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Supply Chain Risk Management for Army Air to Ground Missile Acquisition Programs

December 2025

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Thesis Advisors: Dr. Robert F. Mortlock, Professor
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Naval Postgraduate School

Prepared for the Naval Postgraduate School, Monterey, CA 93943

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ABSTRACT

The Department of Defense (DoD) faces significant challenges in managing supply chain risk due to increasing complexity, globalization, and limited visibility into sub-tier suppliers. This thesis addresses a critical gap in the DoD's ability to identify and mitigate vulnerabilities by applying a qualitative assessment framework to analyze supplier fragility and criticality within the Hellfire and Joint Air-to-Ground Missile (JAGM) programs. Using a combination of Sector-to-Sector, Tier-to-Tier (S2T2) analysis and Fragility and Criticality (FaC) assessment, the research integrates government, industry, and financial data to evaluate supplier dependencies and risks. Findings reveal that while prime contractors are generally stable, the greatest vulnerabilities exist among specialized, lower-tier suppliers exposed to global markets and limited substitutes. The study demonstrates that qualitative frameworks can help to increase supply chain visibility and inform risk mitigation, despite data limitations. Recommendations include integrating qualitative risk reviews into program management, strengthening supplier data reporting, and expanding the framework's application across DoD programs. These steps aim to improve supply chain resilience and support proactive risk management for future defense acquisition efforts.

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MAJ Sarah Hudgins is a logistics and Contracting Officer in the U.S. Army. She was commissioned through OCS in 2013 after receiving her Bachelor of Science from Portland State University. Her prior assignments include Distribution Platoon Leader, Maintenance Control Officer, Company XO, HSC Company Commander, Observer Coach Trainer, and Contingency Contracting Officer. After graduating from Naval Postgraduate School, she will report to Shaw AFB as a Contracting Officer in support of ARCENT.

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LIST OF ACRONYMS AND ABBREVIATIONS

BOM	Bill of Material
COO	Country of Origin
COR	Contracting Officer Representative
DIB	Defense Industrial Base
DoD	Department of Defense
FaC	Fragility and Criticality
JAGM	Joint Air to Ground Missile
NAICS	North American Industry Classification System
NDIS	National Defense Industrial Strategy
NDS	National Defense Strategy
OSD	The Office of the Secretary of Defense
PEO	Program Executive Office
SCD	Supply Chain Disruptions
SCM	Supply Chain Management
SCR	Supply Chain Resilience
SCRM	Supply Chain Risk Management
SCS	Supply Chain Security
S2T2	Sector-to-Sector, Tier-to-Tier
TAGM	Tactical Aviation and Ground Munitions

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EXECUTIVE SUMMARY

A. PURPOSE AND SCOPE

The Department of Defense (DoD) relies on a complex, multi-tiered global supply chain to procure and sustain critical defense systems. However, increasing supply chain complexity, globalization, and a lack of sub-tier visibility led to significant risks to operational readiness and national security. This thesis addresses these challenges by developing and applying a qualitative framework to assess supply chain risk, specifically focusing on supplier fragility and criticality within the Hellfire and Joint Air-to-Ground Missile (JAGM) programs for the U.S. Army Tactical Aviation and Ground Munitions (TAGM) Product Office. The research aims to improve the DoD's ability to identify, assess, and mitigate vulnerabilities in its supply base and to inform sourcing strategies and risk management practices applicable to other DoD acquisition programs.

B. METHODOLOGY

The research uses a qualitative approach, adapting two frameworks: the Sector-to-Sector, Tier-to-Tier (S2T2) analysis and the Fragility and Criticality (FaC) assessment. The S2T2 framework maps the structure of the Hellfire and JAGM supply chains, identifying major sectors and multi-tiered supplier relationships, while the FaC assessment evaluates suppliers' vulnerabilities and their importance to the system. Data sources include government and military publications, Army acquisition resources, defense industrial financial and contracting data, TAGM Product Office supplier lists, and open-source industry research. This study applies these frameworks to a selected sample of suppliers and manufacturers identified as contractors to the Hellfire and JAGM systems.

C. KEY FINDINGS

The following key findings explore themes within the supply base, including the distribution of suppliers' criticality and fragility, overseas sourcing and financial dependency, the effectiveness of the S2T2 and FaC frameworks, and broader applications

of these insights. Together, these themes provide a perspective on the DoD's supply chain challenges and opportunities.

1. Criticality and Fragility Distribution

Prime contractors exhibit high criticality due to their system-integration role but generally have lower fragility, which is supported by stable finances, diversified networks, and mature production capabilities. Their main vulnerabilities stem from heavy reliance on DoD contracts, making them more sensitive to budgetary changes.

Sub-tier suppliers in the study proved to be the most vulnerable, supplying specialized subcomponents and relying on sub-tier suppliers that are more exposed to global markets. This reduces their dependence on DoD revenue but increases the risks related to traceability and global disruptions.

The highest-risk points are at the lower tiers, where disruptions to specialized suppliers can have a large impact on missile production. These suppliers have extremely low reliance on DoD contracts but high reliance on global markets with limited substitutability.

2. Overseas Sourcing and Financial Dependency

Lower-tier suppliers are more likely to rely on global supply chains for subcomponents such as electronics and semiconductors. While prime contractors are financially dependent on DoD contracts (over 60% of revenue), lower-tier suppliers have diversified incomes but are less invested in defense-specific requirements. The supply chain's exposure to overseas sourcing increases risk, especially in lower tiers, while the upper tiers' high DoD dependency exposes them to risks tied to defense budget volatility.

3. Effectiveness of the S2T2 and FaC Frameworks

The S2T2 and FaC qualitative assessment frameworks provide insight into supplier relationships, sub-tier dependencies, and concentrated risk points. These tools enable earlier identification of high-risk suppliers, inform tailored mitigation strategies, and support acquisition decision-making. Data limitations, particularly limited transparency at lower tiers, result in qualitative judgments. The frameworks remain

valuable but would benefit from improved data reporting and the use of advanced analytical tools.

4. Broader Applicability

The framework is adaptable to other DoD programs and aligns with current DoD Supply Chain Risk Management (SCRM) and National Defense Industrial Strategy (NDIS) initiatives. It supports a repeatable, program-level risk assessment methodology.

D. CONCLUSION

The analysis demonstrates that risk in the Hellfire and JAGM supply chains is not evenly distributed. While prime contractors are critical and generally stable, the greatest fragility lies with specialized sub-tier suppliers exposed to global markets, with minimal dependence on defense requirements, but critical nodes that can impact mission production if disrupted. The study also finds that while qualitative assessments can effectively identify risk patterns, their precision and reliability are constrained by data availability. Nonetheless, qualitative frameworks, especially when paired with emerging technologies, can significantly enhance the DoD's supply chain visibility and risk management.

E. RECOMMENDATIONS

To strengthen SCRM within the TAGM Product Office, this study recommends incorporating qualitative risk reviews into program management routines, with particular attention to fragile and critical components such as electronics and specialized subcomponents. Engagement among contracting officers, program managers, and key suppliers should maintain awareness of supply chain vulnerabilities. Integrating SCRM considerations into bill of materials management and program updates, as well as including SCRM-focused terms and data reporting within contracts, will enhance proactive identification and mitigation of risks. It is also essential to improve data collection and transparency requirements throughout the supply base, particularly for lower-tier suppliers, to provide the information necessary for effective risk assessment and mitigation strategies.

From a broader DoD and policy perspective, improving supplier reporting requirements and expanding access to analytical SCRM tools will allow program officers to more reliably identify vulnerabilities and chokepoints. Establishing shared data platforms across programs and portfolios can facilitate the coordination of risk mitigation strategies and help address vulnerabilities across multiple acquisition efforts. Future research should focus on leveraging advanced data analytics and AI to automate risk identification and on encouraging data sharing and collaboration among government stakeholders to enhance overall supply chain resilience. These steps will provide a more robust foundation for program-level and DoD SCRM by ensuring that both immediate and long-term risks are managed effectively.

I. INTRODUCTION

The Department of Defense (DoD) faces challenges in managing resource acquisition in an increasingly complex, interconnected, and multi-tier global supply chain. Supply Chain Risk Management (SCRM) practices have become an important topic for identifying, assessing, and mitigating vulnerabilities across multi-tiered supply chains and manufacturers. Despite current priorities and efforts, the DoD continues to face significant challenges, particularly in maintaining visibility of sub-tier suppliers and understanding the fragility and criticality of their dependencies.

This thesis research addresses these challenges by proposing a framework to enhance the DoD's ability to assess and manage supply chain risks. The Sector-to-Sector, Tier-to-Tier (S2T2) analysis and the Fragility and Criticality (FaC) assessment are paramount for this study to explore and evaluate the relationships among the DoD, its suppliers, and their manufacturing procurement processes. Through a detailed examination of suppliers involved in the production of the Hellfire and Joint Air-to-Ground Missile (JAGM) systems, this research aims to develop a framework with recommendations for improving supply chain resilience and decision-making processes that may be used to assess other DoD acquisition programs.

This project aims to provide a detailed framework for understanding and mitigating supplier sourcing vulnerabilities by bridging the gap between qualitative and quantitative risk management methodologies. Using the Hellfire and JAGM missile systems as a case study, this study looks to provide practical recommendations to the U.S. Army Tactical Aviation and Ground Munitions (TAGM) office's oversight sourcing strategies. Additionally, it seeks to contribute academic research and information on a practical problem with limited existing academic research.

A. PROBLEM STATEMENT

DoD supply chains face significant practical challenges within multi-tiered supplier manufacturing and material sourcing. Suppliers often rely on interconnected global markets and supply chains, making it difficult to detect and trace vulnerabilities. While SCRM practices exist, the DoD often lacks visibility across the complex networks

of sub-tier suppliers. One particular concern is the fragility and criticality of suppliers' relationships with overseas material sourcing and manufacturing processes that can lead to disruptions in the Defense Industrial Base (DIB). These vulnerabilities create a gap in the DoD's risk management metrics, as disruptions at different tiers can severely impair the DoD's ability to maintain consistent production and meet national security objectives.

There is clear evidence that the DoD faces a critical SCRM challenge, as highlighted in recent government guidance and initiatives. The recently published *Supply Chain Risk Management for the Defense Acquisition System Guidebook* (DoD, 2025) emphasizes the importance of proactive decision-making, risk mitigation, and improved supply chain resiliency and security. Recent DoD SCRM priorities stemmed from former President Biden's executive order on securing America's supply chains following disruptions caused by the COVID-19 pandemic (Exec. Order No. 14017, 2021). This has been further amplified by ongoing geopolitical supply chain uncertainties. More specifically, Army acquisitions and procurement processes have made SCRM a top priority to safeguard the defense supply chain by increasing visibility and resilience, thereby mitigating threats to readiness and operational effectiveness.

Despite DoD acquisition control processes, a significant knowledge gap persists regarding how SCRM is understood and applied within the DoD. A RAND study highlights that traditional SCRM practices are focused on commercial sectors and may not adequately address the unique requirements of DoD supply chains (Lucas et al., 2024). Commercial SCRM focuses on quantifiable metrics such as profit and cost, which are less relevant to the DoD priorities of security and readiness capabilities. Lucas et al. (2024) also suggest that qualitative risk management processes are currently understudied and should be tailored to provide a more effective approach for defense-specific supply chains. Additionally, only limited academic research and peer-reviewed evidence are currently available to support DoD SCRM implementation practices.

This thesis aims to address gaps by developing an assessment framework of DoD supply chain suppliers. The framework leverages an S2T2 approach to analyze the complex relationships between the DoD, sub-tier suppliers, and their manufacturers. The research focuses on identified suppliers and manufacturers of the Hellfire and JAGM

missiles. Furthermore, this thesis incorporates an FaC assessment to qualitatively evaluate supplier vulnerabilities related to dependence on government-funded contracts and overseas sourcing. Finally, this research aims to provide recommendations for the TAGM Product Office and an initial framework for continued research to qualitatively assess sourcing with DoD SCRM.

B. RESEARCH QUESTIONS

This study answers the following research questions for the TAGM Product Office's air-to-ground missile portfolio:

1. Primary Research Question:

- How critical and fragile are suppliers and manufacturers within the Hellfire and JAGM missile systems?

2. Secondary Research Questions:

- To what extent are these suppliers relying on overseas sourcing, and to what extent are these businesses financially reliant on government-funded contracts?
- Can a qualitative assessment framework using S2T2 analysis and a FaC assessment improve sourcing strategies of critical sub-tier suppliers and manufacturers?
- How can these findings be used to provide recommendations for the TAGM Product Office?

C. BACKGROUND

Supply Chain Risk Management is used within the DoD to identify, assess, and mitigate vulnerabilities and threats across the product life cycle. The Office of the Assistant Secretary of Defense for Sustainment (OASD(S)) has recently established SCRM policies and guidance, including a taxonomy of 12 risk categories with 95 sub-risk categories (OASD(S), 2025). These categories provide a wide spectrum of potential Supply Chain Disruptions (SCD) that can affect DoD procurement strategies in Supply Chain Management (SCM), Supply Chain Resilience (SCR), and Supply Chain Security (SCS).

The 2023 National Defense Industrial Strategy (NDIS) identifies resilient supply chains as one of the four critical areas to align with the National Defense Strategy (NDS) to mitigate risks. Additionally, in response to former President Biden's Executive Order

No. 14017 (2021), the Office of the Secretary of Defense (OSD) had directed Program Executive Office's (PEOs) to identify suppliers and manufacturers of components and sub-components sourced from countries of origin with volatile supply chains, or geopolitically sensitive. Although initial data collection has begun, continued efforts focus on sequential steps to assess consequences and impacts, and to provide recommendations.

Historically, the DoD has relied on prime contractors to assess, implement, and manage SCRM practices. However, increased attention to SCRM has revealed that traditional industry practices lack supply chain oversight of lower-tier contractors. Additionally, the traditional SCRM practices used by contractors tend to focus on quantifiable metrics such as profit and cost, which are irrelevant in measuring DoD priorities (Lucas et al., 2024). Consequently, the DoD must adopt new approaches to effectively assess supply chains and risk management strategies to reduce reliance on vulnerable supply chains to improve resilience and security.

The Defense Industrial Base (DIB) plays an essential role in supporting and maintaining the DoD's mission by providing essential goods and services. Effective SCRM with the DIB is important to ensure operational readiness and SCR by mitigating vulnerabilities.

D. RESEARCH METHODOLOGY

This research assesses the DIB associated with the Hellfire and JAGM missile system through an S2T2 analysis, which provides a roadmap understanding of supply chain networks and risk indicators. Further, a FaC assessment is used to identify niches within the DIB to support risk management strategies. Paired with a sensitivity decision matrix, these tools help expose risk vulnerabilities to support informed decision-making.

E. SCOPE AND LIMITATIONS

The research scope focuses on SCRM within the DoD acquisition process, using S2T2 and FaC assessment. In this thesis, a selected sample population of suppliers and manufacturers identified as sourcing components from vulnerable supply chains are

analyzed. The sample population is specifically tied to the Hellfire and JAGM programs of the TAGM Product Office under the PEO Missiles and Space (PEO M&S).

Several limitations are acknowledged in this research. First, the research remains unclassified, using only open-source materials and findings to protect sensitive program information. Second, there is limited academic research available on this specific topic, which required using sources primarily from government documents, tools, publications, and commercial practices. Third, the narrow scope of research on a small population does not capture the full complexities of suppliers, manufacturers, and supply chain vulnerabilities. Fourth, the S2T2 and FaC assessments involve subjective judgments with no standardized qualitative indicators or criteria, which may lead to variability in the analysis. Finally, this research is designed to provide an initial framework that will require further research and tailored information for future practical applications.

F. DATA SOURCES

To conduct a comprehensive analysis of SCRM for suppliers and manufacturers of the Hellfire and JAGM missile systems, multiple data sources have been collected and integrated in this research. Primary data sources include government and military resources, Army acquisitions tools, defense industry data, TAGM Product Office contributions, and other academic or commercial sources. The diversity of these sources provides broader SCRM information to focus on specific tools and applications for Army acquisitions within DoD strategies.

1. Government and Military Resources

Essential data for this study were drawn from government documents, regulations, policies, publications, and reports. These documents guided research to understand and align with DoD and Army requirements and acquisition practices. Studies conducted by RAND and the GAO also provide findings on related problem sets, gaps, deficiencies, and discoveries.

2. Army Acquisition Academic Work

Sources from Army acquisitions training, educational materials, and academic studies were used to inform the S2T2 analysis and FaC assessments. Coursework paired with past thesis work from the Naval Postgraduate School and Department of Defense

Management (DDM) provides applicable examples of S2T2 and FaC models. Additionally, the Defense Acquisition University remains a major contributor and repository for training materials, tools, and resources within the defense acquisition workforce. These sources were used as the primary sources for this thesis research.

3. Industry-Based Data Sources

Market research on prime contractors, suppliers, and manufacturers was collected from available open-source websites and publications. This information is important in understanding industries' operations, capabilities, and strategies. Additional information on supplier relationships between the government and prime contractors was based on quantitative financial and government contractual data. To obtain this information, datasets were pulled from websites such as sam.gov and usspending.gov. These sources provided input to conduct the S2T2 analysis for a qualitative FaC assessment.

4. TAGM Product Office Contributions

The TAGM Product Office provided a list of suppliers and manufacturers involved in the Hellfire and JAGM missile systems who source components from countries with fragile supply chains. Additional contributions from the TAGM Product Office include Army-directed objectives, supporting policy, regulations, and current outputs. These sources ensure the research remains focused on the most impactful elements of the supply chain within the TAGM Product Office.

5. Industry Practices

Given the limited availability of academic research and government SCRM practices, this research reviewed sources from the DIB sectors and DoD guidance. These sources provided insight into SCRM practices, strategies, and responses to increasing awareness of supply chain vulnerabilities. Additionally, examination of these practices provided a broader context on supply chain challenges and informed tailored recommendations for defense acquisitions. Specifically, practices and responses from Lockheed Martin, one of the prime defense contractors of missile systems, were used to highlight adaptation and adherence to DoD SCRM policies and initiatives.

G. CHAPTER SUMMARY

This chapter introduced the purpose and scope of research on SCRM within the DoD and the growing importance of identifying and mitigating vulnerabilities across multi-tiered defense supply chains. The problem statement highlights the DoD's challenges in addressing supplier fragility and criticality of DIBs and the need for improving visibility of supplier dependencies. The research questions and methodology outlined how the study applies the S2T2 and FaC assessment to the Hellfire and JAGM programs. Additionally, this chapter summarizes the data sources, scope, and limitations of this study, which aims to serve as a qualitative framework to enhance understanding and assessment of SCRM practices within DoD acquisition.

The following chapters of this thesis are structured into five chapters. Chapter II presents a literature review examining existing research, policies, and frameworks related to SCRM in the DoD DIBs, a perspective on SCRM practices, and application of the S2T2 and FaC model. Chapter III provides details on research methodology, including the qualitative approach, data selection, and application of the FaC framework to assess supplier vulnerabilities within the TAGM Product Office. Chapter IV presents results and analysis of selected suppliers, identifying trends of fragility and criticality. Finally, Chapter V offers conclusions and recommendations for the TAGM Product Office and discusses implications of this study for DoD SCRM practices for future research.

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II. LITERATURE REVIEW

Supply Chain Risk Management has become an increasing priority within Army acquisition due to the complexities and growing vulnerabilities of global supply chains. The DoD faces ongoing challenges in maintaining visibility across multi-tiered suppliers that have exposed SCRM vulnerability due to potential disruptions and adversarial dependencies. These challenges have increased the urgency of prioritizing and understanding the effective SCRM practices needed within the DoD to mitigate risks and strengthen resilience.

This literature review examines existing frameworks, policies, and case studies to evaluate current approaches and identify gaps in the DoD's capacity to manage supply chain vulnerabilities. Insights are drawn from government documents, reports, academic research, and industry studies to provide a foundation for developing a qualitative framework to assess supplier fragility and criticality and inform acquisition decision-making processes.

This chapter addresses three key themes of this thesis. The first section examines how SCRM is defined and applied within the DoD. The second section reviews the existing frameworks of S2T2 analysis and FaC assessment. The third section considers SCRM practices used within the DIB. These sections provide the context for research methodology, analysis, and framework development to connect existing knowledge to findings of this thesis and academic contributions on this subject.

A. SUPPLY CHAIN RISK MANAGEMENT IN THE DOD

SCRM within the DoD is a process of identifying, assessing, and mitigating risks related to the security and resilience of supply chains that support national security and defense missions. The OASD(S) (2025) SCRM Taxonomy defines SCRM as "the systematic process of proactively identifying supply chain vulnerabilities, threats, and potential disruptions throughout the supply chain and implementing mitigation strategies to ensure the security, integrity, and uninterrupted flow of materials, products, and services" (pp. 1). While the DoD definition emphasizes mission assurance for continuous operational capabilities, commercial SCRM approaches are primarily focused on cost

efficiency, speed, and customer satisfaction. Cook (2022) highlights that the DoD operates within a niche industrial base with unique vulnerabilities not commonly seen in commercial supply chains.

The scope of SCRM within the DoD includes all phases of the acquisition life cycle, from research, design, and development to production, sustainment, and disposal. The DoD SCRM Guidebook (2025) emphasizes integration across all acquisitions, contracting, cybersecurity, and logistics functions to mitigate risk to mission-critical systems. Similarly, the National Defense Industrial Strategy (NDIS: DoD, 2023) describes SCRM as a foundational element of industrial base resilience and the interconnectivity of supply chains to national strategic objectives. From these perspectives, SCRM is an important mechanism for anticipating and responding to disruptions, counterfeit components, foreign dependencies, and adversarial infiltration.

The results of globalization over the past several decades have significantly increased the complexity and interdependence of supply chains. The drive for increased efficiency and reduced costs has created new vulnerabilities as defense contractors also rely on sourcing materials and components from the global market. These trends can be observed in the reliance on critical materials such as microelectronics, rare earth elements, and specialized manufacturing. Miller (2022) discusses this in his book, *Chip War*, explaining how globalized semiconductor production networks have created dependencies that constrain technological integrity and defense capabilities. Challenges observed within the DoD are evident in complex, multi-tiered supply networks that limit visibility into lower-tier suppliers and increase vulnerabilities to disruptions or potential exploitation. These pressures constitute the need for DoD to review SCRM frameworks and practices to prioritize visibility, security, and resilience over commercial priorities of short-term economic efficiencies.

In response to these challenges, the DoD has worked to standardize terminology and develop a taxonomy to improve consistency and interoperability (OASD(S), 2025). This effort directly addresses recommendations from prior studies and research that identified inconsistencies within SCRM policies and practices. For example, Sleeper et al. (2014) describe how the lack of shared definitions hinders efforts to assess industrial

base fragility and criticality. Additionally, Clark (2021) observes that DoD assessment tools often produce a wide range of results due to differing interpretations of concepts such as risk or criticality. The recently published DoD (2025) SCRM Guidebook addresses these recommendations by establishing a comprehensive taxonomy including 12 primary risk categories and 95 subcategories (OASD(S), 2025). Table 1 highlights the risk categories and subcategories used in this analysis (see Appendix A for the complete taxonomy). This framework can be seen as a major advancement in standardizing risk and enabling shared understanding across the defense enterprise.

Table 1. Relevant DoD SCRM Taxonomy Risk Categories and Subcategories

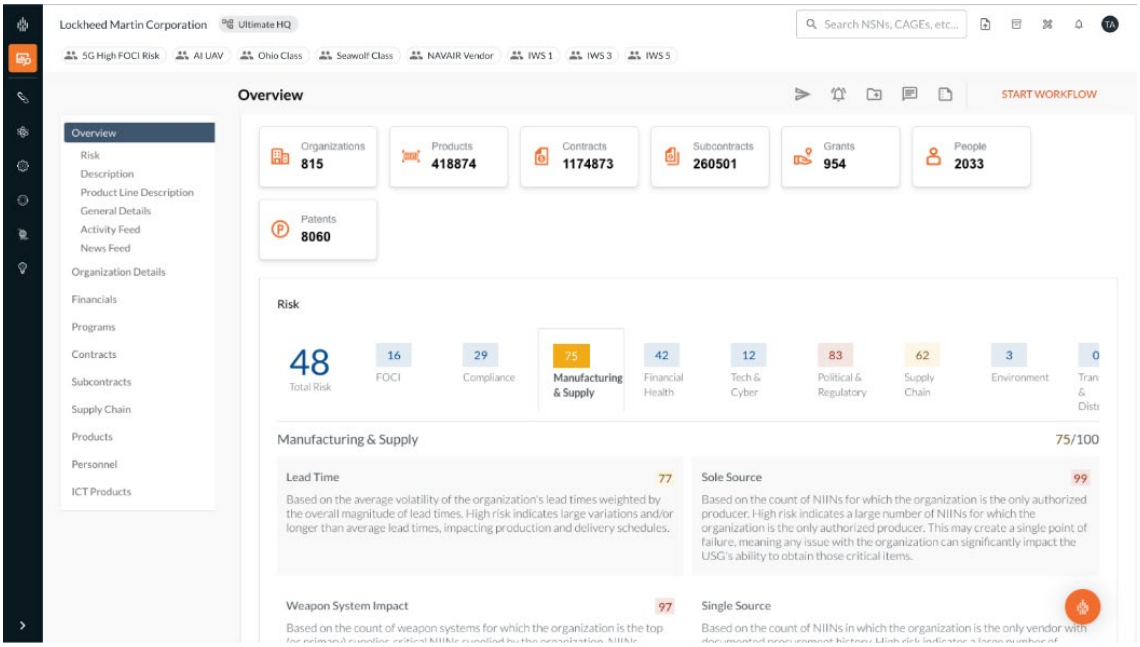
Risk		Sub Category
2	**Manufacturing an Supply**	
	2.1	Obsolescence / Diminishing Manufacturing Source and Material Shortage (DMSMS)
	2.2	Industrial Capability Limitations
	2.3	Industrial Capacity Limitations
	2.4	Sole Source Dependency
	2.5	Single Source Reliance
	2.6	Concentration
	2.7	Underdeveloped Product Pipeline
	2.8	Ineffective Third-Party Vendor Management
	2.9	Ineffective Outsourcing
	2.10	Throughput / Production Delay
	2.11	Spares Inventory Shortage
	2.12	Inventory Mismanagement
4	**Political**	
	4.1	Geopolitical Instability
	4.2	Internal Political Instability
	4.3	Interstate Conflict
	4.4	Failed State
	4.5	Territorial Dispute on Trade Route
	4.6	Trade War
	4.7	Watch List / Entity List
	4.8	Terrorism
	4.9	Governmental Corruption

Risk		Sub Category
6	**Financial**	
	6.1	Operational Efficiency
	6.2	Liquidity
	6.3	Solvency
	6.4	Bankruptcy
	6.5	Lack of Funding Sources
	6.6	Costs Overrun
	6.7	Dependence on Defense Contracts
	6.8	Cyclical Effect
8	**Product Quality & Design**	
	8.1	Product Characteristics Availability
	8.2	Lack of Provenance
	8.3	Non-Conforming Item or Product
	8.4	Counterfeit Item
	8.5	System / Item Performance Failure
	8.6	Unreported Supplier Recall
10	**Transportation and Distribution**	
	10.1	Change in Trade Policy Affecting Flow of Materials
	10.2	Transportation Network Disruption
	10.3	Poor Shipment and Delivery Accuracy (Item and Quantity)
	10.4	Poor Delivery Performance (Location and On-Time)
	10.5	Loss of Cargo
	10.6	Accident

The table identifies the most relevant risk categories and subcategories for this study adapted from the *DoD SCRM Taxonomy Version 2.0* (OASD(S), 2025).

In addition to the updated policy, the DoD has also begun implementing new tools to operationalize SCRM practices across acquisition programs. One of these tools is the recently awarded GSA Supply Chain Risk Illumination Professional Tool and Services (SCRIPTS) Blanket Purchase Agreement (Hale, 2025), which provides DoD agencies with advanced analytical capabilities to assess supplier networks and monitor real-time risks (see Figure 1). For example, PEO Missile and Space has contracted with Govini through the SCRIPTS BPA to map supply chain dependencies and identify choke points

and single-source supplies across all departments for multiple systems (Department of the Army, 2025). Programs like this illustrate DoD efforts to align policy, technology, and strategic objectives to strengthen defense supply chains.



Indicators of configured capabilities available through Ark's Defense Acquisition platform, illustrating tools available through the SCRIPS BPA. Reprinted from Ark.ai – Defense acquisition software (Govini, 2025)

Figure 1. Example Supply Chain Risk Illumination Tool

Despite improved policy and applied practices, peer-reviewed and academic literature addressing SCRM within the DoD remains limited. While there is a large amount of information available on commercial supply chain management that focuses on efficiency, cost reduction, and customer satisfaction, this differs from the DoD's mission-oriented priorities of assurance, security, and resilience. Lucas et al. (2024) argue that commercial SCRM frameworks are ill-suited for defense supply chains because they do not adequately capture DoD-specific constraints seen from limited DIBs, policy, and government-funded contracts.

Similarly, Cook (2022) highlights gaps between specific defense SCRM research that integrates with DIB fragilities and national security considerations. As a result, most information available comes from government reports, policies, studies, and industry publications rather than academic resources (Clark, 2021). This research contributes to the academic knowledge of a topic dominated by commercial research.

B. FRAMEWORK FOR SCRM

Effective SCRM within the DoD uses analytical frameworks to understand supplier relationships and identify vulnerabilities across the DIB. In recent years, the DoD has improved its efforts to strengthen visibility across multi-tiered suppliers and assess risks that could threaten defense programs and national security. The two central frameworks, Sector-to-Sector, Tier-to-Tier (S2T2) analysis and Fragility and Criticality (FaC) assessments, provide systematic approaches to understanding DIB. These frameworks offer insights into interdependencies and supply chain resilience to help guide decision-making in defense acquisition. This section reviews the development, purpose, and application of these frameworks to illustrate ongoing DoD initiatives to increase supply chain visibility and reduce vulnerabilities across the DIB.

1. Sector-to-Sector, Tier-to-Tier Analysis

The Sector-to-Sector, Tier-to-Tier (S2T2) framework is a tool for evaluating the DIB by mapping supply chain networks across industrial sectors and sub-tier suppliers (Cook, 2022). This approach is used to understand the relationships between suppliers and manufacturers, and their dependencies across multiple tiers. It serves as an early warning mechanism for the DoD to identify vulnerabilities, such as dependencies on foreign sources or single points of failure, that could threaten military readiness and supply chains' security.

The DoD recognized supply chain risks in the early 1990s and 2000s, as globalization, budgetary uncertainty, and high operational demands exposed fragility across DIB (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L] and Logistics and Office of the Deputy Assistant Secretary of Defense for Manufacturing, and Industrial Base Policy [ODASD(MIBP)], 2016). The DoD, in collaboration with the Bureau of Industry and Security, developed the S2T2 methodology to address concerns about the visibility of sub-tier suppliers (Cook, 2022). The process of mapping suppliers across sectors and tiers provided valuable insights into the health, diversity, and resilience of DIBs while exposing existing dependencies.

By the early 2010s, geopolitical concerns about Russia's resurgence and the rise of China created an increased demand to strengthen defense supply chains. In 2014, the

Obama Administration invoked the Defense Production Act to pressure companies to provide data for a DoD S2T2 assessment that emphasized sub-tier suppliers and their sourcing practices (Clark, 2021). The finding produced valuable insight into major vulnerabilities, including the risk of disruptions to overseas sourcing or limited supplier capabilities.

While the S2T2 framework provided valuable insight, it also had several efficiency limitations. The assessment process was very labor-intensive and time-consuming, making it difficult to maintain an accurate picture as supply chains and market conditions continued to evolve (Clark, 2021). These challenges initiated the need to refine the methodology into the current FaC assessment.

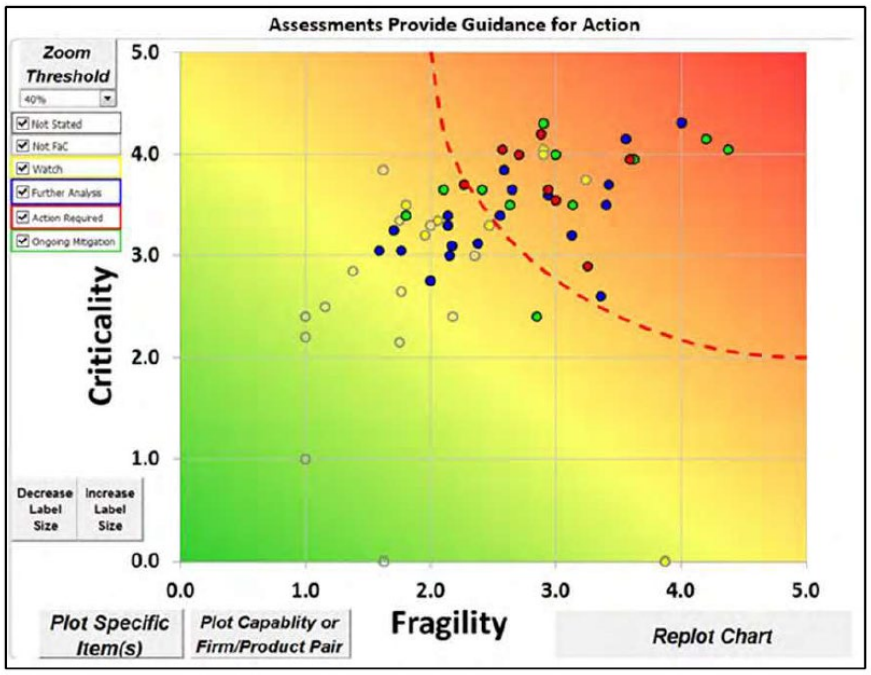
2. Fragility and Criticality Assessment

The Fragility and Criticality (FaC) assessment is the refined framework that evolved directly from the early contribution of the S2T2 analysis. It incorporates more technical rigor and is designed to evaluate the health and resilience of defense supply chains as a repeatable process (Sleeper et al., 2014). The FaC is a structured approach to support decision-making by applying a technical methodology to identify, assess, and prioritize vulnerabilities across the DIB (OUSD(AT&L) & ODASD(MIBP), 2018). It is tailored to evaluate the probability and consequences of risks between the two concepts. While fragility describes the likelihood that a product, sector, or supplier will experience disruption, criticality is the difficulty or consequence associated with replacing or recovering that capability if disrupted (Clark, 2021).

Fragility considers the health, diversity, and number of companies within a sector and their production capabilities (Sleeper et at., 2014). Additionally, it examines dependencies on defense contracts, foreign suppliers, and financial stability. Criticality focuses on the importance of a product or capability and the availability of substitutes or alternative sources (Clark, 2022). This assessment enables the DoD to evaluate both the probability and potential impact of supply chain disruptions, helping inform decision-making.

According to Sleeper et al. (2014), the FaC assessment follows an iterative process to evaluate DIB risks. The process starts by selecting a specific sector, subsector,

or program based on leadership priorities, prior assessments, and industrial base analysis. Once the scope is defined, data is collected and filtered to assess the prioritized risk. Next, the FaC assessment analyzes the sector's health and diversity, as well as key indicators of concern. Likewise, criticality metrics evaluate capability gaps with the presence or viability of alternatives. The assessment concludes with the FaC assessment risk matrix, which scores fragility and criticality to identify high-risk issues and develop mitigation strategies (see Figure 2). This process is iterative to enable the DoD to continuously refine understanding and inform strategic decisions.



Reprinted from Identifying and mitigating industrial base risk for the DoD: Results of a pilot study (Sleeper et al., 2014)

Figure 2. Example FaC Assessment Risk Matrix Heat Map

The FaC methodology was formally validated through a 2013 DoD pilot assessment of 10 defense sectors at varying life cycle stages (Sleeper et al., 2014). The pilot established a repeatable framework for assessing DIB health and provided valuable insight into supply chain dependencies, economic risk, and industrial concentration. Clark (2021) also referenced the FaC methodology as a model for evaluating national security risks associated with reliance on single-source or foreign suppliers. Additionally, the Annual Industrial Capabilities Reports to Congress continue to emphasize the FaC

framework as a key decision-support tool for assessing industrial resilience and a guide for policy development (OUSD(AL&T) & ODASD(MIBP), 2018).

Over time, the S2T2 and FaC assessments have been refined and are now referred to as simply the fragility and criticality (FaC) assessment. This has become the primary framework used by the DoD to evaluate the health and resilience of DIBs by incorporating mapping of supply chain relationships across sectors and tiers and applying quantitative evaluation criteria for risk and consequences. The FaC framework continues to evolve and could see significant improvements through the use of new technologies such as advanced data processing and large language models (Clark, 2021). Recent emphasis on SCRM and maturation of policy and practices within the DoD are increasing the depth of understanding of the DIB sectors and tiers, capabilities, and risk to inform decision-making.

The FaC methodology has been used in critical defense programs to understand vulnerabilities and dependencies in specific DIB. One example is Mortlock's (2024) case study on the hard-body armor industrial base that identified supply chain vulnerabilities and dependencies and assessed product capabilities. The analysis identified fragility within this industrial base sector due to its reliance on a small and specialized number of domestic manufacturers, which experienced fluctuating demand and dependency on limited suppliers and materials. Additional risks were identified in sourcing critical materials, such as ceramics and polyethylene, from foreign suppliers. The case emphasizes criticality of the DoD's reliance on a limited industrial base for mission-essential capabilities. The finding exposed vulnerabilities with limited production capabilities and the need to improve supply chain visibility, diversification, and long-term sustainment planning for critical defense sectors (Mortlock, 2024).

Further academic research conducted at the Naval Postgraduate School (NPS) has expanded the application of the S2T2 and FaC assessments relevant to this study and within defense supply chains. Dabar (2024) uses the S2T2 and FaC model to assess the fragility and criticality of material imports, local manufacturing capacity, and infrastructure of the shipbuilding sector in Djibouti. Similarly, Belko (2022) conducts an S2T2, FaC assessment of U.S. Navy auxiliary systems to analyze market dominance,

vendor lock-in, and risks of minimal vendor competition. These NPS studies demonstrate how FaC assessments can be utilized within defense acquisition to provide insights into sub-tier dependencies, single-source vulnerabilities, and supplier challenges. This research builds on these prior applications and adapts the S2T2 and FaC frameworks to evaluate supplier dependencies within the Hellfire and JAGM missile systems to further contribute to the application of SCRM research within the DoD.

C. SCRM PRACTICES WITHIN THE DEFENSE INDUSTRIAL BASE

The Defense Industrial Base has a critical role in the DoD's ability to design, produce, and sustain critical defense systems. The DIB encompasses a large number of prime contractors, sub-tier suppliers, and manufacturers working with the government to provide supplies and services for mission assurance and national security. Prime contractors are responsible for implementing SCRM practices that align with DoD policies. Recently, reviews of DoD SCRM policies have created new pressure and emphasis for contractors to ensure their practices align with DoD priorities to increase visibility, identify vulnerabilities, and ensure resilient production of mission-critical systems. The partnership between the DoD and the DIB operationalizes policy goals through an actionable process throughout the acquisition life cycle.

Large prime contractors such as Lockheed Martin, Raytheon, and Northrop Grumman play an important role in implementing the DoD's SCRM priorities throughout their extensive supplier and manufacturing networks. Lockheed Martin's presentation on multi-tier SCRM (Chang, 2024) is an example of how major defense contractors are working to improve practices to align with DoD's updated policies. This presentation describes Lockheed Martin's implementation plan to address SCRM through a multi-tier approach to increase visibility across sub-tier suppliers and manufacturers. The process involves mapping supplier relationships across tiers using the bills of material (BOMs), identifying high-risk choke points, and evaluating suppliers against indicators such as foreign dependency, financial stability, and production capacity (Chang, 2024)

Lockheed Martin's SCRM model emphasizes continuous monitoring, multi-source data integration, and quantitative risk scoring. This method closely follows the DoD FaC assessment methodology by using different tools, dashboards, and performance

metrics to quantify vulnerabilities and support-decision making (Chang, 2024). According to Chang (2024), Lockheed Martin incorporates financial health indicators, supplier dependency measures, and geopolitical risk assessments to identify and prioritize risks across multiple tiers of its supply chain. This illustrates a broad approach within the DIB to leverage data collection and continuous monitoring to strengthen SCRM practices rather than deliver definitive solutions to the DoD's multi-tier visibility challenges (Chang, 2024).

Although these tools have the potential to reduce gaps in the DoD SCRM, contractor information may be limited in DoD programs due to proprietary data. Additional limitations may lead to discrepancies, especially from smaller sub-tier suppliers who lack the resources to implement these detailed practices. This could result in a decrease in sub-tier suppliers' willingness to accept government contracts. These disparities highlight some of the challenges that the DoD and large contractors face in understanding the complexity of multi-tiered networks within globalized supply chains.

D. CHAPTER SUMMARY

The literature review demonstrates the importance of SCRM within the DoD to ensure mission success and national security in a complex, globalized environment. The review highlights several challenges associated with limited visibility into sub-tier suppliers, foreign dependencies, and DIB vulnerability, which constrain the DoD's ability to anticipate and mitigate disruptions effectively. The S2T2 and FaC frameworks have become an effective tool for evaluating supplier relationships, identifying risks, and prioritizing mitigation efforts within the DoD. Additionally, updated policies, analytical technologies, and industry practices work to strengthen SCRM capabilities. However, the literature also identifies gaps in current defense-specific research and SCRM operational application of multi-tier visibility and data accessibility at the product office. These insights provide the foundation for this research and FaC assessment of the Hellfire and JAGM missile systems. Chapter III describes the research methodology, data sources, and approach to applying these frameworks to an assessment of supplier dependencies within the TAGM Product Office.

III. METHODOLOGY

This chapter outlines the research design and methodology used to develop and apply a qualitative framework for assessing supply chain vulnerabilities within DoD acquisition programs. This study uses the FaC assessment models to analyze suppliers and manufacturers from the Hellfire and JAGM missile systems. The objective is to develop a qualitative decision-support framework that enables acquisition professionals to identify, prioritize, and mitigate vulnerabilities among critical sub-tier suppliers and fragile sourcing relationships within the industrial base.

This research uses a qualitative approach to examine supplier relationships, sourcing practices, and program dependencies that align with DoD SCRM policies and guidance. The FaC methodology applies qualitative indicators of fragility and criticality to a decision-support matrix to categorize and prioritize suppliers' risks and to recommend mitigation options based on the findings. In this study, fragility refers to the volatility and vulnerability of supply chains used to source missile components, while criticality measures a supplier's importance to the program and the degree to which the supplier relies on government-funded contracts. Together, this provides a framework for evaluating supplier vulnerabilities and for informing risk-based decision-making within DoD acquisition programs.

A. DATA SOURCES

This section describes data sources used and the process for integrating them into a qualitative FaC assessment for this research. Supporting data is collected from government publications, Army acquisition resources, defense industry contracting information, and inputs from the TAGM Product Office. The combination of these sources provides a basic understanding of supplier fragility and criticality within the Hellfire and JAGM missile supply chains.

1. Data Integration Approach

The research uses data from multiple sources to develop a qualitative assessment of supply chain fragility and criticality for suppliers and manufacturers working on the Hellfire and JAGM missile programs. The data integration approach combines these

primary and secondary sources to understand a more holistic perspective of supplier dependencies and vulnerabilities. The integration process aims to identify key indicators related to the fragility of foreign-sourced components and the criticality of suppliers to the DoD.

Collected data is cross-referenced with government datasets and policies to ensure the reliability of the findings. Government and military publications provide the foundational policy and framework context, while industry data offers insight into contractor and supplier operations. Additionally, inputs from the TAGM Product Office provide relevant program-specific information. The combination of these data sources contributes to the qualitative FaC methodology and construction of a decision support matrix.

2. Government and Military Publications

Recently updated government and military documents provide the foundation for understanding DoD SCM practices and policies. The DoD (2025) SCRM Guidebook and supplemental documents are key publications that define policy, terminology, taxonomy, and best practices for risk identification and mitigation. Additional reports produced by RAND (Lucas et al., 2024), GAO (2025), and House Armed Services Committee (2021) provide supporting information on risks within the DIBs. These publications and reports were examined to identify historical challenges and patterns to inform the FaC assessment.

3. Financial Data Collection

Data from USAspending.gov provided the quantitative contract information used to calculate supplier dependencies. This data collection process applied filters across all searches for each supplier, including fiscal year as FY 2024 and awarding agency as the Department of Defense. For prime awards and sub-awards, separate searches were conducted to capture both total DoD contract activities and missile-specific contract activities. Missile-related contract values were isolated by applying North American Industry Classification System (NAICS) codes associated with missile and related component manufacturing. These NAICS codes were selected based on relevance to the JAGM and Hellfire systems and are listed in Figure 3. The complete dataset (see

Appendix B) provides annual revenue comparisons, prime and subcontract award counts, contract dollar values, and dependency indicators for each supplier.

Figure 3. Missile-Relevant NAICS Codes

B. SAMPLE SELECTION

This research applies the FaC assessment model to a selected sample of suppliers supporting the TAGM Product Office to demonstrate the assessment process, its relevance to SCRM efforts, and value in providing informed recommendations. The

sample was selected from a list of suppliers identified by the TAGM office as part of the Hellfire and JAGM missile supply chains. As part of broader DoD SCRM initiatives, these suppliers were identified as procuring components from foreign sources. From this list, a subset of four suppliers was selected based on the availability of data from sam.gov and usaspending.gov to the JAGM and Hellfire programs. This targeted approach maintains a manageable research scope while still capturing representative vulnerabilities and dependencies within the broader industrial base.

C. RESEARCH DESIGN

This research design is an application of the structured FaC assessment, which evaluates suppliers' vulnerabilities associated with the Hellfire and JAGM missile programs. The goal is to ensure the FaC framework is applied consistently to all data inputs and aligned with DoD SCRM guidance. The qualitative approach provides an interpretive assessment of supplier and manufacturer risks related to dependencies on government contracts and reliance on fragile supply chains. By focusing on a limited set of suppliers and available open-source data, this research aims to apply the FaC model as a decision-support tool within an acquisition program office.

Fragility and criticality indicators were adapted from DoD SCRM guidance and tailored to the Hellfire and JAGM missile systems. Fragility considers vulnerabilities associated with foreign sourcing, while criticality evaluates the supplier's reliance on government programs. The information collected from data is applied to a matrix to illustrate suppliers across fragility and critical criteria. The qualitative assessment is used to interpret the suppliers' relative risk levels. By using the FaC approach, this framework for assessing supply chain vulnerabilities may be applied to other acquisition programs to analytically prioritize risk and recommend solutions.

D. LIMITATIONS AND ASSUMPTIONS

This research contains several limitations that affect the depth and precision of its findings. Data analysis relies on open-source, publicly available data that does not capture the full scope of the supplier networks or specific aspects of the Hellfire and JAGM missile program. Additionally, this research does not have visibility of the multi-

tier contractor supply network. The qualitative aspect of this assessment produces results that are subject to thesis research judgments. While these limitations may affect the precision of the data, the study provides useful insights for program managers to use a framework for informed decision-making.

This research makes several assumptions about data availability and accuracy from open-source information and government resources. It is assumed that contract data from government spending sites provides accurate information to represent contractual dependencies on government contracts and to supply chain networks. The study also assumes that supplier sourcing relationships remain consistent for program acquisition. While assumptions about industry and program-specific data do exist, the research offers an assessment framework that can be used to assess sourcing in SCRM.

E. CHAPTER SUMMARY

This chapter outlines the research methodology for applying the FaC framework to assess supplier vulnerabilities and dependencies within the Hellfire and JAGM missile systems. The study uses qualitative indicators of fragility and criticality to assess dependencies. It also identifies risks that impact the TAGM Product Office. The methodologies draw on information from government publications, industry sources, and academic research. Although the research is limited to open-source data, the framework offers insights into supply chain vulnerabilities that support decision-making. Chapter IV analyzes findings from the FaC assessment to identify trends and risks for the TAGM Product Office.

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IV. ANALYSIS

This study uses the S2T2 analysis to map the relationship of the Hellfire and JAGM supply networks and identify fragility and interdependencies across sectors and supplier tiers. The first step in the analysis is a description of the architecture of each weapon system's sector and tier networks. The second step is an assessment of key dependencies and potential points of failure. Finally, the foundation for the FaC assessment and scoring is presented. While complete supplier details are unavailable, this study uses open-source proxies and TAGM Product Office supplier listings to create a basic network representation.

A. HELLFIRE AND JAGM SYSTEM OVERVIEW

The AGM-114R Hellfire and AGM-179 JAGM are tactical missile systems with similar designs and overlapping supply chains. Developed to replace 12 Hellfire variants (Office of the Inspector General [OIG], 2017), the JAGM retains AGM-114R components, such as the propulsion system, warhead, guidance, and control sections (Program Executive Office, Missiles & Space [PEO MS], 2024); see Figure 4. This overlap improves on existing capabilities while minimizing cost and integration risks, resulting in shared sectors and tiers of the supply chain. However, the JAGM differs in its improved guidance section, which introduces a dual-mode semi-active laser, millimeter-wave radar seeker, and improved targeting capabilities (PEO MS, 2024). These similarities and differences shape the supplier network of the S2T2 analysis, where legacy dependencies persist, and modernization efforts can introduce new supply chain fragilities.

Figure 4. Hellfire Missile Sectors. Source: OIC (2017)

B. S2T2 ANALYSIS

The S2T2 analysis begins by mapping the structure of the Hellfire and JAGM supply chains using major subsystem groupings, referred to as sectors, and supplier levels within each sector, referred to as tiers. A basic work breakdown structure helps to identify the system's major sectors, and the levels of tiers illustrate the depth and complexity of the industrial ecosystem supporting missile development and production (DoD, 2022). This analysis focuses on the JAGM system because it is intended to replace the Hellfire, so the JAGM supply chain is applicable to both systems due to their shared components and industrial base.

1. Sector-to-Sector

The first step in the S2T2 approach is defining the major sectors that compose the JAGM missile system to understand how these sectors structure the system's industrial base. This study does not have access to the complete program work breakdown structure, so lower-level component details are aggregated under subsystem sectors identified in the JAGM architecture. Figure 5 depicts the high-level grouping of components two levels down from the overall JAGM system integration.

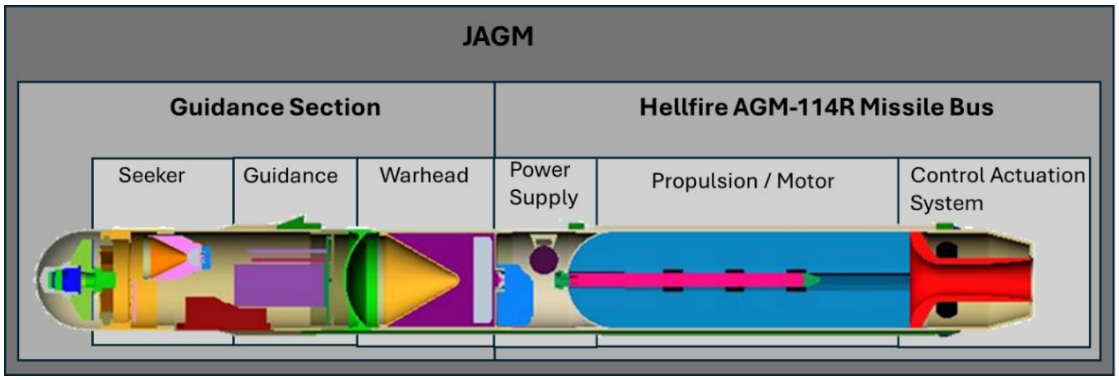


Figure 5. Major Sectors of the JAGM Missile System. Adapted from Common Missile Project Office (2003).

Within the guidance section sector, the primary components consist of the multi-mode seeker, the multi-purpose warhead, and the guidance system, which includes the SAL and MMW components. These components represent some of the new technology incorporated into the JAGM system, which draws on suppliers with missile manufacturing capabilities. The AGM-114R missile bus sector comprises the power

supply, propulsion, and motor, and the control actuation system. This sector reflects existing Hellfire missile components, current industrial relationships and manufacturing processes. The overlap between the Hellfire and JAGM in this sector means that disruptions or bottlenecks can affect the production of both systems.

Together, these sectors connect multiple tiers of suppliers across the industrial base for final missile integration. The delineation of sectors provides a framework for analyzing supply chain vulnerabilities and dependencies among the different suppliers. The FaC scoring criteria are then applied to evaluate sectors' capabilities and vulnerabilities to determine supply chain dependencies, risks, and trends across multiple sectors.

2. Tier-to-Tier

The next step in the S2T2 analysis is identifying supplier tiers that support each sector and illustrate the depth, distribution, and interdependencies of the industrial ecosystem. Lockheed Martin was awarded the production contract for both the JAGM and Hellfire and serves as the Tier 0 prime contractor responsible for overall system integration (Lockheed Martin, 2025). Due to limited open-source information used in the study, the analysis relies on assumptions of subcontractor responsibilities based on common supplier relationships and the TAGM Product Office supplier list, which is aggregated to approximate the lower-tier structure. Figure 6 provides a simplified representation of the JAGM and Hellfire supply chains to illustrate the flow from the prime contractor down to lower-tier suppliers. The flow of tiers demonstrates the complexity of this supply chain and potential vulnerabilities and dependencies of the specialized supply and manufacturing capabilities of the DIB.

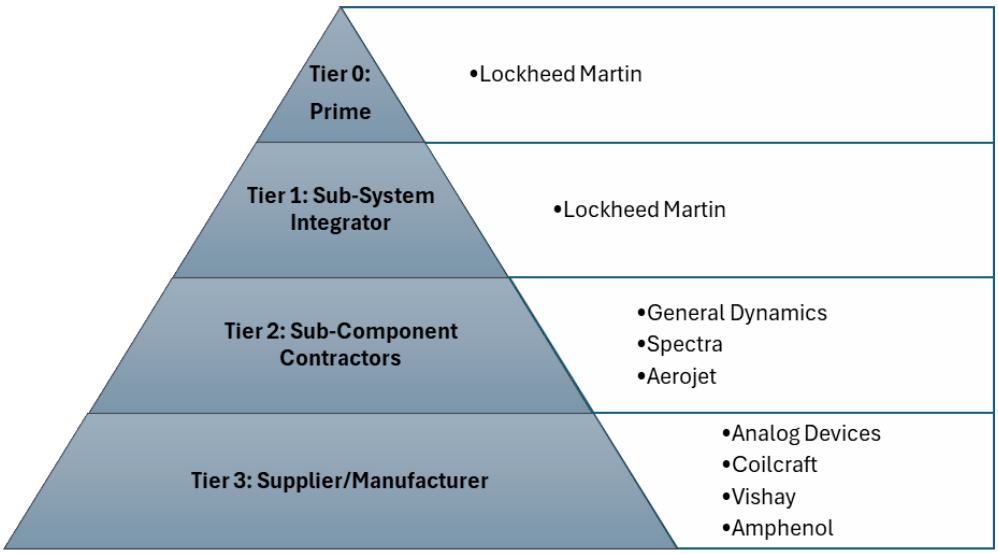


Figure 6. Sample of JAGM Supply Chain Tiers

Tier 0 represents the prime contractor responsible for total system integration of the JAGM program. In this case, Lockheed Martin oversees the performance of all sectors and tiers needed to deliver the final missile. This responsibility includes managing subcontractors' performance, enforcing system engineering requirements, and implementing SCRM activities (FAR 46.105, 2025). The prime contractor holds significant influence over the entire program execution, supply chain resilience, and industrial base stability.

Tier 1 suppliers include the major subsystem integrators responsible for the primary sectors identified in Figure 5, including the guidance section and AGM-114R missile bus. Although the missile bus has evolved over the years through multiple modification efforts by various contractors, Lockheed Martin maintains the current Tier 1 integrator for both of these sectors (Parsch, 2024). This demonstrates how large contractors can dominate a niche industrial base, leading to dependencies between the government and contractors.

Tier 2 suppliers provide major subsystem components to the Tier 1 integrators with products such as the warhead, seeker, and propulsion system for the missile system. These subcontractors manage complex technical manufacturing supply chain requirements. Suppliers and manufacturers at Tier 2 often have large networks that include well developed long-term relationships with prime contractors and lower-tier

subcontractors. The Tier 2 suppliers identified in Figure 6 includes several organizations with missile production capabilities known to have contributed to JAGM or Hellfire components.

Tier 3 suppliers comprise the upstream manufacturers that support Tier 2 through specialized materials, component fabrication, electronics, software, and raw materials (DoD, 2022). Although there are more tiers beyond Tier 3, this study defines any subcontractor below Tier 2 as a Tier 3 organization. The Tier 3 subcontractors represented in Figure 6 are drawn from the supplier source list provided by the TAGM Product Office.

The defined sectors and tiers establish the foundation for applying the S2T2 framework. This enables an assessment of network interactions across tiers and identifies potential vulnerabilities of dependencies and concentrations within the supply chain.

C. NETWORK DEPENDENCIES AND SUPPLY CHAIN VULNERABILITIES

Programs such as the JAGM and Hellfire missiles are part of a specialized segment of the defense industry, in which only a few long-standing contractors compete. Companies like Raytheon and Boeing have played roles in missile technology development, but Lockheed Martin serves as the primary contractor and system integrator for the major components used in both JAGM and Hellfire missiles. According to Lockheed Martin, more than 270 suppliers in 40 states contribute to its air-to-ground missile systems, with over 1.3 million parts processed monthly (Lockheed Martin, 2021). This large and complex network demonstrates the extensive geographic reach and logistical capacity involved in missile system production. Additionally, it suggests a degree of redundancy in manufacturing, fabrication, and skilled labor force capabilities.

However, lower-tier suppliers responsible for specialized subcomponents such as electronics tend to be smaller and harder to trace within specific defense programs. While this study cannot quantify the number of sub-tier contractors, it can be assumed that the industry relies on these niche suppliers and manufacturers. This creates network dependencies that are not always obvious within the prime contractor's apparently large network. These specialty suppliers and manufacturers are often interconnected with

global supply chains and are more vulnerable to disruptions that can affect the overall missile production. Although upper tiers have large network capabilities and capacities, the most critical vulnerabilities are often found deep within the DIB supply chains.

D. FAC ASSESSMENT

The FaC assessment evaluates contractors within the JAGM supply chain by analyzing quantitative financial data and qualitative risk indicators into a unified analytical framework. This assessment combines Fiscal Year (FY) 2024 financial data, DoD contract portfolio data, and qualitative DoD SCRM taxonomy factors to produce a ranked risk matrix for each supplier across all tiers. The complete assessment provides the basis to characterize each supplier's relative vulnerability and dependencies within the system.

1. Overview of Financial and Contracting Data

The baseline dataset for this assessment consists of each supplier's FY2024 financial profile and DoD contracting activity collected for USAspending.gov (n.d.). This quantitative data was collected using FY2024 defense obligations with applicable filters as described in Chapter III, Methods. Appendix B presents the full dataset, including annual revenue, total DoD obligations and related NAICS codes obligations for contract awards by contract dollar amount, and the number of contracts awarded. These metrics capture both prime and subcontract awards to provide a comprehensive view of each company's economic stability and relationship with the DoD. The financial indicators across all suppliers provide the following quantitative indicators (see Table 2) that form the foundation of the initial risk characterizations.

Table 2. Financial and Contractual Indicators. Adapted from Sleeper et al. (2014)

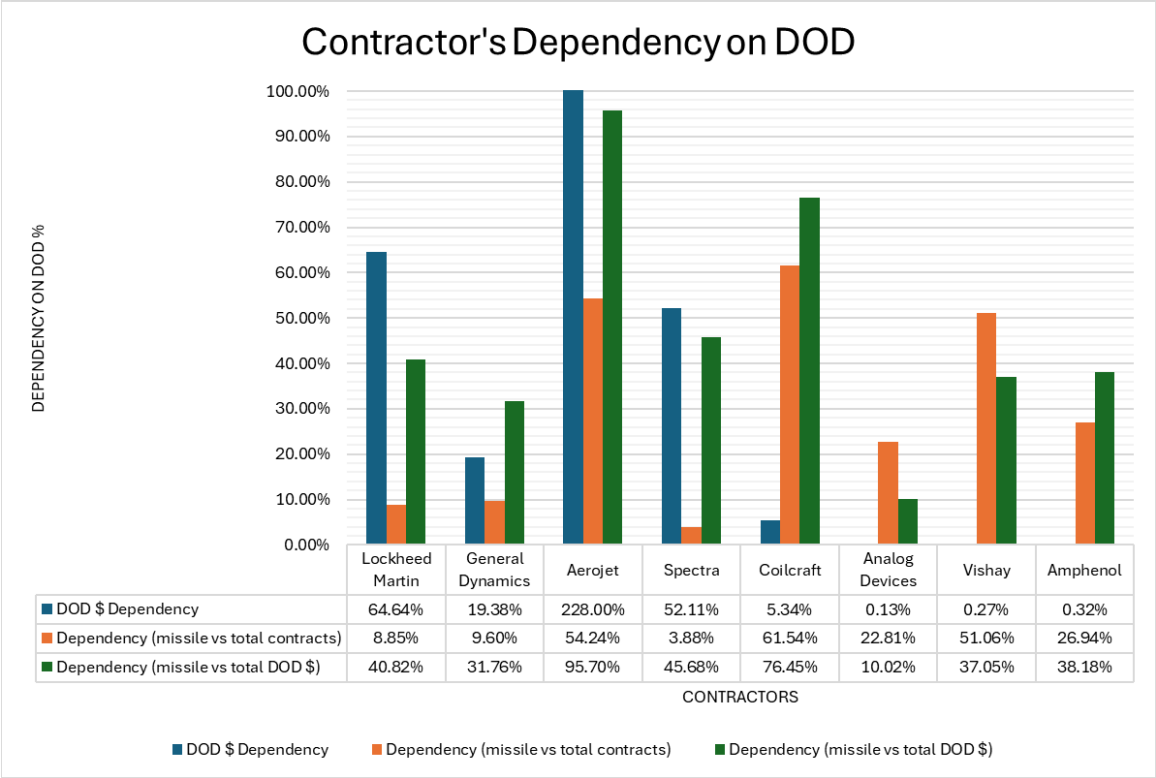
Indicator	Data	Purpose	Risk Relevance
DoD Revenue Dependency	Dollar amounts from all DoD awarded contract divided by annual revenue	Measures how financially dependent a supplier is on DoD spending	High values indicate vulnerability to DoD budget shifts or program reductions
Missile Segment Dependency	Dollar amount from missile related NAICS codes (prime + sub) divided by dollar amount of all DoD contracts	Assesses reliance on missile-related portfolios	High values show fragility to changes within the missile industrial base
Missile Contract Volume (Prime + Sub)	Total number of prime + sub awards under the NAICS code divided by number of total DoD awards	Shows depth of participation and business stability in missile supply chains	Low volume represents niche, specialized industries that are easier to disrupt
Supply Chain Foreign Exposure (CCO CN component count)	Number sub-components sourced by CN COO for Hellfire/JAGM	Counts components with foreign country of origin	Suppliers or components tied to global supply chain or manufacturing dependencies
Market Position / Revenue Scale	Annual revenue	Companies financial capacity to absorb disruption	Lower revenue is more fragile; larger revenue is more resilient but harder to diversify
Prime vs. Subcontractor Profile	Comparison of prime vs sub contract values and volumes	Shows where companies fall within tiered value chains	Prime heavy shows concentration of risk if replaced; sub heavy shows risk of upstream fragility

The calculated dependency ratios based on FY2024 financial and contracting data are shown in Figure 7. One notable outlier is the Tier 2 supplier, Aerojet, whose DoD obligations exceed its annual revenue. This anomaly is likely tied to the company's 2023 merger with L3Harris (Aerojet Rocketdyne Holdings, 2023). Aerojet's DoD obligations may have been reported differently depending on the post-merger financial reporting structure, creating inaccuracies in the dependency dataset of this study.

Excluding the Aerojet outlier, the results provide clear delineation between the tiers. Tier 1 and Tier 2 contractors show a higher overall reliance on DoD dollars, which indicates that defense manufacturing is central to their business strategy. On the other hand, Tier 3 suppliers display very low overall DoD dependencies, typically below 1%, which demonstrates greater diversification across commercial and other markets. Lower dependencies can reduce financial vulnerability caused by fluctuations in defense spending.

The missile-specific dependency metrics (orange and green bars) show that some lower-tier suppliers with niche capabilities rely more heavily on missile-related NAICS categories than other DoD contracts. While Tier 3 suppliers are generally less dependent

on DoD contracts, their influence in missile-related programs could create supply chain vulnerabilities through concentration risks. These distinctions provide important insights into fiscal resilience and mission-specific considerations for the FaC assessment.



This is an author-created graph depicting data collected on USAspending.gov (see Appendix B for the complete dataset).

Figure 7. Graph of Contractors' Financial Dependence

The S2T2 structure and financial dependency measures demonstrate the complexity of this specialized supply chain, where reliance on DoD funding varies across sectors and tiers. The S2T2 analysis identifies potential points of vulnerability where fiscal reliance and concentrated capability exist. These findings inform the following FaC assessment, which ranks each supplier's risk using the quantitative measures with qualitative factors based on the DoD's SCRM taxonomy.

2. Fragility and Criticality Factors

The FaC assessment provides a framework for this research to qualitatively evaluate risk in the JAGM supplier base. Quantitative data from the S2T2 analysis of each contractor's financial profile provided the rationale for the FaC approach to evaluate individual suppliers' influence on the supply chain in the missile defense sector. This

evaluation considers two key dimensions: fragility, which describes a supplier's vulnerability to disruption, and criticality, which indicates the degree to which the JAGM system relies on that supplier's capabilities. (Sleeper et al., 2014).

a. Fragility Factors

This study focuses on fragility factors related to financial conditions that could affect a supplier's reliability. These factors are based on the DoD SCRM taxonomy and have been adapted to fit the data and limitations of this analysis. These factors draw heavily on the FY2024 financial indicators and on assumed attributes of the missile manufacturing industrial base. Table 3 provides a breakdown of the fragility factors considered in the study, along with the relevant DoD SCRM taxonomy categories associated with each factor.

Table 3. Fragility Factors. Adapted from Sleeper et al. (2014) and Office of the Assistant Secretary of Defense for Sustainment (2025)

Fragility Factors	**Description**	**DoD SCRM Taxonomy Category**
Financial Health Risk	Does the supplier have sufficient liquidity and solvency to maintain stable operations and survive shock?	6.2 Liquidity 6.3 Solvency
Dependence on Defense Revenue	How vulnerable is the supplier to DoD budget shifts?	6.7 Dependence on Defense Contracts
Industrial Capacity Limitations	Does the supplier have sufficient production capacity and surge ability?	2.3 Industrial Capacity Limitations
Limited Funding Sources	Can the supplier reinvest, scale, or stabilize operations?	6.5 Lack of Funding Sources
Labor availability / Workforce Constraints	Does the supplier operate in a region or skill field where specialized labor is scarce?	9.2 Lack of Access to Capable Workforce

Essential considerations in assessing fragility include financial health indicators such as liquidity and solvency. First, suppliers with lower financial revenue may experience difficulties absorbing project cost changes from unexpected delays, fluctuating costs, or requirement quantity changes, which increase the risk of disruptions. Second, reliance on revenue from the DoD can greatly affect a supplier's financial resilience. The DoD SCRM taxonomy (OASD(S), 2025) describes high dependency "as 60% or greater reliance on DoD contracts," while "mixed dependence is defined as approximately 50% reliance on DoD contracts" (pp. 10). On the other hand, "low dependence on DoD contracts makes the DoD more susceptible to business decisions by

the company and/or trends in the broader market" (OASD(S), 2025, pp. 10). Third, a supplier's access to available funds may restrict its ability to modernize, expand, or adapt to changing environments. Finally, industrial capacity and workforce availability may limit the capacity of manufacturing and production, especially within companies operating in smaller or extremely specialized sectors typically found at lower tiers. These fragility factors identify supplier characteristics that make them more susceptible to disruption.

b. Criticality Factors

Criticality factors measure how the JAGM program would be affected if a supplier was disrupted. While fragility focuses on a supplier's internal weaknesses, criticality stresses the importance of a supplier's contributions to key missile components such as the warhead, seeker, and propulsion systems. Table 4 presents the criticality factors used in this study along with the relevant DoD SCRM taxonomy categories.

Table 4. Criticality Factors. Adapted from Sleeper et al. (2014) and Office of the Assistant Secretary of Defense for Sustainment (2025).

Criticality Factors	**Description**	**DoD SCRM Taxonomy Category**
Single-Source / Limited Competition Risk	Is the supplier providing a component with no or few alternative?	2.4 Single Source Reliance 2.6 Concentration
Specialized Industrial Capability	Does the supplier possess unique technical processes or qualifications that make replacement difficult?	2.2 Industrial Capability Limitations
Position within the Tiered Network	Will suppliers problems cause issues for other parts of the supply chain?	2.6 Concentration (network concentration)
Exposure to Trade Policy and Global Sourcing Disruptions	Is the supplier's component or material subject to trade policy change, potentially causing system-wide delays?	10.1 Change in Trade Policy 4.6 Trade War
Product Traceability / Provenance Risk	Is the supplier able to trace the history of components from point of origin through final production?	8.1 Product Characteristics Availability 8.2 Lack of Provenance

The first criticality factor addresses situations in which a company relies on a single or limited number of suppliers to meet program requirements. Since missile manufacturing is unique to DIBs, components typically have few suppliers and little competition in the upper tiers. Additionally, the unique capabilities of certain suppliers across all tiers may be more critical, as proprietary processes and technologies create

barriers to entry that can limit competition and alternative solutions. A supplier's position within the network can also affect its ability to source. Large primary contractors often have extensive networks to provide redundancy in sourcing, while smaller sub-tier suppliers can become bottlenecked by highly specialized inputs. Similar to other industries, DIBs are affected by global supply chain disruptions and trade policies. Although specific DoD procurement policies, such as the Berry Amendment, promote domestic industry, many materials and components, including raw materials and electronics like semiconductors, are subjected to global supply chains. The complexity of the DIBs' sectors and tiers within globalized supply chains becomes a major critical factor in component traceability. Prime contractors are responsible for ensuring SCRM implementation; however, traceability becomes extremely difficult at lower tiers.

Assessing both fragility and criticality factors enables this study to identify suppliers that may have consequential effects on the JAGM program, ranging from vulnerabilities to disruptions, as well as internal weaknesses. These factors form the basis of the risk matrix, in which each supplier is evaluated across the combined fragility and criticality spectrum to determine its overall supply chain risk level.

E. SUPPLIER RISK ASSESSMENT AND RISK MATRIX

The fragility and criticality factors provide the basis for evaluating each supplier's overall risk to the JAGM supply chain. This study uses a qualitative risk matrix, with each supplier ranked along the fragility and criticality axes. This approach allows for a comparison of suppliers' vulnerabilities by magnitude and potential impacts to missile production.

The risk matrix synthesizes the quantitative financial indicators, dependencies, and qualitative SCRM factors. Each supplier is assigned a fragility score based on indicators such as DoD dependency, financial resiliency, access to capital, and capacity limitations. Criticality scores reflect the suppliers' tier positions within the JAGM sector, the uniqueness of the capabilities they provide, the presence or absence of alternative sources, and their exposure to external market conditions.

1. Rish Matrix Categories

This matrix uses an ordinal scoring method because quantitative datasets are limited for all suppliers, especially for lower-tier companies. Suppliers are categorized into low, medium, or high levels for both fragility and criticality based on the S2T2 analysis and FaC assessment. This study incorporates DoD SCRM guidance and risk categories to meet initial assessments for the TAGM Product Office. Figure 8 shows the four quadrants of the matrix that represent risk types.

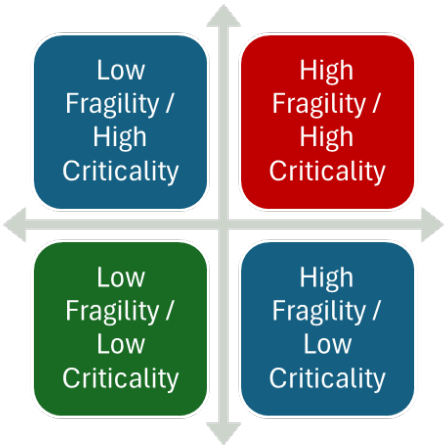


Figure 8. Risk Types Quadrants

- **High Fragility/High Criticality** (highest concern): Suppliers in this quadrant demonstrate internal vulnerabilities while also providing crucial components or services to the JAGM. Disruptions could generate significant production output challenges. These suppliers require the most SCRM monitoring and mitigation efforts.
- **Low Fragility/High Criticality** (essential but stable): These suppliers are critical to major missile sectors, but show strong financial health, diversification, or industrial capabilities. Stability reduces near-term risk, but the suppliers' importance to the program requires close oversight, especially in cases of limited competition or specialized component manufacturing.
- **High Fragility/Low Criticality** (vulnerable but replaceable): Suppliers in this quadrant exhibit financial or operational weaknesses, but their contributions can be sourced elsewhere in the industrial base. Although disruptions may cause inefficiencies, they are unlikely to threaten overall system production.
- **Low Fragility/Low Criticality** (lowest concern): These suppliers demonstrate stable financial conditions and operate in competitive sectors. This quadrant has very minimal risk to the overall system.

2. Results of the Risk Matrix

The risk matrix in Table 5 and Table 6, evaluates each company on the fragility and criticality factors. The matrix reflects qualitative assessment from earlier data, assumptions, and discussion within the analysis. The fragility and criticality risk matrix highlights patterns of risk distribution across the JAGM missile supply chain. While individual supplier scores vary, the results show tier-level clusters of the industrial base. These patterns help illustrate where the supply chain is resilient, weak, or has increased risk indicators.

Tier 1 integrators such as Lockheed Martin and General Dynamics remain the most resilient suppliers in the supply chain, with low fragility and criticality. Low fragility is driven by strong financial health, diversified revenue bases, and mature industrial capacity. Both suppliers show low criticality with robust supply networks. Lockheed Martin has some high and medium risks, primarily due to its reliance on the DoD for over 60% of its revenue. However, these higher scores do not elevate the overall risk and suggest that Tier 1 suppliers are unlikely to be primary points of failure.

Tier 2 subsystem suppliers show the highest risk within the JAGM supply chain. This group includes Aerojet and Spectra, which are suppliers of propulsion and energetic materials. High fragility is driven by limited funding sources dependent on DoD revenue and burdened by constrained production capacity. The medium criticality score reflects these suppliers' specialized manufacturing capabilities and the limited availability of competitive alternative components. These suppliers are some of the most vulnerable nodes in the supply chain. Their tier position significantly contributes to the elevated risk due to responsibilities and reliance on sub-tier supplier components, as well as the lower overall financial resources to scale or absorb disruptions. These factors indicate that Tier 2 suppliers are more sensitive to disruptions or demand fluctuations and may lack the operational resilience of prime contractors.

Tier 3 suppliers show low fragility but high criticality scores, largely due to specialized component concentrations and global market positioning. Fragility is generally low among these companies, which have strong financial health, diversified commercial markets, and stable workforces. This is primarily driven by their unique

production capabilities and exposure to global trade. High criticality scores result from specialized components with few substitutes. Additionally, high scores for traceability and provenance risk indicate limited visibility into upstream markets, increasing exposure to global market disturbances. However, despite their financial stability, Tier 3 suppliers serve as a crucial chokepoint in the JAGM supply chain because these essential nodes are most at risk of disruptions that affect multiple tiers.

Table 5. Supplier Risk Assessment for Fragility Factors

Fragility						
Company	**Financial Health Risk**	**Dependence on DOD Revenue**	**Industrial Capacity Limitations**	**Limited Funding Sources**	**Workforce Constraints**	**Overall Risk Level**
Lockheed Martin	LOW	HIGH	LOW	MEDIUM	MEDIUM	MEDIUM
General Dynamics	LOW	LOW	LOW	LOW	MEDIUM	LOW
Aerojet	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	HIGH
Spectra	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	HIGH
Coilcraft	MEDIUM	LOW	MEDIUM	LOW	MEDIUM	MEDIUM
Analog Devices	LOW	LOW	MEDIUM	LOW	MEDIUM	LOW
Vishay	LOW	LOW	MEDIUM	LOW	MEDIUM	LOW
Amphenol	LOW	LOW	MEDIUM	LOW	MEDIUM	LOW

Table 6. Supplier Risk Assessment for Criticality Factors

Criticality						
Company	Single-Source / Limited Competition	Specialized Industrial Capability	Position of Tiered Network	Exposure to Global Trade Disruptions	Traceability / Provenance Risk	Overall Risk Level
Lockheed Martin	MEDIUM	MEDIUM	LOW	LOW	LOW	LOW
General Dynamics	MEDIUM	LOW	LOW	LOW	LOW	LOW
Aerojet	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Spectra	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM
Coilcraft	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH
Analog Devices	HIGH	LOW	MEDIUM	HIGH	HIGH	MEDIUM
Vishay	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	HIGH
Amphenol	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	HIGH

Together, the fragility and criticality matrices provide the foundation for the FaC assessment, which visually maps supplier risk across both dimensions. Table 7 is a simple, non-weighted ordinal score measurement for each category with low = 1, medium = 2, and high = 3. A supplier's total fragility and total criticality scores were generated as a summation across all factors. These totals were then plotted in a heat map (Figure 9), with fragility on the x-axis and criticality on the y-axis. In this visualization, lower combined scores indicate more resilient but less critical suppliers, while higher scores indicate suppliers with more risk to the JAGM industrial base. This approach provides a comparative way to see how suppliers cluster by risk level and highlights which companies require greater monitoring of mitigation.

Table 7. Fragility and Criticality Scores

Company	Fragility	Criticality
Lockheed Martin	9	7
General Dynamics	6	6
Aerojet	13	12
Spectra	12	12
Coilcraft	8	14
Analog Devices	7	12
Vishay	7	13
Amphenol	7	13

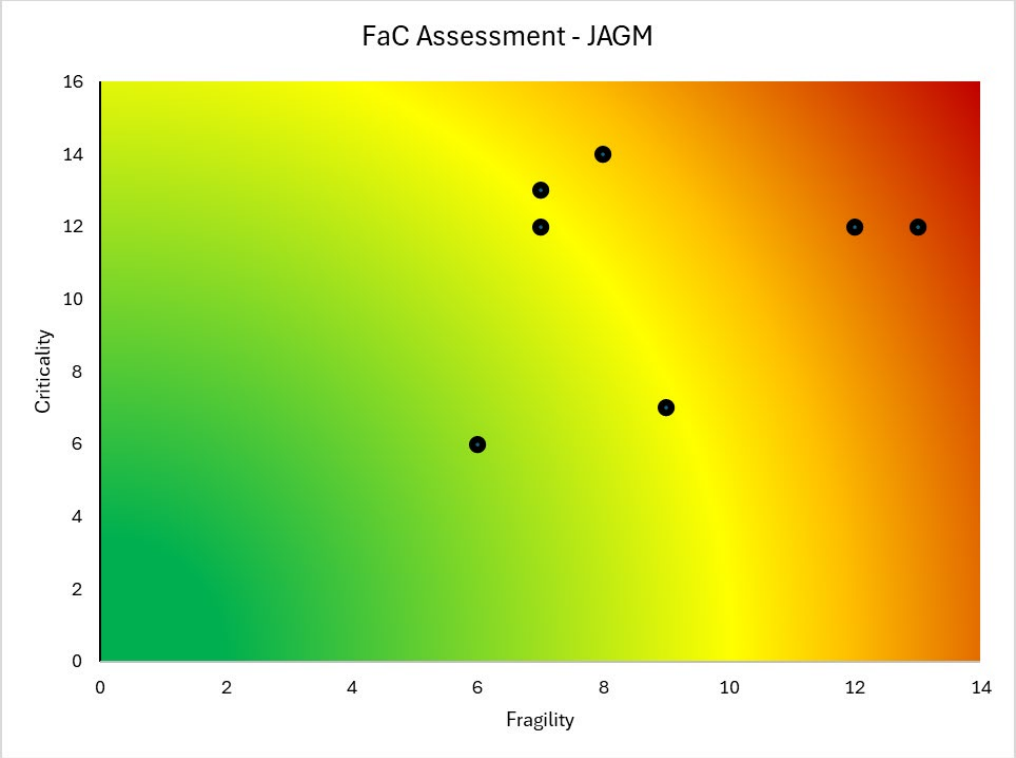


Figure 9. FaC Assessment Heat Map

F. ANALYSIS CONCLUSION

The results of the S2T2 analysis and FaC matrix reveal concentrated vulnerability below the prime contractor level. While the JAGM program benefits from strong Tier 1 integrators, its supporting industrial base shows fragility and criticality dependency concentration among component manufacturers.

Lockheed Martin's extensive supplier network provides dispersed supply networks that offer redundancy at higher tiers. However, the Tier 2 and Tier 3 suppliers frequently perform niche, highly specialized industrial processes with few alternatives. These specialized nodes can become single points of failure despite their operations within a large supply chain ecosystem. The limited competition in specialized industrial capabilities and reliance on specialized manufacturing and component sourcing lead to the highest risks.

The FaC matrix and heatmap reinforce these findings, demonstrating that fragility risks cluster in suppliers whose financial, workforce, or capacity constraints limit their ability to absorb or recover from disruptions. Criticality risks are highest among Tier 3

suppliers with unique industrial competencies or exposure to globalized supply chains. These companies display low fragility with high criticality, indicating that a disruption would have a greater downstream impact on the JAGM program than it would on internal instability.

Overall, this analysis shows that the JAGM supply chain's resilience depends less on the strength of its primary integrators and more on the vulnerabilities of specialized lower-tier suppliers that perform unique capabilities. The risks from these specialized workforces and reliance on global markets make it harder to monitor provenance risk and traceability. The next chapter provides recommendations for the JAGM supply chain related to policy, acquisition, and the industrial base.

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V. RECOMMENDATIONS AND CONCLUSION

This thesis identifies and assesses the fragility and criticality of suppliers and manufacturers for the Hellfire and JAGM systems, providing recommendations for the TAGM Product Office and information on DoD policies. Using S2T2 analysis and FaC methodologies, the research reveals risks at multiple supplier and manufacturer tiers, offering a limited view of the DIB supply chain supporting air-to-ground missile production. This chapter presents key findings that answer the research questions and offers recommendations.

A. KEY FINDINGS: PRIMARY RESEARCH QUESTION DISCUSSION

1. How critical and fragile are suppliers and manufacturers within the Hellfire and JAGM missile system?

The FaC assessment and risk matrix show that suppliers exhibit different levels of criticality and fragility depending on the sector or tier in which they operate in the missile system. Patterns based on the tier in which contractors operate reveal common risk factors within these clusters. Prime integrators such as Lockheed Martin carry system-level criticality because they rely on numerous sub-tier suppliers within the program supply chain. However, their internal fragility is relatively low due to strong financial health, large and diversified supply networks, and mature production infrastructure and capabilities. Their greatest vulnerability stems from their specialization in defense production, which results in a heavy reliance on DoD-funded contracts that tie their business strategy to DoD budgeting considerations.

In contrast, sub-tier suppliers are the most vulnerable within this ecosystem because their contributions often consist of specialized sub-components with limited substitutability. Their operations rely more on globalized markets than on defense-specific industries. While this reduces their dependence on DoD revenue, it also means they are less invested in defense-specific mission assurance, quality controls, and long-term supply responsiveness. Their exposure to globalized sourcing increases traceability and provenance risks, along with DoD vulnerabilities.

These findings show that criticality risks tend to increase with technical uniqueness and a lack of substitutes, while fragility tends to concentrate among lower-tier suppliers with limited capacity, global dependencies, and lower financial margins. The overall FaC assessment identifies the highest-risk points in the Hellfire and JAGM industrial base as specialized subcomponents, such as electronics, where disruptions would impose the greatest constraints on missile production.

B. KEY FINDINGS: SECONDARY RESEARCH QUESTIONS DISCUSSION

2. To what extent are these suppliers relying on overseas sourcing, and to what extent are these businesses financially reliant on government-funded contracts?

Data for this study were limited to open-source information and did not include details on foreign sourcing. However, the analysis allows several general observations and assumptions to be inferred about global exposure across the Hellfire and JAGM supply chains. All companies examined in this study are U.S.-based and vetted as responsible contractors for DoD programs. However, many subcomponents of the Hellfire and JAGM, such as semiconductors and capacitors, rely on upstream processing in multiple countries before assembly in the United States. While all suppliers have vulnerabilities stemming from these globalized markets, the greatest exposure to overseas sourcing observed in this study is in the lower tiers, where niche suppliers are more closely connected to commercial, globally distributed industries.

The analysis identifies that financial reliance on DoD funding shapes contractors' capabilities and risk. Prime contractors and major subsystem integrators typically depend more heavily on government-funded contracts. The DoD SCRM taxonomy (OASD(S), 2025) defines high reliance on the DoD as greater than 60% of a company's revenue coming from the DoD. This can lead to vulnerabilities associated with DoD budgetary changes that are closely tied to a company's primary revenue source. However, suppliers with balanced DoD revenue, around 50%, show "mixed dependency" (OASD(S), 2025, pp. 10)) and tend to offer a healthy balance of financial health, diversification, capabilities, and incentives to meet government performance requirements. The analysis (excluding Aerojet's data set, which is skewed) shows that mid-tier suppliers offer the best balance.

On the other end of the spectrum, the lower-tier suppliers show very low dependency on DoD revenue, falling below 5%. While this diversification in commercial sectors can strengthen their financial stability, it can also create vulnerabilities for the government. First, these companies may lack surge capacity, have minimal invested interest in defense programs, and be more exposed to global market fluctuations and trade disruptions. Additionally, they may lack the resources or skills to implement defense-specific quality systems and mission assurance processes, which can also lead to reduced transparency and more complex traceability efforts by the prime contractors.

Overall, these findings suggest that overseas sourcing risks increase as the supply chain extends downward to lower-tier contractors, while financial dependence on the DoD increases at the higher tiers.

3. Can a qualitative assessment framework using S2T2 analysis and a FaC assessment improve sourcing strategies of critical sub-tier suppliers and manufacturers?

Yes. A qualitative assessment framework using the S2T2 analysis and FaC assessment can improve sourcing strategies by giving program offices greater visibility into supplier relationships, sub-tier dependencies, and points of concentrated risk. The structured approach of the S2T2 clarifies how sectors and tiers interact, while the FaC framework highlights where suppliers may be fragile or operationally critical. These tools allow acquisition and sustainment personnel to identify high-risk sub-tier suppliers earlier and tailor mitigation strategies, such as alternative sourcing, stockpiling, or targeted industry engagement, based on each supplier's highest risks.

However, the effectiveness of a qualitative approach is constrained by the availability and accuracy of the data. Without comprehensive data, the assessment relies on assumptions that introduce bias and uncertainty, especially at the lower tiers. The challenges are that many sub-tier suppliers do not report detailed sourcing information and global supply chains often lack transparency below the first few tiers. This results in qualitative judgments that can help identify risk patterns but cannot always help accurately assess severity or probability.

Future improvements to the DoD SCRM tools can address this limitation by leveraging large-scale data repositories, integrating industry contributions, and using

advanced analytical tools. Potential tools to improve the accuracy of qualitative assessment include AI-enabled supplier mapping, automated risk assessments, and machine learning of commercial sourcing data. Use of these technologies can improve visibility and understanding of supplier networks, foreign sourcing risks, global market disruptions, and financial health indicators.

While advanced technology can assist analysts with large quantitative datasets, the S2T2 and FaC frameworks provide a useful structure for program offices to organize and interpret risks effectively using a qualitative approach. As the DoD continues to refine its SCRM practices, the use of qualitative methods with data-driven analytical tools can significantly strengthen sourcing monitoring at sub-tier levels that may be less visible under traditional practices alone.

4. How can these findings be used to provide recommendations for the TAGM Product Office?

The findings from this analysis, and the use of FaC assessment, support the TAGM Product Office by strengthening its awareness of supplier fragility and criticality across the Hellfire and JAGM supply base. While the TAGM office does not directly manage lower-tier suppliers, understanding where risks tend to cluster can help apply SCRM interpretations to the BOM to recognize parts that may require increased attention.

The FaC results also highlight the value of monitoring key indicators, including financial health, global sourcing exposure, dependency on DoD revenue, and specialized industrial capabilities. This framework provides a structured way to identify areas where disruptions may be likely to occur and where to focus mitigation efforts. While this assessment does not provide specific actions, it does offer a more informed basis for decision-making related to areas such as provisioning, forecasting, evaluating alternative sources, and coordinating with Army and OSD SCRM efforts.

C. RECOMMENDATIONS

Based on the key findings from this research, this section presents recommendations across several areas of practice and policy. It begins by assessing the methodological strengths and limitations to identify opportunities for refinement. It then

offers recommendations for applying this approach beyond the JAGM and Hellfire missile systems. Finally, it provides recommendations for the TAGM Product Office and broader DoD policies. Together, these recommendations provide actionable steps to improve supply chain insights, strengthen program-level decision-making, and inform future research and implementation efforts.

1. Methodology Strengths and Limitations

This thesis's methodology combined an S2T2 analysis and a FaC assessment to provide a framework for evaluating supplier risks within the JAGM and Hellfire supply chains. One of its strengths is its repeatable, tailorable approach to provide insights from available data. The assessment illustrates an overall picture of risk distributions across tiers and sectors through the lens of different indicators. Additionally, this method offers a flexible framework that can scale based on data availability, from high-level assessments of prime integrators to more detailed analyses of sub-tier components. This approach offers a versatile way for continual programmatic monitoring rather than a one-time assessment. Finally, the use of common language from the DoD SCRM taxonomy ensures shared understanding of risk factors and definitions.

The most significant constraint identified in this study was access to quality data, particularly at the sub-tier levels. The analysis relied on publicly available data, which introduces bias and uncertainty. Results are unable to capture the full operational capabilities of each supplier without validated sourcing data, traceability of country of origin, or capacity constraints. Finally, this study made several assumptions about risk behavior, DoD dependency, and supply chain positions. While these assumptions are based on SCRM literature, they lack vendor-specific, detailed assessments. This is particularly evident with mapping lower-tier suppliers and components with less visible traceability.

2. Methodological Improvements

Refined methodologies for this approach focus on improving the quality and structure of program-specific data. Incorporating collection sources such as the BOM, contractual requirements, contracting officer representative reports, and supplier information would improve the accuracy of risk assessments. Program offices would

benefit from formalizing SCRM reporting requirements and standardizing information collected by collaborating with internal stakeholders and contractors to ensure reportable data is consistent and actionable. Finally, integrating advanced technology and digital tools would improve the automation of data and analysis of supplier indicators for continuous monitoring.

3. Applicability beyond JAGM/Hellfire

This study focused on the JAGM and Hellfire missile supply chain; however, the methodology can be adopted by other PEO programs. Additionally, this methodology aligns with DoD SCRM initiatives and NDIS frameworks by providing a repeatable, program-level method for identifying and prioritizing supplier risks. The structured FaC approach can supplement existing tools and SCRM priorities by improving supply chain awareness to inform decision-making.

4. Recommendations for the TAGM Product Office

The findings of this study lead to several recommendations for the TAGM Product Office to improve SCRM practices. First, incorporating regular qualitative risk reviews into routine program management updates and BOM reviews could improve monitoring and mitigating strategies. Based on this study, the focus should be on components with high fragility and criticality, such as electronics and specialized subcomponents. Additionally, regular reports from the contracting officer representative or other stakeholders' engagements with prime contractors and key sub-tier suppliers should provide specific updates on the SCRM metrics. Contracting strategies should also include terms, conditions, or clauses that relate to SCRM policies, data reporting, and sourcing strategies. Finally, SCRM vulnerabilities should be tracked and discussed in management meetings to provide ongoing monitoring and control measures. Overall, SCRM needs to be a regular touch point to ensure awareness and enable a more proactive response to potential disruptions.

5. Broader DoD and Policy Recommendations

Current DoD SCRM initiatives provide a good baseline that could be strengthened by improving visibility and data sharing across programs for major DIBs. Improving supplier reporting requirements, especially for sub-tier suppliers and overseas

sourcing, would provide program offices with more reliable data to assess supply chain vulnerabilities. Additionally, expanding access to DoD SCRM tools and integrating these within program-level systems could improve mitigation strategies. Finally, integrating a shared data platform for suppliers and components would help identify systemic chokepoints and coordinate mitigating strategies across similar portfolios rather than programs responding to individual risk factors. While DoD-wide policy improvements can enhance collective processes for data compilation, access, and processing, PEO and program office policies must be tailored to specialized sectors while enforcing DoD policy.

D. CONCLUSION

This thesis examined the fragility and criticality of suppliers and manufacturers of the Hellfire and JAGM missile systems using an S2T2 analysis and FaC assessment. The study found that risk is not evenly distributed across the supply chain. Prime integrators are highly critical but generally stable, while the greatest fragility lies in specialized sub-tier suppliers supporting components with limited substitutes and greater exposure to globalized markets. Although data limitations constrained assessment depth, particularly at the lower tiers, the methodologies proved effective in revealing patterns of risk and generalizing about where disruption is likely to occur within missile production.

The research also demonstrated that qualitative assessments could have a meaningful impact on sourcing risk assessments within supply chains. Qualitative assessments, paired with emerging tools and technologies, can help expand visibility into DIBs. The study examines how limited data can still provide insights to inform mitigation strategies and decision-making through qualitative assessments.

Overall, this thesis demonstrates how a qualitative approach to evaluating supply chain vulnerabilities within missile programs can provide a tailored, repeatable, and scalable framework for generating insights and recommendations for the TAGM Product Office and broader DoD SCRM policies. The application of a structured risk identification methodology can help to increase supply chain visibility, anticipate vulnerabilities, and strengthen critical production to ensure the resilience of DIBs.

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APPENDIX A. TAXONOMY

Risk Category	Sub Category
1	**Regulatory and Compliance**
1.1	Pending Change in Statute, Policy, or Regulation
1.2	Market Monopoly or Oligopoly
1.3	Contractor Non-Compliance
1.4	Contractor Misconduct
1.5	Fraud (Procurement and Government)
1.6	Import / Export Violation
1.7	Securities and Exchange Commission (SEC) Enforcement Action
1.8	Suspension or Debarment
1.9	Use of Conflict Minerals and Raw Materials
1.10	Defective Pricing
1.11	Price Fixing
1.12	Insider Threat
1.13	Human Rights Violation
1.14	Trafficking in Persons
1.15	Worker Health & Safety Violation
2	**Manufacturing an Supply**
2.1	Obsolescence / Diminishing Manufacturing Source and Material Shortage (DMSMS)
2.2	Industrial Capability Limitations
2.3	Industrial Capacity Limitations
2.4	Sole Source Dependency
2.5	Single Source Reliance
2.6	Concentration
2.7	Underdeveloped Product Pipeline
2.8	Ineffective Third-Party Vendor Management
2.9	Ineffective Outsourcing
2.10	Throughput / Production Delay
2.11	Spares Inventory Shortage
2.12	Inventory Mismanagement
3	**Foreign Ownership, Control, or Influence (FOCI)**
3.1	Cross-Border Merger & Acquisition Regulations
3.2	Veiled Corporate Venture
3.3	Economic Espionage
3.4	Industrial Espionage
3.5	Industrial Sabotage
3.6	Foreign Intelligence Entity (FIE)
3.7	Foreign State-owned Enterprise
3.8	Nationalization
3.9	Executive Poaching

Risk	Sub Category
4	**Political**
4.1	Geopolitical Instability
4.2	Internal Political Instability
4.3	Interstate Conflict
4.4	Failed State
4.5	Territorial Dispute on Trade Route
4.6	Trade War
4.7	Watch List / Entity List
4.8	Terrorism
4.9	Governmental Corruption
5	**Technology and Cybersecurity**
5.1	Unsecure Network or System
5.2	Unauthorized Disclosure of Classified Information, Controlled Unclassified Information (CUI), or other Critical Information and Indicators (CII)
5.3	Malicious Cyber Intrusion, Insertion, or Tampering
5.4	Compromise of Critical Information Infrastructure (CII)
5.5	ICT Functional Obsolescence
5.6	ICT Implementation Failure
5.7	ICT Disruption or Degradation
5.8	Critical Hardware/Software Vulnerability
6	**Financial**
6.1	Operational Efficiency
6.2	Liquidity
6.3	Solvency
6.4	Bankruptcy
6.5	Lack of Funding Sources
6.6	Costs Overrun
6.7	Dependence on Defense Contracts
6.8	Cyclical Effect
7	**Economic**
7.1	Recession / Economic Slowdown
7.2	Economic Sanctions
7.3	Demand Shock
7.4	Price Volatility
7.5	Inflation
7.6	High Unemployment Rate

Risk	Sub Category
8	**Product Quality & Design**
8.1	Product Characteristics Availability
8.2	Lack of Provenance
8.3	Non-Conforming Item or Product
8.4	Counterfeit Item
8.5	System / Item Performance Failure
8.6	Unreported Supplier Recall
9	**Human Capital**
9.1	Labor Shortage
9.2	Lack of Access to Capable Workforce
9.3	Attrition of Critical Skills
9.4	Work Stoppage
9.5	Labor Dispute
9.6	Boycott, Consumer or Collective
10	**Transportation and Distribution**
10.1	Change in Trade Policy Affecting Flow of Materials
10.2	Transportation Network Disruption
10.3	Poor Shipment and Delivery Accuracy (Item and Quantity)
10.4	Poor Delivery Performance (Location and On-Time)
10.5	Loss of Cargo
10.6	Accident
11	**Environmental**
11.1	Natural Disaster
11.2	Extreme Weather Event
11.3	Water Scarcity
11.4	Pandemic
11.5	Chemical, Biological, Radiological, or Nuclear Incident
12	**Infrastructure**
12.1	Building / Facility Conditions
12.2	Transportation Infrastructure Conditions
12.3	Access to Utilities
12.4	Equipment Operability
12.5	Infrastructure Security

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APPENDIX B. DATA

FY24		Tier 1	Tier 2			Tier 3			
		Lockheed Martin	**General Dynamics**	**Aerojet**	**Spectra**	**Coilcraft**	**Analog Devices**	**Vishay**	**Amphenol**
	# Contracts COO CN (Hellfire/JAGM)	NA	NA	NA	NA	6/2	1/1	2/0	0/2
	FY 24 Annual Revenue	$71,060,000,000.00	$47,700,000,000.00	$2,350,000,000.00	$294,800,000.00	$58,000,000.00	$9,400,000,000.00	$2,940,000,000.00	$15,220,000,000.00
Prime Contract Awards	$ from Missile NAICS code	$18,750,000,000.00	$2,520,000,000.00	$137,520,000.00	$58,460,000.00	$0.00	$0.00	$0.00	$610.00
	# Contracts from Missile NAICS codes	630	198	7	9	0	0	0	1
	Total $ from DOD wide contracts	$45,930,000,000.00	$8,400,000,000.00	$197,900,000.00	$128,330,000.00	$0.00	$61,989.00	$41,534.00	$653,051.00
	Total # DOD contracts	7118	3607	25	404	0	2	3	43
Sub-Contract Awards	$ from Missile NAICS code	$0.00	$415,070,000.00	$4,990,000,000.00	$11,720,000.00	$2,370,000.00	$1,220,000.00	$2,950,000.00	$18,340,000.00
	# Contracts from Missile NAICS codes	0	214	57	8	16	13	24	96
	Total $ from DOD wide contracts	$0.00	$842,740,000.00	$5,160,000,000.00	$25,290,000.00	$3,100,000.00	$12,110,000.00	$7,920,000.00	$47,380,000.00
	Total # DOD contracts	0	683	93	34	26	55	44	317
Analysis	DOD $ Dependency	**64.64%**	**19.38%**	**228.00%**	**52.11%**	**5.34%**	**0.13%**	**0.27%**	**0.32%**
	Dependency on Missile vs Total # DOD Contracts	**8.85%**	**9.60%**	**54.24%**	**3.88%**	**61.54%**	**22.81%**	**51.06%**	**26.94%**
	Dependency on Missile vs Total $ DOD Contracts	**40.82%**	**31.76%**	**95.70%**	**45.68%**	**76.45%**	**10.02%**	**37.05%**	**38.18%**

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