



Strategies to Mitigate Obsolescence Risks for U.S. Army Precision Guided Missiles

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March 27, 2022



**Submitted to Defense Acquisition University
in partial fulfillment of the requirement of the
Senior Service College Fellowship**

Approval Page

Title: Strategies to Mitigate Obsolescence Risks for U.S. Army Precision Guided Missiles

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Organization: Senior Service College Fellowship

Date of Paper: 03/27/2022

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Abstract

Exponential technology growth comes with an undesirable consequence known as obsolescence. Given the advanced technology used in weapon systems, the Department of Defense (DoD) inevitably faces obsolescence challenges. A single obsolescence event can cost programs on average up to ~\$11.7 million (BY 2021) (Defense Standardization Program Office, 2021). Obsolescence is found across the life cycle to include development where 70% of electronic parts are obsolete before the system is even fielded (Sandborn, 2013).

The purpose of this qualitative study is to explore strategies to mitigate obsolescence risks for U.S. Army Precision Guided Missiles (PGM). A literature review was performed on obsolescence to include definitions, associated risks and available mitigation strategies for PGM. The term ‘obsolescence’ is often interchanged with Diminishing Manufacturing Sources and Material Shortages (DMSMS), as most DMSMS issues are caused by obsolescence (Defense Standardization Program Office, 2021). Different definitions of obsolescence exists in the literature which may lead to different interpretations among stakeholders. PGM systems were found to include a wide range of electronic and non-electronic items which carry associated obsolescence risk. Other factors identified that increased obsolescence risks for PGM included a diminishing industrial base and limited Government visibility into sub-tier suppliers (OSD A&S Industrial Policy, 2020). To mitigate these risks, an obsolescence management strategy framework was identified to include reactive, proactive, and strategic strategies (Sandborn, 2008). Available reactive and proactive strategies are presented (Romero Rojo, Roy, & Shehab, 2010), and strategic strategies described (Sandborn, 2008; Mandelbaum & Patterson, 2021). Concluding recommendations are proposed to improve PGM obsolescence management.

Chapter 1 - Introduction

“Obsolescence is the very hallmark of progress”, Henry Ford II, former CEO and Chair of Ford Motor Company (Sugrue, 1995, p. 125)

Background

Since the prediction by Intel’s former CEO, Gordon Moore, that transistor density would double every year for ten years (Moore, 1965), which later evolved into Moore’s law, exponential technology growth has impacted our lives. From the development of the global positioning system (GPS) to hypersonic missiles, technology continues to grow exponentially, and it was from this perspective that Henry Ford II recognized that obsolescence was really just a result of progress. Given the progress of advanced technology found in modern weapon systems, the Department of Defense (DoD) faces significant challenges due to obsolescence. However, instead of the term ‘obsolescence’, the Department of Defense (DoD) refers to it as, Diminishing Manufacturing Sources and Material Shortages (DMSMS). Both terms are commonly used interchangeably, as obsolescence drives most DMSMS issues (Defense Standardization Program Office, 2021). However, though not common, there can be situations when obsolescence exists without resulting in a DMSMS issue. Note that the particular DMSMS information included in this paper is relevant for the discussion of obsolescence. The definition of obsolescence and the relationship of obsolescence to DMSMS is addressed further in the literature review and findings.

Obsolescence occurs throughout the DoD to include U.S. Army Precision Guided Munitions (PGM) programs and can result in significant impacts to programs if not managed. A U.S. Department of Commerce survey conducted across the DoD in 2014 captured the average

costs for implementing various DMSMS resolutions by program. The survey reported that the redesign of major items within a weapon system, annotated in Table 1 as “Redesign – complex/system replacement”, had an average cost in base year 2021 dollars of \$11.652M (Defense Standardization Program Office, 2021, p. 142).

Table 1. Average Cost Associated with Implementing Each DMSMS Resolution Option (Defense Standardization Program Office, 2021, p. 142)

Resolution option	Average ^a
Approved item	\$1,165
LON buy	\$5,928
Simple substitute	\$14,247
Complex substitute	\$28,779
Extension of production or support	\$28,850
Repair, refurbishment, or reclamation	\$73,637
Development of a new item or source	\$742,333
Redesign—NHA	\$1,237,793
Redesign—complex/system replacement	\$11,652,368

^a Resolution costs adjusted for inflation using a factor of 1.8% per “National Defense Budget Estimates for FY 2016—Office of the Under Secretary for Defense (Comptroller),” Table 5-2: Pay and Inflation Rate Assumptions—Outlays, 54 and then adjusted using the 2021 DoD Greenbook, Column: Total DoD Excluding Medical, Table 5-4: Department of Defense Deflators—Total Obligation Authority by Public Law Title (Base Year = 2021).

In addition to obsolescence impacts on individual DoD programs, impacts across multiple programs that share similar technologies or components also occur. A recent example in the FY21 Omnibus Reprogramming describes that the U.S. Air Force was required to initiate a \$2B life-of-type buy (LTB) for a processor due to an unforeseen production facility closure. A LTB is a “one-time procurement...for the total future requirement of an item that is no longer expected to be produced” (OSD A&S, 2019, p. 46). Failure to procure a sufficient quantity of processors through a LTB would significantly increase risks across multiple DoD programs until a replacement processor becomes available in approximately four years (DoD Comptroller, 2021).

Obsolescence is also normally highlighted as impacting programs during the sustainment of DoD weapon systems. For example, the U.S. Government Accounting Office (GAO) highlighted in a 2020 report a decline in mission capable rates for selected Air Force, Navy, and Marine Corps aircraft which listed parts obsolescence as a contributing factor for more than 40% of the platforms (U.S. Government Accountability Office, 2020). However, obsolescence also impacts programs during the development and production phases. Sandborn (2013) observed that for sustainment-dominated systems, defined as systems where the sustainment costs dominate the total life cycle costs, more than 70% of electronic parts used during development are obsolete before the system is even fielded. Additionally, as obsolescence occurs across the life cycle of a weapon system, various stakeholder communities are involved in obsolescence management (Sandborn, 2013).

Sustainment-dominated systems, such as PGMs, have been highly impacted by electronic parts obsolescence because there is no control over their supply chains due to relatively low production volumes (Sandborn, 2013); and concerns with the U.S. defense industrial base are continuing to increase. In 2017, the President signed Executive Order 13806, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*, requiring a comprehensive review of materiel, raw materials, other goods, and manufacturing capabilities essential to national security. In 2021, the President signed Executive Order 14017, *America's Supply Chains*, which directed the Secretary of Defense to submit a report on the defense industrial base and civilian supply chains, and to identify areas where supply chains are dependent upon competitor nations.

During this period of increasing industrial base concerns and to improve management of obsolescence affecting DoD weapon systems, the Undersecretary of Defense for Acquisition and

Sustainment (USD (A&S)) released a DoD Instruction (DoDI) 4245.15, *Diminishing Manufacturing Sources and Material Shortages (DMSMS) Management*, in 2020 establishing policy to “implement risk-based, proactive DMSMS management throughout the life cycle of all DoD items” (p. 3).

Statement of Purpose

The purpose of this qualitative study is to explore strategies to mitigate obsolescence risks for U.S. Army Precision Guided Missiles (PGM).

Research Questions

1. What is obsolescence?
2. What obsolescence risks are associated with U.S. Army PGM?
3. What obsolescence management strategies are available to mitigate PGM obsolescence risks?

Conceptual Framework

Obsolescence mitigation strategies applicable to U.S. Army PGMs are researched to inform the development of a risk-based, proactive obsolescence management strategy. This research will review the definition of obsolescence, obsolescence risks associated with PGMs, and a review of management strategies to include reactive, proactive and strategic to mitigate obsolescence risks.

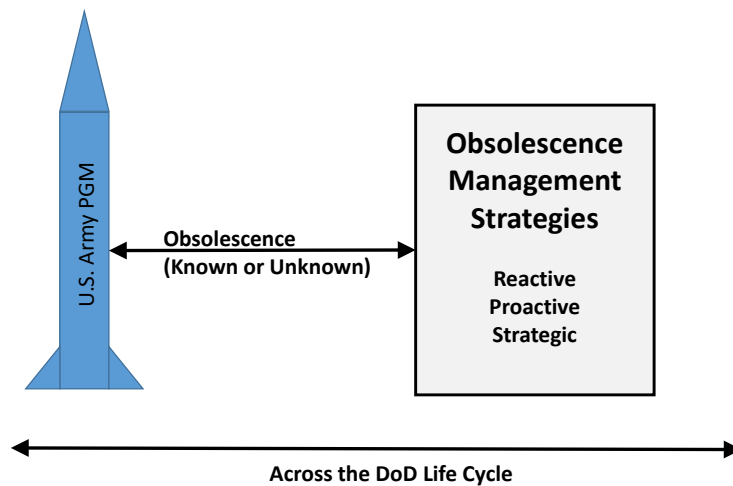


Figure 1. Obsolescence Mitigation Strategies Conceptual Framework

Significance of This Research

Obsolescence management across the life cycle is becoming increasingly important due to increases in Service Life Extension Programs (SLEP), increases in supply chain risks, and accelerating technology life cycles (DMSMS Lead, Defense Standardization Program Office, 2015). This study investigates how to help PGM teams implement risk-based, proactive obsolescence management. Additionally, DoD policy requires program offices to plan for and manage obsolescence.

DoD Instruction 4245.15 (2020) states that it is the DoD policy to:

- a. Establish and implement risk-based, proactive DMSMS management throughout the lifecycle of all DoD items.
- b. Evaluate all DoD system designs and redesigns for potential DMSMS issues that could arise during the life cycle of DoD items.
- c. Implement resolutions, if necessary, to minimize or eliminate risks and negative impacts (e.g., cost, schedule delays, readiness) resulting from DMSMS issues throughout the life cycle of DoD items.

- d. Implement improvements to DMSMS management processes throughout the life cycle of all DoD items across the DoD enterprise. (p. 3)

Overview of the Research Methodology

This study utilized a qualitative research methodology to address the research questions. Data collection was performed by a literature review of peer-reviewed journal articles; U.S. Government orders, directives, instructions and guides; published case studies and other online sources associated with strategies to mitigate obsolescence risks for U.S. Army PGMs. Using the research questions, key terms were selected to focus the literature review, such as obsolescence management, obsolescence strategies, obsolescence risks, and precision guided missiles. Literature sources were found and obtained through the Defense Acquisition University (DAU) Virtual Research Library, Lawrence Tech Library, Google Scholar, U.S. Government Accounting Office (GAO), and the DoD Defense Technical Information Center (DTIC). Sources were reviewed and categorized by background information, obsolescence definitions, PGM obsolescence risks, and obsolescence strategies. To ensure a high validity for this research, literature sources were primarily selected from U.S. Government documents, peer-reviewed articles, industry magazines, and other high quality sources.

Obsolescence definitions in the literature were reviewed and compared to DoD's definition, as well as how obsolescence relates to DMSMS. Next, obsolescence associated with PGM systems was researched to understand the risks and impacts. Last, management strategies to include reactive, proactive, and strategic were reviewed to help PGM teams implement risk-based obsolescence management.

Limitations of the Study

The study was limited to a review of published literature and U.S. Government documents, and excluded surveys and interviews which may have provided more information on mitigation strategies being utilized currently by PGM obsolescence teams. With regard to obsolescence associated with U.S. Army PGM, obsolescence risks were limited to examples found in the literature. This study excluded obsolescence management of software, as software is a separate domain. This study did not address the full scope of DMSMS, but rather a subset associated with obsolescence. For example, this study excluded DoD supply chain vulnerabilities, such as issues associated with supply chain security and adversary dependencies for materials and manufacturing. Cost, schedule and performance tradeoffs associated with specific obsolescence mitigation strategies were also not addressed, as tradeoffs for each strategy can have unique circumstances that must be considered in terms of specific program goals.

Summary

Obsolescence was introduced to include some impacts on individual and/or multiple programs sharing technologies or components. Obsolescence occurring across all phases of a system life cycle was discussed. The DoD policy to improve the management of obsolescence was concisely summarized to provide a foundation for this paper. The purpose of this qualitative study, research questions, and a conceptual framework was presented. The significance of this research highlighted the need for improved obsolescence management. An overview of the research methodology and limitations of the study were also addressed.

Chapter 2 – Literature Review

“Not all obsolescence results in DMSMS [Diminishing Manufacturing Sources and Material Shortages] issues, and not all DMSMS issues result from obsolescence. However, most DMSMS issues result from some form of obsolescence” (Defense Standardization Program Office, 2021, p. 158).

Introduction

The literature review begins with definitions of obsolescence, and how obsolescence relates to DMSMS. Components for a generic PGM are described, and examples of obsolescence associated with PGM are provided. Obsolescence management strategies are discussed to include reactive, proactive, and strategic mitigation strategies.

Statement of Purpose

The purpose of this qualitative study is to explore strategies to mitigate obsolescence risks for U.S. Army precision guided missiles (PGM).

Obsolescence Definitions

Sandborn (2013) offers the following definition:

Obsolescence is defined as the loss or impending loss of original manufacturers of items or suppliers of items or raw materials [1]. The type of obsolescence addressed ... is known as DMSMS (Diminishing Manufacturing Sources and Material Shortages), which is caused by the unavailability of technologies or parts (where “part” refers to the lowest management – manufacturing, sparing, repairing level for the system) that are necessary to manufacture or sustain a system. (p. 15)

Mellal (2020) highlights differences in how obsolescence is defined:

The standard IEC 62402: 2007 uses the word “obsolete” referring to a product that is “no longer available” for various reasons and the word “obsolescent” for a product “subject to the announcement of a future end of” availability. Under this standard, these terms do not mean the loss of use of the item but its unavailability, and they differ only by a time gap (the item is obsolescent before becoming obsolete), i.e. obsolescence of an item (obsolete item) is defined as follows: the item is no longer suitable for current demands, or the item is no longer available from the original manufacturer. The standard AFNOR NF X60-012: 2006, meanwhile, defines “obsolete” to mean “no longer used” or “outdated;” that does not necessarily mean that it is no longer available. (p. 1)

The DMSMS Guidebook explains:

The term “obsolescence” is similar, yet different, from DMSMS. The differences are small—DMSMS encompasses 1) items that are not obsolete but where there are shortages and 2) obsolete items that are out of production and there is demand. Both terms are used interchangeably...with a distinction being made where needed for clarity. (Defense Standardization Program Office, 2021, p. 4)

The DMSMS Guidebook also states that:

[Obsolescence] is less definitive and is situationally dependent in that an item can be obsolete from one perspective, but not from another. In the context of DMSMS management, an item is obsolete if it is out-of-date and superseded by something new. (Defense Standardization Program Office, 2021, p. 157)

Figure 2 shows the relationship between DMSMS (blue vertical box) and obsolescence (red horizontal box) where the overlapping area represents where the terms ‘DMSMS’ and ‘obsolescence’ can be considered as interchangeable. This area represents the most common situation, but other areas exist specific to either DMSMS or obsolescence. For example, a parts

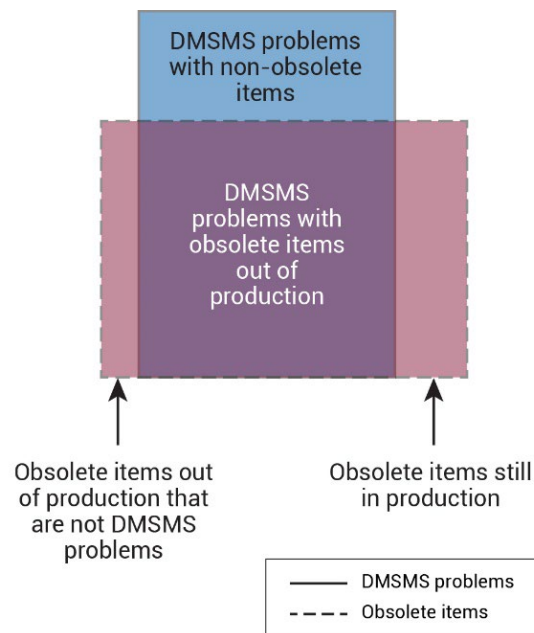


Figure 2. Notional Relationship between DMSMS and Obsolescence (Defense Standardization Program Office, 2021, p. 158)

shortage of a non-obsolete item due to supply chain capacity limits is a DMSMS issue, but not an obsolescence issue. An obsolete item out of production is not necessarily a DMSMS problem if sufficient inventory remains for the obsolete part. Likewise, an item may be obsolete but still produced and available to support program needs; therefore, the item would not be a DMSMS issue (Defense Standardization Program Office, 2021).

DoD defines DMSMS Management as:

A multidisciplinary process to identify risks resulting from obsolescence, loss of manufacturing sources, or material shortages; to assess the potential for negative impacts on schedule or readiness; to analyze potential mitigations; and then to

implement the most cost-effective resolution. (DoD Instruction 4245.15, 2020, p. 10)

Precision Guided Missile Overview

Heaston and Smoots (1983) provide a tutorial on the architecture and function of a generic precision guided missile (PGM). The PGM block diagram in Figure 3 shows the relationship among the major subsystems. The missile seeker locates the target through the sensor and signal processing computer and electronics. The radome material located at the nose protects the sensor

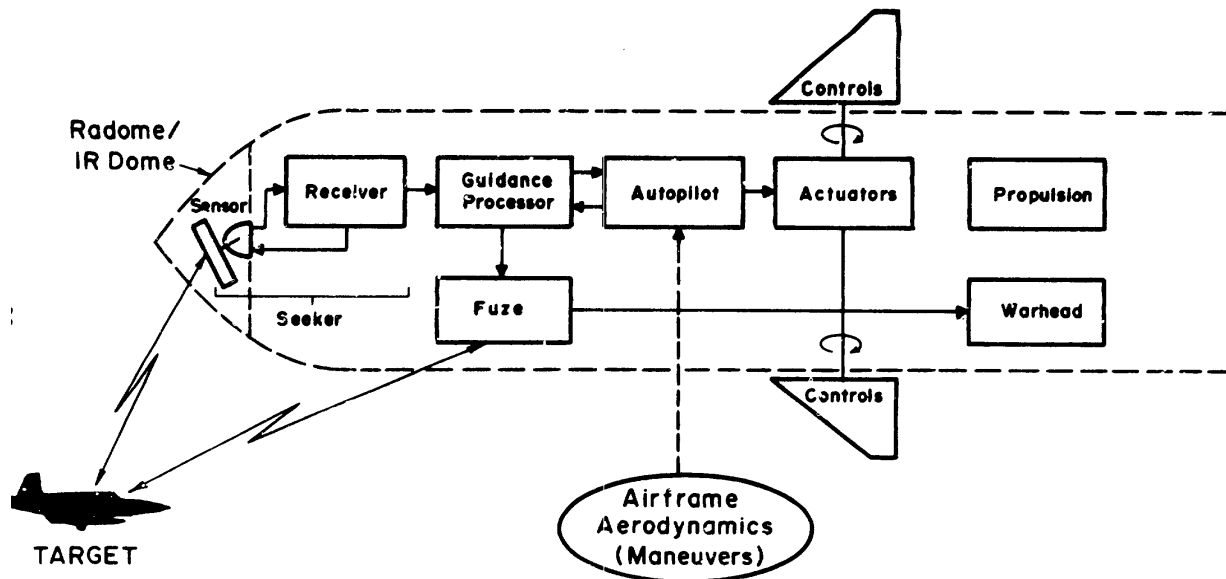


Figure 3. Block Diagram of Components of a Guided Missile (Heaston & Smoots, 1983, p. 26)

and electronics while allowing signals of interest to pass through to the sensor. The guidance processor is the brain comprised of microelectronics responsible for overall control of the missile. The guidance processor provides electronic commands to the autopilot which translates commands into a suitable form for driving the actuators. The actuators move the control surfaces that result in missile motion in the commanded direction. The fuze is responsible for warhead

detonation; contact fuzes are generally mechanical devices that activate on impact, and proximity fuzes activate prior to impact via sensors. The warhead destroys the target utilizing various designs involving explosives and materials. The propulsion system provides the launch and in-flight thrust to the missile (Heaston & Smoots, 1983).

Obsolescence associated with Precision Guided Missiles

Pearce (2002) discusses that the majority of obsolescence in missile pre-production programs occurs with electronic components, primarily microcircuits. Two major driving forces for missile obsolescence were identified as the electronic parts industry turnover rate of eighteen to twenty-four months and DoD's less than 1% market share of electronic parts.

The 'Perry Memo' issued by former Secretary of Defense William J. Perry marked a shift in DoD acquisition to rely on commercial instead of military specifications (Perry, 1994). The decision to shift toward commercial-off-the-shelf (COTS) brought with it shorter life cycles of components. In commercial microcircuit technology, a relatively short turnover rate of eighteen (18) to twenty-four (24) months compared to DoD system life cycles was a major driver for obsolescence experienced by missile programs (Pearce, 2002).

Consequently, DoD systems end up utilizing microelectronic technology generations behind the commercial sector. High requalification costs also deter technology refresh which would allow for technology insertion. Because DoD's microelectronic purchase quantities of older generation parts is insufficient to sustain commercial production, obsolescence occurs frequently requiring costly lifetime buys and/or requalification efforts. Obsolescence is not usually budgeted for by programs further complicating the situation (OSD A&S Industrial Policy, 2021).

Defusco (2017) discusses obsolescence as a continuous challenge for the rocket propulsion industry. Obsolescence often arises at third-tier commercial material suppliers due to a lack of

demand and/or increasing environmental regulations for these unique materials. As a result, the need for alternative materials lead to cost and schedule impacts for requalification efforts. The industry has also experienced significant consolidation where there remains only two U.S. second-tier rocket propulsion contractors, and critical components for munitions are dominated by single- or sole-source suppliers. “Interestingly, there is approximately one supplier for every two critical munitions components, reflecting a lack of competition and adequate depth at the subprime level, where most of the issues previously discussed arise” (Defusco, 2017, p. 13).

DoD led an interagency task force that assessed the U.S. manufacturing and defense industrial base and supply chain resiliency. The report listed obsolescence resulting from declining relevant suppliers as one of the major risks threatening the U.S. manufacturing and defense industrial base. One example cited involved a voltage control switch used in all DoD missile systems that became unavailable due to a semiconductor chip foundry closing. DoD was not informed on the closing and did not have planned quantities included in the life-of-type buy. As a result, the remaining stockpile quantity could only cover DoD needs for approximately 6 months adding significant risk to all DoD missile systems (OSD A&S Industrial Policy, 2018).

As part of an annual DoD report to Congress on industrial capabilities, a missile and munitions sector overview provides a listing of major risks and issues, developments, and the sector outlook. Consolidation of the industrial base continues with 97% of DoD’s missile procurement funds accounted for by only two prime contractors. Additionally, consolidation also exists at the sub-tier suppliers where, for example, there remains only two domestic suppliers of solid rocket motors, Aerojet Rocketdyne and Northrop Grumman Innovation Systems. Obsolescence remains a critical issue due to a lack of proactive and collaborative planning between the government and industry. Once an obsolescence issue is identified, requalification efforts and

costs are extensive. The issue is compounded by a lack of visibility into sub-tier suppliers leading to reactive actions that result in schedule delays and increased costs. DoD's ability to engage with sub-tier suppliers is severely limited by federal acquisition regulations which leads to reactive strategies (OSD A&S Industrial Policy, 2020).

Obsolescence Management Strategies

Sandborn (2008) defines three levels of management strategies for DMSMS as reactive, proactive, and strategic. Figure 4 shows the relationship and definitions of the three levels. Each of the three levels of management strategies are performed concurrently.

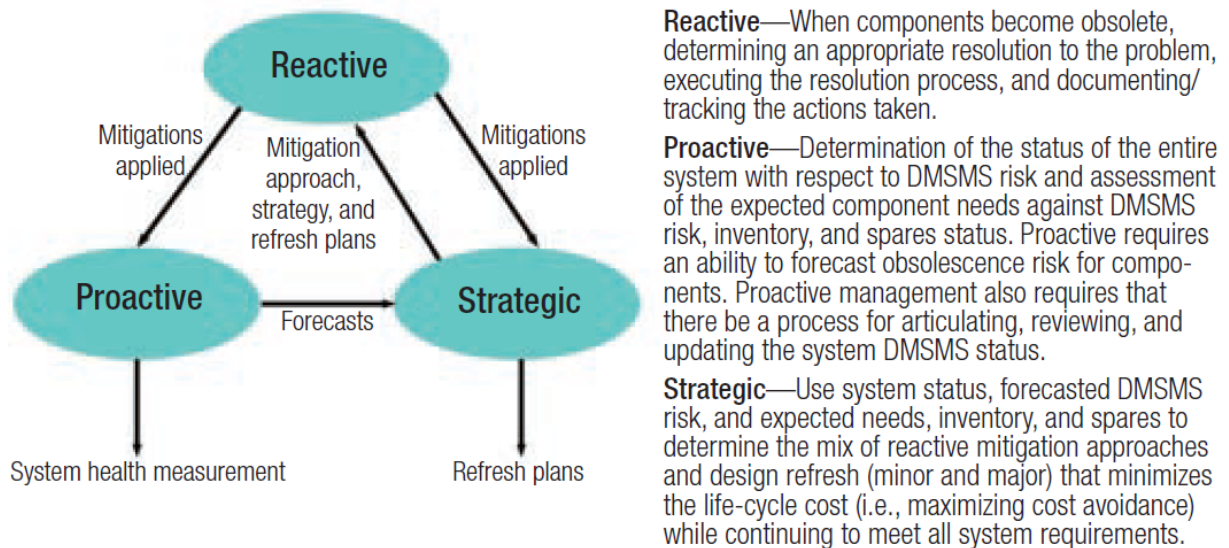
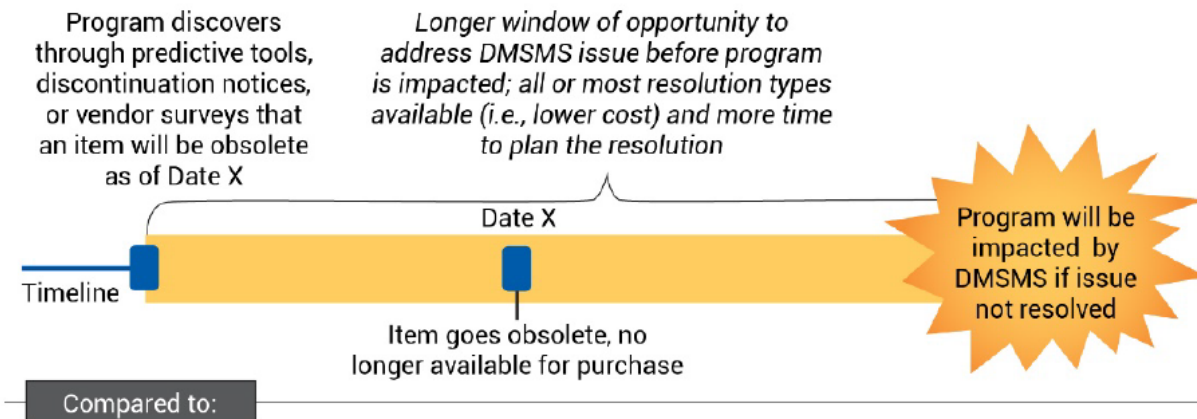


Figure 4. DMSMS Management Strategy and Definitions (Sandborn, 2008, p. 25)

To highlight the advantages of a risk-based, proactive obsolescence management approach, Figure 5 shows a comparison between the proactive and reactive management approaches. The increased window of opportunity afforded by proactive management provides the project office time to weigh options in terms of cost, schedule, and performance in order to determine the best value or return on investment. Reactive approaches often lead to increased costs and risks to the program, as options can be limited by time constraints. An example is when a broker is required

to obtain parts that are suddenly no longer available from the original manufacturer, often a last resort when there is no time to pursue other options; obtaining parts from a parts broker may appear to resolve the shortage, but may introduce new risks, such as counterfeit parts (Defense Standardization Program Office, 2021).

PROACTIVE DMSMS MANAGEMENT APPROACH



REACTIVE DMSMS MANAGEMENT APPROACH

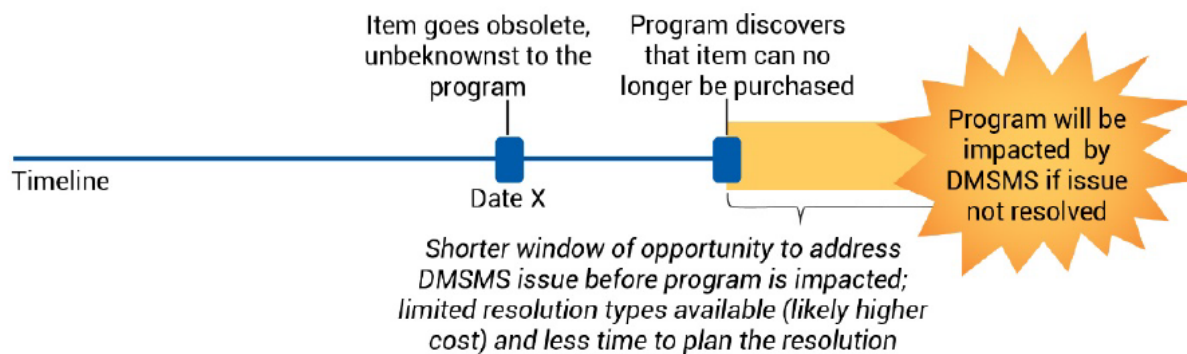


Figure 5. How Proactive DMSMS Management Increases the Window of Opportunity for Resolving a DMSMS Issue (Defense Standardization Program Office, 2021, p. 66)

Reactive Mitigation Strategies. When a component is discovered to be obsolete and no longer available, a variety of reactive obsolescence strategies can be implemented. As shown in Figure 6, Romero Rojo, Roy, and Shehab (2010) categorize the available reactive strategies or

‘resolution approaches’ into four categories: same component, form-fit-function (FFF) replacement, emulation, and redesign.

The ‘same component’ category utilizes the replacement of the obsolete part with the same exact part from existing stock, a life-of-type buy of the part to cover remaining requirements, an authorized aftermarket third party broker, or from cannibalizing or salvaging the needed part from other working units. The ‘FFF replacement’ category includes the use of alternate parts that may not meet all of the original part performance specifications, and equivalent parts that are qualified to meet all of the original specifications. The ‘emulation’ category includes the use of parts developed to provide identical form, fit, and function through an interface that allows use of legacy software. The ‘redesign’ category includes minor and major upgrades focused on improved performance, maintainability, and reliability utilizing newer components (Romero Rojo, Roy, & Shehab, 2010).

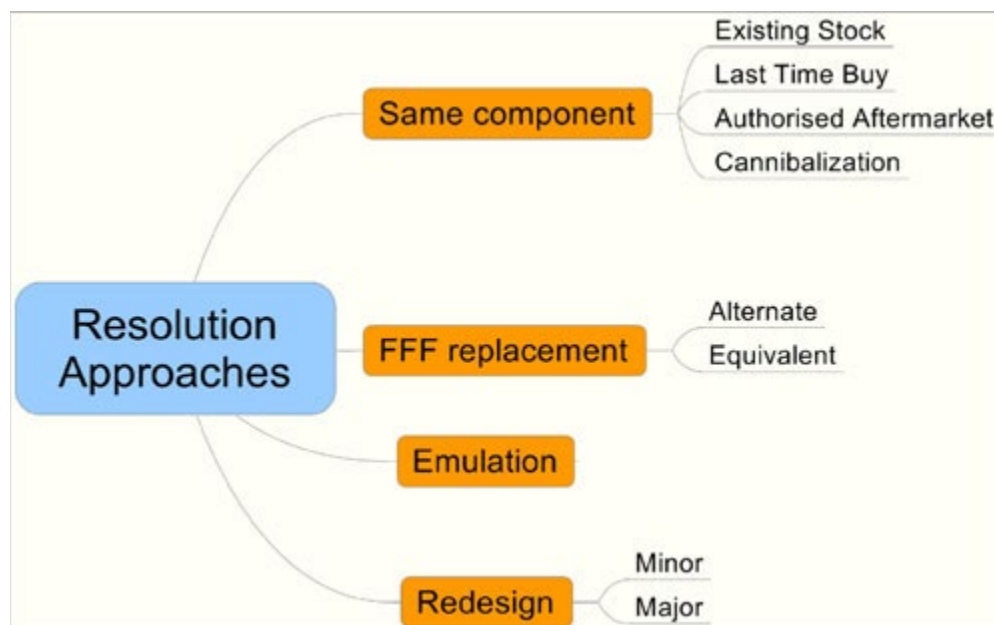


Figure 6. Obsolescence Resolution Approaches (Romero Rojo, Roy, & Shehab, 2010, p. 1242)

Proactive Mitigation Strategies. As shown in Figure 7, Romero Rojo, Roy, and Shehab (2010) categorize the proactive mitigation strategies into three categories: supply chain, design for obsolescence, and planning. The supply chain category includes a risk mitigation buy to procure enough quantity to meet the life cycle requirements, and partnering agreements with suppliers to ensure support. The design for obsolescence category includes a variety of proactive strategies that provide flexibility to incorporate future part updates when necessary, and parts less likely to become obsolete. The planning category includes proactive mitigation strategies that include monitoring and forecasting parts for obsolescence, technology roadmap and refresh, and development of an obsolescence management plan.

One proactive strategy example involved the Terminal High Altitude Area Defense (THAAD) program which faced an obsolescence issue with the seeker requiring an immediate redesign. However, the team had been tracking a potential need to upgrade seeker capabilities five years into the future. The THAAD team executed the seeker redesign to address the current obsolescence, but included design features to support the future upgrade. The proactive strategy resulted in a cost avoidance of \$100 million in future redesign costs while accelerating capability to the field (Defense Standardization Program Office, 2021).

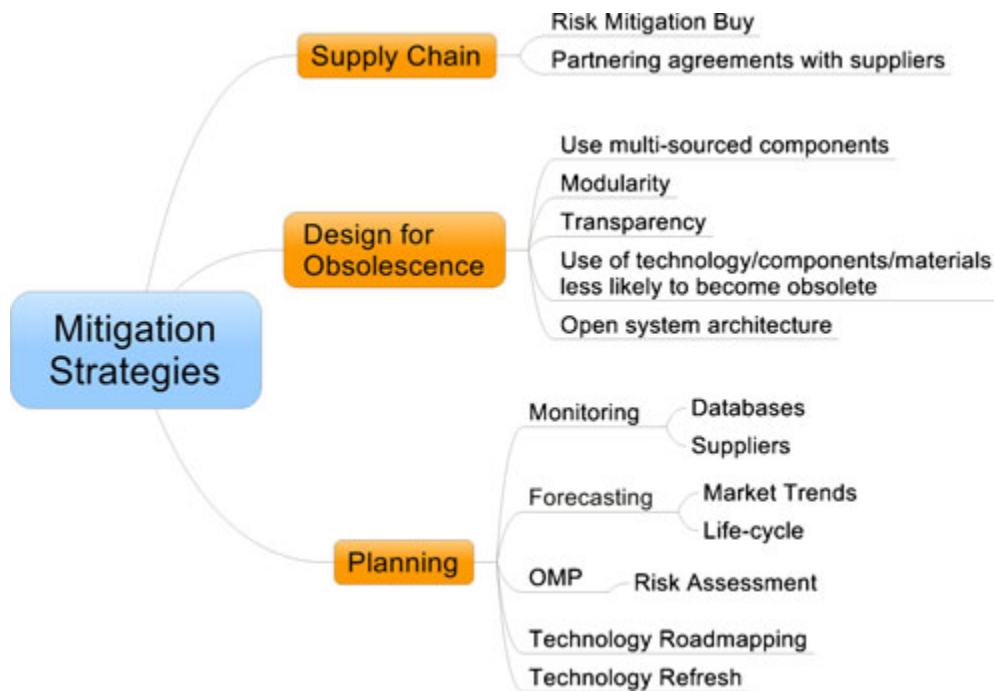


Figure 7. Obsolescence Mitigation Strategies (Romero Rojo, Roy, & Shehab, 2010, p. 1241)

Strategic Strategies. Mandelbaum and Patterson (2021) present a case for solving DMSMS issues collaboratively among the various stakeholders to realize cost savings. That is, instead of solving DMSMS issues independently, one at a time, developing a technology roadmap could allow planned technology refreshment and insertion efforts to address DMSMS issues. Such strategies are employed successfully by car manufacturers that use planned periodic updates to add newer technology and capabilities while also addressing obsolescence.

Mandelbaum, Patterson, and Brown (2014) details in a report the following recommendations to program leadership:

- Establish the Strategic Underpinnings for DMSMS Management
- Establish a Strong Foundation for Robust DMSMS Management
- Ensure DMSMS is Fully Funded

- Make DMSMS Management a High Priority in the Program Office and with the Prime Contractor
- Link DMSMS Health Assessments to Product Roadmaps
- Obtain DMSMS Comments on All Designs, Redesigns, and Design Reviews. (pp. 1-2)

A strong foundation for DMSMS management requires program office leadership involvement to set the priorities for the DMSMS management team (DMT) and to document the scope of activities in the DMSMS management plan (DMP). Failure by program leadership to engage on and lead this effort can result in an unfunded DMP with ad hoc implementation and increased risks (Defense Standardization Program Office, 2021).

A proactive obsolescence management effort should begin as early as the system requirements review and should entail a risk based approach throughout the system life cycle. Contract language requiring a proactive approach by the prime and suppliers drives monitoring activities and reporting to the project office. Also, obtaining technical data and associated intellectual property rights should be planned up front to provide the necessary information to support monitoring activities. For example, an indentured bill of materials (BOMs) that include the original manufacturer's part numbers should be obtained to screen parts for discontinuance notices (Defense Standardization Program Office, 2021).

In a case study on obsolescence management for the Virginia-Class submarines, the program office responsible for the submarine's acquisition established a Technology Refresh Integrated Product Team (TR IPT) responsible for resolving obsolescence issues. The team was comprised of stakeholders from all of the product platforms that supported the manufacturing effort. A process was developed and utilized by the TR IPT to identify, validate, distribute,

collaborate, implement a resolution, and track through closure. This approach combined stakeholders focused on obsolescence issues with others involved in product updates to generate approximately \$96 million in cost avoidance over a ten year period (Defense Standardization Program, 2011). The following were the key lessons learned to proactively manage obsolescence:

- Formalize the obsolescence program
- Develop strong communication ties with program managers, contractors, original equipment manufacturers (OEM), and other entities that may be affected by the obsolescence issues
- Establish a process for notifying all stakeholders when an issue is identified
- Involve all stakeholders in identifying possible solutions to obsolescence issues. (Defense Standardization Program, 2011, p. 8)

DMSMS risks should be taken into account to inform the management strategy, as it is time consuming and not very cost effective to implement a robust, proactive approach for every item. DMSMS proactive management should be balanced between high-risk items requiring constant monitoring, and low-risk items where replacements are readily available. Prioritizing subsystems to focus the DMSMS management effort can be based on safety, mission criticality, costs, existing problems, life-cycle phase, sustainment strategy, and/or availability of technical data. A bill of material (BOM) or parts list for these subsystems identifies the materials, components, and assemblies and provide the most important data necessary for DMSMS management. DMSMS management efforts should filter down a BOM with large numbers of parts

to focus on the higher risk items. COTS assemblies can also present a challenge in that the BOM is usually not available (Defense Standardization Program Office, 2021).

Summary

The literature review covered definitions of obsolescence, and how obsolescence relates to DMSMS. An overview of a generic PGM provided a description on the architecture and functions. Obsolescence risks and issues in the missile industry associated with PGM was highlighted. Last, an obsolescence management framework was provided that included reactive, proactive, and strategic strategies.

Chapter 3 – Research Methodology

Introduction

The research methodology chapter explains how the study was performed to answer the research purpose and questions. The purpose and research questions for this study are restated first. The research methodology then provides an explanation for the research method chosen to answer the research questions. How the data collection was performed and organized is described next, followed by the study limitations. A summary is provided to conclude the chapter.

Statement of Purpose

The purpose of this qualitative study is to explore strategies to mitigate obsolescence risks for U.S. Army Precision Guided Missiles (PGM).

Research Questions

1. What is obsolescence?
2. What obsolescence risks are associated with U.S. Army PGM?
3. What obsolescence management strategies are available to mitigate PGM obsolescence risks?

Research Methodology

This study utilized a qualitative research methodology to address the research questions. A qualitative research methodology was chosen as the intent of this study was to explore and develop the topic of obsolescence; to conduct a literature review to justify the problem; to develop the purpose and research questions as open-ended; and to interpret the findings (Creswell & Guetterman, 2019). The research questions were created to focus the literature

review on developing an in-depth understanding of obsolescence, obsolescence risks associated with PGM, and management strategies available to mitigate these risks.

Data collection was performed through a literature review of peer-reviewed journal articles; U.S. Government orders, directives, instructions and guides; published case studies and other online sources associated with strategies to mitigate obsolescence risks for U.S. Army PGMs. Using the research questions, key terms were selected to focus the literature review, such as obsolescence management, obsolescence strategies, obsolescence risks, and precision guided missiles. Literature sources were found and obtained through the DAU Virtual Research Library, Lawrence Tech Library, Google Scholar, U.S. Government Accounting Office (GAO), and the DoD Defense Technical Information Center (DTIC). Sources were reviewed and categorized by background information, obsolescence definitions, PGM obsolescence risks, and obsolescence strategies. To ensure a high validity for this research, literature sources were primarily selected from U.S. Government documents, peer-reviewed articles, industry magazines, and other high quality sources.

Obsolescence definitions were reviewed in the literature and compared to DoD's definition, as well as how obsolescence relates to DMSMS. Next, obsolescence associated with PGM systems was researched to understand the risks and impacts. Last, management strategies to include reactive, proactive, and strategic were reviewed to help PGM teams implement risk-based, proactive obsolescence management.

The study was limited to a review of published literature and U.S. Government documents, and excluded surveys and interviews which may have provided more current information on mitigation strategies being utilized by PGM obsolescence teams. With regard to obsolescence associated with U.S. Army PGM, obsolescence risks were limited to examples

found in the literature. This study excluded obsolescence management of software, as software is a separate domain. This study did not address the full scope of DMSMS, but rather a subset associated with obsolescence. For example, this study excluded DoD supply chain vulnerabilities, such as issues associated with supply chain security and adversary dependencies for materials and manufacturing (U.S. House of Representatives Armed Services Committee, 2021). Cost, schedule and performance tradeoffs associated with specific obsolescence mitigation strategies were also not addressed, as tradeoffs for each strategy can have unique circumstances that must be considered in terms of specific program goals.

Summary

A qualitative research methodology was chosen to address the research questions. Data collection was accomplished through a literature review of peer-reviewed journal articles; U.S. Government orders, directives, instructions and guides; published case studies and other online sources associated with strategies to mitigate obsolescence risks for U.S. Army PGM. Limitations of the study included the use of published literature and U.S. Government documents, and excluded surveys and interviews. This study limited the focus to management strategies for obsolescence and does not attempt to address the larger scope of DMSMS. Software obsolescence mitigation strategies were also excluded.

Chapter 4 – Findings

Introduction

The research purpose and questions are restated to frame the analysis and findings presented for each question. Obsolescence definitions, precision guided missile obsolescence risks, and strategies to mitigate precision guided missile obsolescence risks are analyzed based on the information presented in the literature review. A summary is provided to conclude this chapter.

Statement of Purpose

The purpose of this qualitative study is to explore strategies to mitigate obsolescence risks for U.S. Army Precision Guided Missiles (PGM).

Research Questions

1. What is obsolescence?
2. What obsolescence risks are associated with U.S. Army PGM?
3. What obsolescence management strategies are available to mitigate PGM obsolescence risks?

Obsolescence Definitions

Definitions of obsolescence were found to have varied across the literature. The International Electrotechnical Commission (IEC) in *IEC 62402: 2007 Obsolescence Management* defines ‘obsolete’ as ‘no longer available’; whereas, the French national organization for standardization, Association Française de Normalization (AFNOR) in *AFNOR NF X60-012: 2006 Vocabulary of Components and their Supplies for Durable Goods* defines ‘obsolete’ to mean ‘outdated’ (Mellal, 2020). This difference in the definition of obsolescence, that is whether an item was available or whether it was outdated, categorizes the two different

types of definitions encountered across the literature review. The DoD utilizes the latter definition in the DMSMS Guidebook that defines obsolescence as items out-of-date and superseded due to key underlying causes, such as technology, function, regulation, supportability, and market demand (Defense Standardization Program Office, 2021). In Figure 2, the relationship between DMSMS and obsolescence shows one situation as ‘obsolete items still in production’ which represents items that are obsolete due to functionality or other causes but are still produced or available and thus not a DMSMS issue. Another situation depicted in Figure 2 shows ‘obsolete items out of production that are not DMSMS problems; that is, even though the items are out of production, a sufficient stockpile may exist that again does not result in a DMSMS issue. In another area of Figure 2 where DMSMS problems and obsolescence overlap, it is labeled as ‘DMSMS problems with obsolete items out of production’. Because “...most DMSMS issues result from some form of obsolescence”, the center region where DMSMS and obsolescence overlap is depicted as the largest area (Defense Standardization Program Office, 2021, p. 158). The last area located in the upper center of Figure 2 is labeled as ‘DMSMS problems with non-obsolete items’; this area represents various other supply chain factors that result in a DMSMS issue not caused by obsolescence.

The overall relationship between DMSMS and obsolescence, as depicted in Figure 2, provides a robust framework to compare and contrast the different situations that may arise in a PGM program with respect to obsolescence. By using this framework, PGM teams can assess where each item belongs in the figure in order to consider the associated risks. For example, an item that is ‘obsolete but still in production’ does not result in a DMSMS issue to the program, but certainly the risks of the item becoming an issue are increased especially if there are no other available suppliers.

Precision Guided Missile Obsolescence Risks

PGM hardware includes electronic & non-electronic - materials and structural, mechanical, and electrical (MaSME) items, and it is a sound assumption that modern PGMs include hundreds, if not thousands, of items when traced down to individual components. Because proactively monitoring all items to mitigate obsolescence risks is impractical, the DMSMS Guidebook provides recommendations on the prioritization of subsystems based on safety, mission criticality, costs, current/historical problems, life cycle phase, sustainment strategy and availability of technical data; program offices must determine which factors best prioritize subsystems for monitoring and surveillance (Defense Standardization Program Office, 2021).

For PGM programs, obsolescence management teams may utilize any number of factors to prioritize proactive management efforts on subsystems to mitigate risks. For example, a safety assessment report may help teams prioritize subsystems that include safety critical items. Actual or estimated PGM program obsolescence costs or cross-service cost surveys, as shown in Table 1, may help to focus efforts on subsystems with the highest expected obsolescence cost impacts. However, some factors, such as mission criticality, may not provide a clear distinction in prioritizing PGM subsystems. That is, basic PGM subsystems perform various functions needed for mission execution (Heaston & Smoots, 1983). However, as each PGM configuration may have unique features, a mission criticality factor may still help inform the prioritization of subsystems. Another factor that may complicate the prioritization of management efforts concerns the availability of technical data. The DoD shifted toward the use of COTS specifications on items nearly three decades ago (Perry, 1994). DoD missiles rely on the use of COTS items, and specifically, COTS microelectronics were found to be a major driver of

obsolescence on missiles (Pearce, 2002). For COTS items, BOM's necessary to perform monitoring and surveillance are not normally available or are cost-prohibitive to attain (Defense Standardization Program Office, 2021).

In addition to the factors provided in the DMSMS Guidebook concerning the prioritization of proactive management on subsystems, additional factors related to the PGM industrial base environment, such as a diminishing supply base and limited Government visibility into sub-tier suppliers, may also increase obsolescence risks. To highlight concerns with the diminishing supply base, the DoD reported that 97% of all missile procurement funds were accounted for by only two prime contractors (OSD A&S Industrial Policy, 2020). Also of concern is consolidation at sub-tier suppliers, as there remains only two U.S. suppliers of DoD solid rocket motors. At the second-tier and third-tier suppliers, critical components for munitions are dominated by single- or sole-source suppliers with approximately one supplier for every two critical munitions components. This supply base consolidation increases obsolescence risks as suppliers cut production of items that are no longer viable forcing propulsion suppliers and prime contractors to continually assess new materials. "One such material that presented an unplanned obsolescence issue... was butanetriol (BT), which resulted from a nearly depleted stockpile (Defusco, 2017, p. 12).

Furthermore, planning for item cancellations can be difficult for DoD to plan for because of restrictive access to sub-tier suppliers. The DoD's ability to engage with sub-tier suppliers is severely limited by federal acquisition regulations which often result in reactive strategies that create schedule delays and increased costs (OSD A&S Industrial Policy, 2020). One example where limited visibility impacted all DoD missile systems involved a voltage control switch that had become unavailable due to a semiconductor chip foundry closing. DoD was not informed on

the closing and, as a result, the remaining stockpile quantity could only cover DoD needs for approximately 6 months adding significant risk to missile programs (OSD A&S Industrial Policy, 2018).

Strategies to Mitigate Precision Guided Missile Obsolescence Risks

The three levels of management strategies for obsolescence are reactive, proactive, and strategic. Each management level is interconnected, as shown in Figure 4, and operates concurrently (Sandborn, 2008). Reactive, proactive and strategic management strategies available to PGM programs are discussed further.

Reactive approaches to mitigate obsolescence risks, as shown in Figure 5, result in a decreased window of opportunity to address the obsolescence issue before impacting the program; however, when multiple sources exist for items, or other sources are able to provide alternate items that are acceptable, then a reactive strategy may be an acceptable approach (Defense Standardization Program Office, 2021). However, given the diminishing industrial base in the missile sector (OSD A&S Industrial Policy, 2020), multiple sources are unlikely for many items. Even so, reactive approaches are still necessary due to limited resources, lack of technical data, and/or unplanned obsolescence events (Defense Standardization Program Office, 2021). The military has traditionally dealt with obsolescence using reactive approaches. As shown in Figure 6, there are four categories of reactive approaches, or resolution approaches, to include same component, form-fit-function (FFF) replacement, emulation, and redesign. Each category includes specific resolutions which should maintain the capabilities of the original part (Romero Rojo, Roy, & Shehab, 2010). Depending on the situation, PGM teams must decide which of the resolution approach categories, along with specific options, are most appropriate to resolve the obsolescence issue with minimal impact to the program. One situation that could

arise is when a supplier decides to no longer produce an item unexpectedly. In response, PGM teams could choose the ‘same component’ resolution approach where they may be able to utilize existing stock to bridge until a replacement is available. The team could also choose to execute a life-of-type buy to support the needed quantities through end of life. Other available options under the ‘same component’ approach include obtaining parts through the use of OEM authorized brokers, or cannibalizing serviceable parts from other systems (Romero Rojo, Roy, & Shehab, 2010). Of course, the team could also choose to utilize one of the other resolution approach categories. PGM teams should consider all available reactive approaches and choose one that is most suitable to resolve the obsolescence issue.

In contrast to the shortened window of opportunity that results from the reactive approach, the proactive management approach, as shown in Figure 5, maximizes the time available to pursue optimal solutions to address obsolescence. Proactive approaches should target both electronic and non-electronic – MaSME items, and focus on subsystems or items that carry a higher obsolescence risk to the program based on factors, such as safety, known problems, availability of technical data, cost and schedule impacts, and others (Defense Standardization Program Office, 2021). Figure 7 identifies three categories of proactive mitigation measures: supply chain, design for obsolescence, and planning. Within each category, specific mitigation options are available. The level of proactive management needed is a function of the probability of an item becoming obsolete and the impact to the program (Romero Rojo, Roy, & Shehab, 2010). As many mitigation options are available, PGM teams must again decide which one is appropriate for the situation. For example, a PGM team may choose to pursue a proactive risk mitigation buy (RMB) of an item that carries a high risk of obsolescence, especially when other sources or alternates are not readily available. An RMB

may be cost prohibitive to the program, so pros and cons must be evaluated to determine if this action is suitable. Another example could involve an item that carries a medium obsolescence risk, and the team might choose to proactively monitor the item using tools if the associated bill-of-material (BOM) is available to the Government. If the BOM is not available, then the team could seek other proactive options, or may even decide to manage the item reactively.

Strategic approaches, the last type of management strategy, seek to develop an optimal mix of reactive and proactive approaches that minimize life-cycle costs while meeting all system requirements. Programs often address obsolescence on a case-by-case basis which may increase costs. Instead, strategic obsolescence management takes the long term view by aggregating costs of forecasted individual obsolescence events compared to a single design refresh to include the additional costs to bridge buy items to reach the future design refresh date. This strategic view extends beyond just the individual parts out to the subsystem, system, and enterprise (Sandborn, 2008).

In practice, obsolescence management teams face challenges convincing leadership to invest in strategic approaches, such as the consolidated expense of bridge buys. As a result, some leaders take the position that a design refresh approach may not be the most financially attractive. Therefore, teams must carefully analyze the use of strategic approaches, such as design refresh, to ensure it is cost effective (Sandborn, 2008).

Technology [obsolescence] refresh efforts are planned updates to the system design to mitigate obsolescence risks and issues. Technology insertion, on the other hand, are planned updates to the design to improve system performance. Technology refresh and insertion efforts are often executed as separate, uncoordinated activities. In part, because multiple stakeholder communities have different priorities and are unaware of each other's efforts. Whereas, a

strategic approach would leverage both types of updates to maximize efficiencies (Mandelbaum & Patterson, 2021).

A case study on obsolescence management for the Navy's Virginia-Class submarines reported approximately \$96 million in cost avoidance over a ten year period since establishing a technology refresh integrated product team (TR IPT). The TR IPT involved both stakeholders focused on planned design updates and stakeholders focused on obsolescence to identify the best obsolescence solutions for the platform as a whole. Key lessons learned to achieve the reported cost avoidance included regular communications among all stakeholders, plus their involvement in identifying and selecting the best obsolescence solution for the platform as a whole (Defense Standardization Program, 2011). "For example, stakeholders aware of planned designed changes and subsystem upgrades can share that knowledge with stakeholders whose primary concern is to mitigate an obsolescence issue" (Defense Standardization Program, 2011, p. 8).

Summary

The research purpose and questions were restated to frame the analysis. Obsolescence definitions were discussed, as well as the relationship to DMSMS. PGM obsolescence risks were identified along with the need to prioritize proactive efforts on higher risk and/or impact items. Last, a framework of management strategies to include reactive, proactive, and strategic approaches available for PGM programs were examined.

Chapter 5 – Conclusions and Recommendations

Introduction

This chapter provides conclusions with respect to the research questions presented in this study. Recommendations are provided and areas for future research are identified. A summary of the paper concludes the chapter.

Conclusions

As various definitions of obsolescence exist in the literature (Mellal, 2020), coupled with multiple stakeholder communities with different obsolescence priorities (Mandelbaum & Patterson, 2021), inefficient approaches to obsolescence mitigation may result. For example, Army Science and Technology (S&T) stakeholders may focus efforts on ‘outdated’ items that are unable to support priorities related to the exploration of new capabilities for next-generation systems. In contrast, development and production stakeholders may focus obsolescence efforts on ‘unavailable’ items that are unable to support priorities related to the planned production quantities.

As obsolescence strategies are developed, PGM teams should consider both the obsolescence and availability of items. By addressing both, stakeholders better understand whether the strategy is focused on mitigating an items’ obsolescence risk, or solving an availability issue caused by obsolescence.

The number of electronic and non-electronic items within a PGM makes the proactive management of every item impractical. In response, the DMSMS Guidebook recommends prioritizing efforts based on factors decided by the program management team (Defense Standardization Program Office, 2021); this approach should be followed to focus limited resources on the highest risk items. For PGM programs, deciding on the appropriate factors to

focus the management efforts can be challenging. Factors, such as ‘mission critical’, may not help focus efforts especially if all subsystems are required in mission execution. Obsolescence cost estimates or actuals may not have been separated from overall program costs which can make future obsolescence costs difficult to predict. Further, proactively managing some items may not be possible regardless of the obsolescence risk, if technical data, such as the BOM, is not available to the Government.

Two additional factors were also identified associated with the PGM industrial base that further complicates the decision on which items to proactively manage. That is, a diminishing industrial base and limited Government visibility into sub-tier suppliers are major obsolescence risks for the missile industrial base (OSD A&S Industrial Policy, 2020). Items assessed as having a low obsolescence risk can quickly turn into a major program impact if a supplier suddenly decides to stop producing; this can have significant impacts if the supplier was the sole-source for the discontinued item. Additionally, with limited Government insight at sub-tier suppliers, future supplier plans may not be communicated which increases the likelihood of an unplanned obsolescence event.

Given these conditions, focusing the PGM team’s management efforts to effectively mitigate obsolescence risks can be difficult. However, the potential obsolescence impacts to programs is significant and must be managed. The focus on which items to proactively or reactively manage will not always be right due to any number of reasons, such as when a readily available item is suddenly discontinued with no other alternatives available. Therefore, PGM teams must continuously reassess current obsolescence plans and adjust over time.

Effective long-term obsolescence management strategies consider reactive, proactive, and strategic approaches concurrently (Sandborn, 2008). Reactive strategies are executed after an

obsolescence event leaving less time to resolve the issue before it impacts the program.

Numerous reactive strategies and options are available to teams, as shown in Figure 6. Although reduced timelines after an obsolescence event may lead to increased impacts, reactive strategies are necessary for several reasons to include a lack of technical data, a sudden unplanned obsolescence event, and/or impracticality of proactively managing all items (Defense Standardization Program Office, 2021). Significant impacts can result when reactive approaches involve redesign efforts because no alternatives were available (OSD A&S Industrial Policy, 2018). For these reasons, PGM teams must plan to align reactive strategies to easily replaceable items that carry the least obsolescence risk to the program.

In contrast to reactive strategies, proactive strategies are executed before an obsolescence event occurs maximizing the time available to resolve the issue. Various proactive strategies and options are also available to teams, as shown in Figure 7. Proactive strategies have been shown to provide value to programs, such as THAAD's execution of a design for obsolescence strategy that resulted in \$100 million in cost avoidance and accelerated fielding of new capability (Defense Standardization Program Office, 2021). Because proactive management requires additional investments to implement, these efforts should align with items that carry the highest obsolescence risk to the program. However, PGM teams may also need to consider proactive management of sole-source items, even if the items are considered to carry a low and/or medium risk, because of the diminishing industrial base for missiles.

Strategic management, the last strategy, focuses on optimizing the mix of available reactive and proactive approaches to minimize life cycle costs while meeting system requirements. To accomplish this goal, obsolescence management teams should plan beyond individual obsolescence events and consider combining the separate events into a single design

refresh along with bridge-buying the required items to reach the future design refresh date (Sandborn, 2008). Teams should also work to combine obsolescence refresh and technology insertion efforts which are typically uncoordinated and separately executed (Mandelbaum & Patterson, 2021). Synergizing stakeholder engagement has proved beneficial, such as the Navy's establishment of a technology refresh integrated product team (TR IPT) whose efforts resulted in approximately \$96 million of cost avoidance over a ten year period (Defense Standardization Program, 2011).

Despite potential benefits of a strategic approach, leaders can be hesitant to make some investments, such as bridge-buying items to last until a future obsolescence refresh event (Sandborn, 2008). Management teams should consider the added benefits of bridge-buying items, especially given the diminishing industrial base for missiles. That is, by bridge-buying items for a design refresh strategic approach, unplanned obsolescence events may also be mitigated in addition to the expected financial benefits of a properly planned design refresh.

Recommendations

Recommendation #1: Establish a Technology Refresh IPT (TR IPT). Army precision guided missile (PGM) programs should consider establishing a TR IPT to provide management oversight of obsolescence refresh and technology insertion plans in order to pursue optimal approaches that maximize cost avoidance. A TR IPT could also be established at the U.S. Army Program Executive Office (PEO) Missiles and Space (MS) to help synergize efforts across the numerous programs within the portfolio. Additionally, a single command touch point for obsolescence at PEO MS would foster communications with stakeholder communities, such as U.S. Army Combat Capabilities Development Command (CCDC), U.S. Army Aviation and Missile Command (AMCOM), DoD, other Services, other PEOs, and industry.

Recommendation #2: Develop Integrated Product Roadmaps. Integrated product roadmaps that combine technology insertion and refreshment plans help foster communication and transparency among stakeholders. Programs utilizing this approach can benefit from lower obsolescence costs and improved mitigation of obsolescence risks (Mandelbaum & Patterson, 2021).

Recommendation #3: Build obsolescence management plans that consider incorporating strategic, proactive (Figure 7), and reactive (Figure 6) approaches presented in this paper. Strategic management focuses on achieving an optimal mix of the available reactive and proactive management approaches in order to minimize life cycle costs while meeting system requirements (Sandborn, 2008).

Recommendation #4: Implement DMSMS Guidebook (SD-22) Best Practices. PGM teams should consider implementing the best practices outlined in the guidebook to include the establishment of a DMSMS management team (DMT) with assigned roles; completing recommended training; and developing and resourcing a risk-based, proactive obsolescence management plan (Defense Standardization Program Office, 2021).

Areas for Future Research

Reactive approaches are often associated with increased cost and schedule impacts to programs, but must be planned for as proactively managing every item is impractical (Defense Standardization Program Office, 2021). Therefore, future research is needed on how to improve reactive approaches by minimizing response times and costs.

One research area that may help improve reactive approaches is additive manufacturing. Researchers investigated multiple solutions for parts obsolescence with three-dimensional (3D)

printing with potential use in reactive mitigation strategies. Three-dimensional printing is the latest technology, also known as additive manufacturing, which produces parts through the layering of materials. Additive manufacturing is in use and expanding into the aerospace industry (Alqarni, 2020). Additive manufacturing technologies could potentially accelerate response times for reactive solutions when a part is no longer available. Continued research into the types of parts that additive manufacturing is appropriate for and an understanding of the associated qualification efforts and production rates would help inform which parts might be appropriately managed using reactive strategies.

A diminishing industrial base for missiles (OSD A&S Industrial Policy, 2020) to include consolidation at sub-tier suppliers where critical components for munitions are dominated by single- or sole-source suppliers (Defusco, 2017) increases the likelihood and consequence of unplanned obsolescence as there are no available alternatives. A research area that could potentially help identify sole-source suppliers within the DoD is blockchain technology. Blockchain is being investigated in supply chains to increase traceability of materials, reduce counterfeit risks, improve visibility of outsourced manufacturing, and reduce administration. Blockchain technology is a digital distributed record shared across all of the supply chain participants. The technology is based on a distributed verification method that facilitates authenticity of records by checking that all other user record copies match. Blockchain technology could potentially provide obsolescence management teams with an authentic record that traces the origin of each material, a list of suppliers involved, and other manufacturing details (Deloitte Consulting LLP, n.d.). Blockchain might help the DoD identify sole-source suppliers by comparing manufacturing records for an item across programs in order to determine

the number of available suppliers and their location. Blockchain applications in supply chains is new and further investigation on how to best apply this technology to obsolescence is needed.

Summary

Exponential technology growth often has an undesirable consequence known as obsolescence and given the advanced technology used in weapon systems, obsolescence remains a significant concern in the Department of Defense (DoD). Obsolescence impacts can require considerable resources to resolve which are often not budgeted for by programs, especially when an unplanned obsolescence event arises. Obsolescence is found across every phase of the weapon system life cycle to include development, production and sustainment. As obsolescence cannot be avoided, obsolescence management is necessary to effectively mitigate risks to programs.

The purpose of this qualitative study was to explore strategies to mitigate obsolescence risks for U.S. Army Precision Guided Missiles (PGM). Toward this purpose a literature review was performed on obsolescence to include definitions, associated risks and available mitigation strategies for PGM.

The term ‘obsolescence’ is often interchanged with Diminishing Manufacturing Sources and Material Shortages (DMSMS), as most DMSMS issues are caused by obsolescence (Defense Standardization Program Office, 2021). Definitions of obsolescence vary in the literature, and this may lead to different interpretations by different stakeholders with different priorities for a specific life cycle, such as development or sustainment. When communicating with stakeholders, PGM teams should remain consistent with the DoD definition of obsolescence as a part that is ‘outdated’ and superseded due to key underlying causes (Defense Standardization Program Office, 2021). Additionally, teams should also communicate the availability of an

obsolete item. By addressing both the obsolescence and availability, teams better communicate with stakeholders whether the focus is on mitigating an obsolescence risk, or solving a DMSMS issue.

PGM systems include a wide range of electronic and non-electronic – MaSME items which carry obsolescence risk. The number of electronic and non-electronic items within a PGM makes the proactive management of every item impractical. Teams should perform a risk analysis to determine which high risk items, items with a high probability or consequence of obsolescence, require monitoring and surveillance. Other factors identified that increased obsolescence risks for PGM included a diminishing industrial base and limited Government visibility into sub-tier suppliers (OSD A&S Industrial Policy, 2020). In the rocket motor propulsion industry in particular, there are often no alternatives readily available if a supplier decides to stop producing (Defusco, 2017). A supplier's decision to stop producing an obsolete item can be either planned or unplanned. Unfortunately, Government visibility into sub-tier suppliers is severely limited by federal acquisition regulations which can lead to surprise, even when an item's discontinuance was planned (OSD A&S Industrial Policy, 2020).

To mitigate risks, the reactive, proactive, and strategic management strategies, as shown in Figure 4, provide a framework for PGM teams to utilize when developing plans to mitigate obsolescence risks for PGM programs. Reactive management strategies, as shown in Figure 6, are executed after an obsolescence event and are categorized into four resolution approaches: same component, form-fit-function (FFF) replacement, emulation, and redesign (Romero Rojo, Roy, & Shehab, 2010). Reactive strategies are less preferred, but are necessary due to limited resources, and other reasons, e.g. unplanned obsolescence (Defense Standardization Program

Office, 2021). PGM teams should work to align reactive strategies with items that carry the least obsolescence risk and/or consequence to the program.

Proactive management strategies, as shown in Figure 7, are executed before an obsolescence event and categorized into three mitigation strategies: supply chain, design for obsolescence, and planning (Romero Rojo, Roy, & Shehab, 2010). Proactive management strategies require resources up front and are implemented using a risk-based approach, as it is impractical to proactively manage every item (Defense Standardization Program Office, 2021). PGM teams should align proactive strategies to those items that carry the highest obsolescence risks and/or consequences in order to provide more options to minimize impacts.

The last strategy, strategic management, is focused on optimizing the mix of reactive and proactive approaches to minimize life cycle costs while meeting system requirements. In addition to the financial benefits of a properly planned strategic approach, such as a design refresh, there can be additional benefits to PGM programs. Consolidation of the missile industrial base has led to increased obsolescence risks (OSD A&S Industrial Policy, 2020). Consolidation at sub-tier suppliers, such as in the solid rocket motor industry, is also occurring with approximately one supplier for every two critical munitions components (Defusco, 2017). By bridge-buying high risk items in support of a strategic design refresh, unplanned obsolescence events can be mitigated through an increased inventory of items.

Technology refresh to mitigate obsolescence, and technology insertion to improve system performance, are two different types of updates that are often executed as separate, uncoordinated activities by different communities with different priorities (Mandelbaum & Patterson, 2021). PGM teams can achieve obsolescence solutions at lower costs by involving all

stakeholders associated with obsolescence management, technology roadmapping, and planned technology insertion and refreshment (Mandelbaum & Patterson, 2021).

This paper discussed obsolescence definitions and how obsolescence relates to DMSMS, obsolescence risks associated with PGM systems, and what management strategies are available to mitigate obsolescence risks. Continued progress on U.S. Army PGM systems will rely on incorporating the latest technology. As Henry Ford II recognized obsolescence as the hallmark of progress (Sugrue, 1995), obsolescence risks must be effectively managed through reactive, proactive, and strategic approaches in order to provide U.S. Warfighters continued dominance on the battlefield.

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Appendix A – Glossary of Acronyms

AMCOM.....	Aviation and Missile Command
BOM.....	Bill of Materials
COTS.....	Commercial Off-The-Shelf
DAU	Defense Acquisition University
DoD.....	Department of Defense
DoDI	Department of Defense Instruction
DMSMS.....	Diminishing Manufacturing Sources and Material Shortages
DMT	DMSMS Management Team
FFF	Form-Fit-Function
MaSME.....	Materials, Structural, Mechanical, and Electrical
OMP	Obsolescence Management Plan
PEO	Program Executive Office
PGM.....	Precision Guided Missile
RDECOM.....	Research, Development and Engineering Command
RMB.....	Risk Mitigation Buy

Appendix B – Author Biography

Mr. English served within PEO Missiles and Space as the Product Director for Army Tactical Missile System (ATACMS) since 2014. During the past year, while detailed to the Rapid Capabilities and Critical Technologies Office (RCTTO), he led the initial start-up of the Fielding and Transition team for one of the Army's highest priority long-range fires programs, Mid-Range Capability (MRC). Prior to ATACMS, he served as the Army Centrally Selected (CSL) Product Manager for the Terminal High Altitude Area Defense (THAAD) Launcher & Interceptor Product Office at Missile Defense Agency. Mr. English has held numerous positions and assignments within the PEO Missile and Space to include Deputy Product Manager for the Missiles and Platforms Product Office, Assistant Product Manager for Surface Launched Advanced Medium-Range Air-to-Air Missile, Product Director for TPY-2 (FBM) Transition, and Department of the Army Systems Coordinator (DASC). Mr. English started his Government career in the U.S. Army Aviation & Missile Research, Development & Engineering Center (AMRDEC) as a Computer Engineer. Prior to Government service, Mr. English worked in industry as a Turbine-Generator Start-Up Engineer for General Electric Power Systems.

Mr. English graduated from the Georgia Institute of Technology with a Bachelor's degree in Electrical Engineering in 1992 and a Master's degree in Electrical & Computer Engineering in 2004. He is a graduate of the Competitive Development Group / Army Acquisition Fellowship, Excellence in Government Fellows Program, Program Manager's Course at Defense Acquisition University, and the Advanced Civilian Education System. He is a registered professional engineer in Alabama, a member of the Army Acquisition Corps and is Level III certified in Program Management, Information Technology, and Systems Planning, Research, Development and Engineering.