.13116	-0.09418	-0.10581	-0.08692	-0.0694	-0.05983	-0.07121	0.028426	-0.06251	-0.0711
Overage of Capabilities	**1***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
Underage of Capabilities	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Balanced Resilience	**28**
Overage of Capability	**2**
Underage of Capability	**0**

* 95% Confidence Level

V2	Resilience Score														
Respondents	R2.1	R2.2	R2.3	R2.4	R2.5	R2.6	R2.7	R2.8	R2.9	R2.10	R2.11	R2.12	R2.13	R2.14	R2.15
A	0.125	0.095833	0.16875	0.033333	0.075		0.1375	0.2	0.1375	-0.075	0.047222	-0.025	0.0125	-0.05	0.1375
B	0.275	0.15	0.108333		0.15	0.15	0.18125	0.1875	0	0.15	0.15	0.096429	0.18125	0.15	0.15
C	-0.1	-0.25833	-0.15417	-0.33125	-0.15417	-0.19286	-0.25833	-0.25	-0.1125	-0.175	-0.19063	-0.175	-0.05	-0.175	-0.21667
D	-0.0125	-0.04688	0.0625	-0.0625	0.0625	0.026786	0.0375	0.0625	-0.0125	-0.0625	0.039773	0.0625	0.083333	0.0625	0.0625
E	0.15	0.125	0.166667	0.15	0.166667	0.03125	0.166667	0.083333	0.25	0.1	0.159091	0.214286	0.25	0.125	0.2
Mean	0.0875	0.013125	0.070417	-0.0526	0.06	0.003795	0.052917	0.056667	0.0525	-0.0125	0.041092	0.034643	0.095417	0.0225	0.066667
Std Dev	0.146309	0.169839	0.133109	0.205081	0.128039	0.142981	0.182809	0.181969	0.141808	0.134048	0.140994	0.145235	0.121892	0.134745	0.165857
tα/2	2.132	2.132	2.132	2.353	2.132	2.353	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132
Count	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5
Confidence Level(90.0%)															
+ Conf. Interval	0.226999	0.17506	0.19733	0.188674	0.18208	0.172011	0.227218	0.230167	0.187708	0.115309	0.175524	0.173118	0.211636	0.150974	0.224805
- Conf. Interval	-0.052	-0.14881	-0.0565	-0.29388	-0.06208	-0.16442	-0.12138	-0.11683	-0.08271	-0.14031	-0.09334	-0.10383	-0.0208	-0.10597	-0.09147
Overage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Underage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Balanced Resilience	30
Overage of Capability	0
Underage of Capability	0

V3	Resilience Score														
Respondents	R3.1	R3.2	R3.3	R3.4	R3.5	R3.6	R3.7	R3.8	R3.9	R3.10	R3.11	R3.12	R3.13	R3.14	R3.15
A	0.008333	-0.02083	0.052083	-0.08333	-0.04167		0.020833	0.083333	0.020833	-0.19167	-0.06944	-0.14167	-0.10417	-0.16667	0.020833
B	0.145833	0.020833	-0.02083		0.020833	0.020833	0.052083	0.058333	-0.12917	0.020833	0.020833	-0.03274	0.052083	0.020833	0.020833
C	-0.175	-0.33333	-0.22917	-0.40625	-0.22917	-0.26786	-0.33333	-0.325	-0.1875	-0.25	-0.26563	-0.25	-0.125	-0.25	-0.29167
D	0.05	0.015625	0.125	0	0.125	0.089286	0.1	0.125	0.05	0	0.102273	0.125	0.145833	0.125	0.125
E	0.108333	0.083333	0.125	0.108333	0.125	-0.01042	0.125	0.041667	0.208333	0.058333	0.117424	0.172619	0.208333	0.083333	0.158333
Mean	0.0275	-0.04688	0.010417	-0.09531	-2.2E-17	-0.04204	-0.00708	-0.00333	-0.0075	-0.0725	-0.01891	-0.02536	0.035417	-0.0375	0.006667
Std Dev	0.124917	0.164455	0.146945	0.221647	0.146575	0.156197	0.186837	0.182536	0.156442	0.138557	0.156743	0.177376	0.147975	0.16298	0.177771
tα/2	2.132	2.132	2.132	2.353	2.132	2.353	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132
Count	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5
Confidence Level(90.0%)															
+ Conf. Interval	0.146603	0.109926	0.150523	0.165455	0.139754	0.141728	0.171058	0.170707	0.141661	0.059608	0.130541	0.143763	0.176505	0.117895	0.176164
- Conf. Interval	-0.0916	-0.20368	-0.12969	-0.35608	-0.13975	-0.2258	-0.18522	-0.17737	-0.15666	-0.20461	-0.16836	-0.19448	-0.10567	-0.19289	-0.16283
Overage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Underage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Balanced Resilience	30
Overage of Capability	0
Underage of Capability	0

V4	Resilience Score														
Respondents	R4.1	R4.2	R4.3	R4.4	R4.5	R4.6	R4.7	R4.8	R4.9	R4.10	R4.11	R4.12	R4.13	R4.14	R4.15
A	-0.075	-0.10417	-0.03125	-0.16667	-0.125		-0.0625	0	-0.0625	-0.275	-0.15278	-0.225	-0.1875	-0.25	-0.0625
B	0.166667	0.041667	0		0.041667	0.041667	0.072917	0.079167	-0.10833	0.041667	0.041667	-0.0119	0.072917	0.041667	0.041667
C	0.075	-0.08333	0.020833	-0.15625	0.020833	-0.01786	-0.08333	-0.075	0.0625	0	-0.01563	0	0.125	0	-0.04167
D	0.133333	0.098958	0.208333	0.083333	0.208333	0.172619	0.183333	0.208333	0.133333	0.083333	0.185606	0.208333	0.229167	0.208333	0.208333
E	0.066667	0.041667	0.083333	0.066667	0.083333	-0.05208	0.083333	0	0.166667	0.016667	0.075758	0.130952	0.166667	0.041667	0.116667
Mean	0.073333	-0.00104	0.05625	-0.04323	0.045833	0.036086	0.03875	0.0425	0.038333	-0.02667	0.026926	0.020476	0.08125	0.008333	0.0525
Std Dev	0.092684	0.088112	0.094786	0.136755	0.120041	0.098921	0.110923	0.107545	0.120163	0.142327	0.124384	0.165243	0.160768	0.165097	0.112485
tα/2	2.132	2.132	2.132	2.353	2.132	2.353	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132
Count	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5
Confidence Level(90.0%)															
+ Conf. Interval	0.161704	0.082969	0.146625	0.117663	0.160287	0.152467	0.14451	0.14504	0.152904	0.109036	0.14552	0.178029	0.234536	0.165746	0.159749
- Conf. Interval	-0.01504	-0.08505	-0.03412	-0.20412	-0.06862	-0.08029	-0.06701	-0.06004	-0.07624	-0.16237	-0.09167	-0.13708	-0.07204	-0.14908	-0.05475
Overage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Underage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Balanced Resilience	30
Overage of Capability	0
Underage of Capability	0

V5	Resilience Score														
Respondents	R5.1	R5.2	R5.3	R5.4	R5.5	R5.6	R5.7	R5.8	R5.9	R5.10	R5.11	R5.12	R5.13	R5.14	R5.15
A	-0.03929	-0.06845	0.004464	-0.13095	-0.08929		-0.02679	0.035714	-0.02679	-0.23929	-0.11706	-0.18929	-0.15179	-0.21429	-0.02679
B	0.25	0.125	0.083333		0.125	0.125	0.15625	0.1625	-0.025	0.125	0.125	0.071429	0.15625	0.125	0.125
C	-0.10556	-0.26389	-0.15972	-0.33681	-0.15972	-0.19841	-0.26389	-0.25556	-0.11806	-0.18056	-0.19618	-0.18056	-0.05556	-0.18056	-0.22222
D	-0.02813	-0.0625	0.046875	-0.07813	0.046875	0.011161	0.021875	0.046875	-0.02813	-0.07813	0.024148	0.046875	0.067708	0.046875	0.046875
E	0.011111	-0.01389	0.027778	0.011111	0.027778	-0.10764	0.027778	-0.05556	0.111111	-0.03889	0.020202	0.075397	0.111111	-0.01389	0.061111
Mean	0.017629	-0.05675	0.000546	-0.13369	-0.00987	-0.04247	-0.01695	-0.0132	-0.01737	-0.08237	-0.02878	-0.03523	0.025546	-0.04737	-0.0032
Std Dev	0.136515	0.139595	0.094131	0.147556	0.113567	0.140816	0.153771	0.156047	0.082018	0.140689	0.127147	0.137121	0.126695	0.146043	0.133796
tα/2	2.132	2.132	2.132	2.353	2.132	2.353	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132	2.132
Count	5	5	5	4	5	4	5	5	5	5	5	5	5	5	5
Confidence Level(90.0%)															
+ Conf. Interval	0.147791	0.076352	0.090296	0.039907	0.09841	0.123197	0.12966	0.13558	0.060829	0.05177	0.092451	0.095511	0.146344	0.091875	0.124365
- Conf. Interval	-0.11253	-0.18984	-0.0892	-0.30729	-0.11815	-0.20814	-0.16357	-0.16199	-0.09557	-0.21651	-0.15001	-0.16597	-0.09525	-0.18662	-0.13077
Overage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Underage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Balanced Resilience	30
Overage of Capability	0
Underage of Capability	0

V6	Resilience Score														
Respondents	R6.1	R6.2	R6.3	R6.4	R6.5	R6.6	R6.7	R6.8	R6.9	R6.10	R6.11	R6.12	R6.13	R6.14	R6.15
A	0.125	0.095833	0.16875	0.033333	0.075		0.1375	0.2	0.1375	-0.075	0.047222	-0.025	0.0125	-0.05	0.1375
B															
C	0	-0.15833	-0.05417	-0.23125	-0.05417	-0.09286	-0.15833	-0.15	-0.0125	-0.075	-0.09063	-0.075	0.05	-0.075	-0.11667
D	-0.11667	-0.15104	-0.04167	-0.16667	-0.04167	-0.07738	-0.06667	-0.04167	-0.11667	-0.16667	-0.06439	-0.04167	-0.02083	-0.04167	-0.04167
E	0.025	0	0.041667	0.025	0.041667	-0.09375	0.041667	-0.04167	0.125	-0.025	0.034091	0.089286	0.125	0	0.075
Mean	0.008333	-0.05339	0.028646	-0.0849	0.005208	-0.088	-0.01146	-0.00833	0.033333	-0.08542	-0.01843	-0.0131	0.041667	-0.04167	0.013542
Std Dev	0.099303	0.123379	0.102633	0.134364	0.063042	0.009204	0.128622	0.14798	0.120905	0.059073	0.069266	0.071349	0.062639	0.03118	0.114229
tα/2	2.353	2.353	2.353	2.353	2.353	2.92	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353	2.353
Count	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4
Confidence Level(90.0%)															
+ Conf. Interval	0.125163	0.09177	0.149393	0.073184	0.079377	-0.07248	0.139866	0.165765	0.175578	-0.01592	0.063065	0.070847	0.115361	-0.00498	0.147932
- Conf. Interval	-0.1085	-0.19854	-0.0921	-0.24298	-0.06896	-0.10351	-0.16278	-0.18243	-0.10891	-0.15492	-0.09992	-0.09704	-0.03203	-0.07835	-0.12085
Overage of Capabilities	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Underage of Capabilities	0	0	0	0	0	1**	0	0	0	1	0	0	0	1	0

Balanced Resilience	27
Overage of Capability	0
Underage of Capability	2

** 99% Confidence Level

Appendix D: Blue Dart

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Word Count: 506

Supply Chain Resilience

Supply chains throughout the world have become very complex and the USAF is no exception. The USAF's supply chain is one of the largest and most complex supply chains in the world. Due to the complexity of supply chains, organizations cannot rely on traditional risk management processes to protect them from unforeseen events. Supply chains must become more resilient. Supply chain resilience is defined many different ways. One definition from The Ohio State University's Center for Resilience is the *capacity of a system to survive, adapt, and grow in the face of unforeseen changes, even catastrophic incidents*.

In 2003, the Department of Defense (DoD) directed the implementation of modern supply chain practices for all DoD components with the release of DoD 4140.1-R, Supply Chain Material Management Regulation. Under this guidance, the Air Force created the Global Logistics Support Center (AFLGSC), which is responsible for improving supply chain processes within the Air Force. A collaboration effort between Air Force Institute of Technology and the AFGLSC enabled the research of supply chain resilience as a potential enhancement to Air Force traditional risk management processes.

Through literature, a supply chain resilience framework and measurement tool was identified to determine potential benefit to current Air Force supply chain management processes. Individual Air Force weapon system acquisition and sustainment programs were identified and segmented into two distinct phases of the weapon system

life cycle. The phases included; Phase I – concept through production, and Phase II – post production through disposal. This research analyzed data from individual weapon system program office self-assessments to compare the two phases, Phase I and Phase II. The self-assessments measured supply chain resilience in two factors, vulnerabilities and capabilities. In this research, vulnerabilities are defined as *fundamental factors that make an enterprise susceptible to disruptions* and capabilities are defined as *attributes that enable an enterprise to anticipate and overcome disruptions.*

The results of the study indicate that the supply chain resilience framework and measurement tool provides leadership with beneficial information to improve and assist in the management of their specific weapon system's supply chain, as well as, providing insight into changes required as weapon systems mature in the life cycle. First, the individual weapon system assessments provide leadership with an overall resilience score identifying vulnerabilities and capabilities in their supply chain. Once identified, corrective action required to achieve a balanced resilience can be taken. For example, an overage in vulnerabilities requires more attention to capabilities to reduce risk. However, an overage in capabilities provides managers an opportunity for resource reduction or moving resources to other high risk areas. Furthermore, the second benefit is the identification of measurable differences in the results of the Phase I and Phase II comparison. This information allows Air Force leadership to proactively manage risk by providing insight to specific supply chain vulnerabilities and capabilities between the different life cycle phases. This information assists Air Force leadership with strategic planning of weapon systems as they mature and progress through the life cycle.

Appendix E: Supply Chain Resilience Storyboard

Supply Chain Resilience: Assessing USAF Weapon System Life Cycle

SMSgt Brian Tobin
Advisor: Lt Col Timothy Pettit, PhD
Department of Operational Sciences (ENS)
Air Force Institute of Technology

INTRODUCTION

Supply chains throughout the world have become very complex and the USAF is no exception. Matter of fact, the USAF's supply chain is one of the largest and most complex supply chains in the world. Due to the complexity of supply chains, organizations cannot rely on traditional risk management processes to protect them from unforeseen events. Supply chains must become more resilient.

RESEARCH FOCUS

This research investigated the use of the Supply Chain Resilience Assessment and Management (SCRAM™) tool to measure identified vulnerabilities and capabilities within a supply chain.

IQ_1 - Will the SCRAM™ tool identify an overage of capabilities compared to vulnerabilities in selected weapon system at a current point in time in the weapon system life cycle?

IQ_2 - Will the SCRAM™ tool identify an underage of capabilities compared to vulnerabilities in selected weapon system at a current point in time in the weapon system life cycle?

IQ_3 - Do supply chain vulnerabilities and capabilities vary across the separate weapon system life cycle phases?

Supply Chain Resilience Framework

Vulnerabilities

- V1-Turbulence
- V2-Deliberate Threats
- V3-External Pressures
- V4-Resource Limits
- V5-Sensitivity
- V6-Connectivity

Capabilities

- C1-Flexibility in Sourcing
- C2-Flexibility in Manufacturing
- C3-Flexibility in Order Fulfillment
- C4-Capacity
- C5-Efficiency
- C6-Visibility
- C7-Adaptability
- C8-Anticipation
- C9-Recovery
- C10-Dispersion
- C11-Collaboration
- C12-Organization
- C13-Security
- C14-Financial Strength
- C15- Product Stewardship

Vulnerabilities – Fundamental factors that make an enterprise susceptible to disruptions

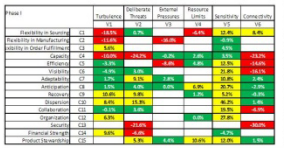
Capabilities – Attributes that enable an enterprise to anticipate and overcome disruptions

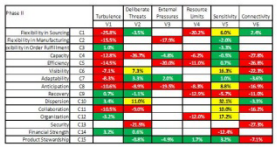
Weapon System Life Cycle with Research Phases

Concept Refinement	Technology Development	System Development & Demonstration	Production & Deployment	Operations & Support	Disposal

Phase I **Phase II**

Resilience Gaps





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CONTRIBUTIONS

- Measure organization's current level of resilience
- Provide insight to reducing risk by identifying an overage of vulnerabilities
- Provide insight for better utilizations of resources by identifying an overage of capabilities
- Provide strategic insight for planning as weapon systems progress from Phase I to Phase II

FUTURE RESEARCH

- Larger sample size of targeted weapon systems
- Identifying and researching more distinct phases of life cycle
- Cost analysis study

Factor Changes from Phase I to Phase II

Factor	Phase I to Phase II	Factor	Phase I to Phase II	Factor	Phase I to Phase II
V1		C1		C8	Decreased
V2		C2		C9	Decreased
V3	Increased	C3		C10	
V4		C4		C11	Decreased
V5		C5	Decreased	C12	
V6		C6		C13	
		C7	Decreased	C14	
				C15	

Indicates no significant difference

Sponsor:
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DEPARTMENT OF OPERATIONAL SCIENCES

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14. ABSTRACT

The Air Force Global Logistics Support Center (AFGLSC) is responsible for the United States Air Force's supply chain. One of the AFGLSC's responsibilities is to improve AF supply chain processes. This thesis investigates the subject of supply chain resilience and its potential impact for improving supply chain management. Through literature a supply chain resilience framework and measurement tool was identified for potential benefit to Air Force supply chain management. Air Force weapon systems were identified and segmented into two phases of the weapon system life cycle. This research analyzes data collected on supply chain resilience factors, vulnerabilities and capabilities, for each individual weapon system to determine if differences exist as weapon systems progress through the weapon system life cycle. The results indicate that the supply chain resilience framework and measurement tool provides Air Force leadership with beneficial information to improve and assist in the strategic management of their supply chain.

15. SUBJECT TERMS

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