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Strategic Research Paper

Readiness, Acquisition, and Design for Supportability –The Current State of the Supportability Analysis/Engineering Process in Product Acquisition and Root Cause of Why Gap Exists Between Policies and Practices

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ABSTRACT

Product support in the Operations and Sustainment Phase comprises the largest portion of the overall product life cycle cost. Much of what needs to be done earlier on in the product development cycle is well documented in Department of Defense policies, guidance, and procedures. However there is still difficulties and insufficiencies in the early integration of product support analysis and planning in the early phases of product development. Due to the recent rollout of the Adaptive Acquisition Framework and the inclusion of "Middle Tier Acquisition" framework, it requires the emphasis of product support planning and analysis earlier on, especially for the rapid prototyping and rapid fielding projects. This research paper seeks to examine the current state of product support activities and if it is found to be lacking, the root cause of the lack of execution.

DEDICATION AND ACKNOWLEDGEMENTS

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A. Title

Readiness, Acquisition, and Design for Supportability – What is the Current State of the Supportability Analysis/Engineering Process in Product Acquisition and How It Contributes to Army's Pursuance of Readiness?

B. Background

In the current acquisition environment, product supportability attributes and metrics are often not pursued until later on in the product development life cycle. This creates a gap in performance and supportability and it hinders the Army's ability to later effectively sustain and deploy a highly mobilized force in support of large contingency operations. The lack of integrated thinking from performance driven Material Solutions Analysis (MSA) to the Operations and Support (O&S) Phase creates an incoherent acquisition methodology that does not support a highly ready fleet of weapon systems for deployment and operation.

A lack of early product support analysis also could result in higher overall life cycle cost of the weapon system. In today's fiscal limitations and the rollout of new acquisition life cycle framework, earlier product support analysis and if applicable, engineering, are required to ensure the product can be fielded and sustained in a cost-effective manner.

C. Purpose of This Study

This qualitative research paper seeks to examine the current state of product supportability integration in the systems engineering process and acquisition process, specifically supportability requirements analysis and metrics development. Then discuss the why and how there is a gap

between what is written in policies and procedures versus what is actually conducted in projects. Finally this research paper seeks to propose potential solutions to resolve the gap and enhance readiness thinking throughout the acquisition process.

D. Research Questions

The following are the five questions that this research paper will attempt to address as accompanying information to the main topic.

- What is the current logistics supportability analysis and engineering process in the acquisition process and is it adequately executed?
- If it is not adequately executed, why is this happening despite plenty of policies and guidance that encourages to do so?
- If it is adequately executed, how can it be enhanced so the Army's priority to seek "readiness" can be incorporated in the product acquisition process?
- Who are the major direct stakeholders that need to pay attention to this topic?
- What/Who are the distractions that turn projects' attention away from thinking early about product support? And why?

E. Significance of This Research

When the term "readiness" is discussed, it is easy for stakeholders to see a row of heavily armored equipment, neatly lined up and ready to go. However, technically it requires sufficient maintenance and repair parts to achieve that picture. Operationally the equipment cannot be static, but instead should be transportable, employable, and easily trainable so it can be moved and utilized in an efficient manner. All of these readiness related attributes are inherently "designed-in" during product development. This research paper aims to investigate the adequacy

of readiness related elements built-in during the product development phases (MSA – EMD phase), namely supportability analysis and engineering activities throughout the product development and acquisition life cycle. Specifically, are supportability requirements and metrics adequately embedded in the systems engineering practices and product acquisition life cycle? Plenty of policies and guidance mention the importance of early involvement from the supportability community, but there could be a gap that exist between written policies and actual ground level execution. This research paper seeks to inform the reader the current state and provide recommendation for the path forward regarding how the acquisition process can help achieve the "readiness" priority through proper product supportability activities in a timely and effective matter.

F. Overview of the Research Methodology

This will be a qualitative research in which report reviews, observations, and manual collection of data are used. The reason for utilizing the qualitative research method has multiple dimensions. First, in the grand view, the qualitative research allows the author to propose a hypothesis that is too broad and too deep to collect quantitative data. Second, this method allows the author to investigate the strength and weakness of the acquisition process, stemmed from analysis of past lessons learned and historical facts. Third, the topic of this research paper relates to the twelve product support elements, and the data sets related to the entire suite of the twelve product support elements are impossible to collect in a comparative manner. For example, the question of "If product X imbedded supportability requirements at milestone A instead of catching up post-milestone B, the readiness level (or life cycle cost) would have been improved by y%". This paradox exists in that if product X did imbed supportability requirements at milestone A, the resulting cost saving would have already been reflected in the final cost. There

will be no baseline cost to compare against. If product X did not imbed supportability requirements at milestone A, the same argument will manifest itself.

Also, this paper seeks to answer the "why" of a gap that exists between written policy and actual practice. This might stem into human behavior and also the over governing structure and funding structure, thus a qualitative research is most suitable for this possibility.

G. Limitations

Due to the breadth and depth of the product support elements, this paper will not be able to dive deeper into the technical aspect of each element. This paper will focus on the life cycle systems engineering process of integrating logistics supportability metrics and requirements earlier in the product acquisition life cycle. The focus of this paper is the adequacy of the acquisition process and project management processes instead of technical adequacy. As an analogy, this paper aims to examine whether or not the weekly grocery shopping process sufficiently satisfies my requirements instead of answering "what is a good apple?" or "how to ensure the apples I acquire are good tasting and long lasting?".

II. CHATPER 2 – LITERATURE REVIEW

A. Introduction

This literature is aimed to examine existing research papers that discuss the current state of Design for Supportability (DFS) in the Department of Defense's acquisition process. Even though this research paper focuses on military applications, but it is found that the commercial private industry is also faced with similar problems. Pay now or pay later? Therefore this

literature review will also include non-military papers that address product support and product sustainment in the commercial sector.

Another purpose of this literature review is to survey the research landscape to ensure the author is presenting a novel and necessary topic that provides value to the acquisition community. The five research questions presented in the Purpose of the Study paragraph in chapter one will be closely monitored and necessary adjustment to the research paper will be made to ensure uniqueness is maintained.

B. Design for Supportability

Product support is the necessary actions and means required to support and sustain a given product after it is released (fielded) to the customer. In the DoD Acquisition Life Cycle Framework or the new Adaptive Acquisition Framework (AAF), product support is defined as twelve "Integrated Product Support" (IPS) activities that are required to fully support and sustain weapon and other non-weapon systems. These twelve elements are:

1. Product Support Management
2. Supply Support
3. Packaging, Handling, Storage & Transportation (PHS&T)
4. Maintenance Planning & Management
5. Design Interface
6. Sustaining Engineering
7. Technical Data
8. IT Systems Continuous Support
9. Facilities & Infrastructure

10. Manpower & Personnel
11. Support Equipment
12. Training & Training Support

These twelve IPS elements are further categorized into three categories and they are:

1. Life Cycle Sustainment Management (IPS elements 1, 2, 3, and 4).
2. Technical Management (IPS elements 5, 6, 7, and 8)
3. Infrastructure Management (IPS elements 9, 10, 11, and 12)

However for the commercial sector, in Dr. Anagnostopoulos' "Product Support and the New Product Development Process" research paper, a comprehensive list of customer support activities that suits the commercial sector is listed (Anagnostopoulos, Product Support and the New Product Development Process, 2006, p. 6). The activities include:

1. Customer Support
    a. User Training
    b. Customer Consulting
    c. Upgrades
    d. Comprehensive Documentation
    e. On-line Support
    f. Customer Support Organization Usability
2. Service
    a. Installation
    b. Maintenance
    c. Repair

d. Spare Parts

e. Warranty

f. Field Service

Furthermore, if product development is to be linked to product support activities, then product support activities that are directly affected by product design are the following:

1. Installation
2. Repair
3. Maintenance
4. Warranty/Cost of Ownership
5. Comprehensive Documentation
6. Upgrades
7. User Training

In Dr. Goffin's "Design for Supportability: Essential Component of New Product Development", it is stated that product support is the "name given to the various forms of assistance that companies offer customers to help them gain maximum value from manufactured products" (Goffin, Design for Supportability: Essential Component of New Product Development, 2000). Product support used to be thought of as service heavy actions, but now it also includes upgrading and user training. This development is also evident in the IPS element "IT Systems Continuous Support" and "Training and Training Support".

Product support ensures the on-going usability of the product and the maximum utilization of its intended functions and is no longer just serving the traditional "support role". As a matter of fact, one can understand that product support is the main element in customer satisfaction after

the product is fielded (sold) to the customer. However, product support now is not only related to customer satisfaction, but it actually services as an "enabling" element that directly contributes to the success of the use scenario.

To illustrate this, in order to satisfy the new "Multi-Domain Operation" (MDO) strategy, the US military needs to have better coordinated operational sustainment strategy in order to keep up with the dynamic battlefield scenarios and that current operational sustainment capabilities must be analyzed based on the understanding of the future challenges to determine those capabilities are inadequate (Maples, Sustainment Considerations for the Multi-Domain Battle, 2018). "According to ADRP 4-0 Sustainment, the sustainment warfighting function is 'the related tasks and systems that provide support and services to ensure freedom of action, to extend operational reach, and to prolong endurance" (Maples, Sustainment Considerations for the Multi-Domain Battle, 2018, p. 12). In her article, it is further explained that "When it comes to the US Army, primarily operating in the land domain, these actions to enable the air domain will require ground forces to conduct operations in very austere environments, where communications are significantly degraded, united are separated and potentially surrounded by the enemy, and traditional sustainment operations are no longer feasible for support the fight" (Maples, Sustainment Considerations for the Multi-Domain Battle, 2018). It is evident in this article that the current US Army's sustainment operation will not be able to support high intensity MDO operations and the sustainment community's ability to operate in this environment becomes the problem frame. Product support is no longer just service in this military context, but now has become a key enabling factor that will make or break an important operation.

DFS speaks to the action of considering these future use cases, and in many cases, a complex use case (such as the MDO) and design the product according to these sustainment scenarios. If a

weapon system has a high rate of fire, naturally it would require higher resupply frequency and thus resupply (sustainment engineering) becomes a key design factor. If a weapon system requires high mobility, then transportation (PHS&T) size, weight, anchor points, high speed tie-down procedures will become a design spotlight.

The terminologies "product support (ability)", "sustainment", DFS, and "logistics engineering" are all understood to be interchangeable terms. With some specific occasions where one term is more appropriate than the other, most of the time they point towards the same goal: Taking care of the product after it leaves the production facility. With specific definition of "supportability" speaking to the Design for "ilities" effort, such as reliability, maintainability, availability. Supportability is the considerations that design engineers need to address while the system is being developed. Sustainment is the actual action of executing supportability elements, such as performing maintenance, transportation of repair parts, the acquisition of repair parts, the storage of ammunition, etc. Operational sustainment speaks to the ability to maintain combat capability while the mission is being executed; one direct example is ammunition resupply missions.

C. Importance of Design for Supportability Early in Product Development

In Dr. Russel J King's "A Decision-Making Framework for Total Ownership Cost Management of Complex Systems: A Delphi Study", it is apparent that most business and military leaders understand the importance of integrating sustainment scenarios into the product development process earlier on (King, 2007). Since it is widely accepted that operations and sustainment cost of a product composes more than 60-70% of the product's life cycle cost, or "total ownership cost", it is important for decision makers to understand that cost. The panel members he interviewed strongly agree the most important element in the development of a total ownership

cost framework is to make this consideration a priority “from the very beginning in a development program”.

Product supportability considerations is progressing to be incorporated earlier in the development phase. “Involvement of product support is greater in the products developed in recent years than in the past” (Anagnostopoulos, Product Support and the New Product Development Process, 2006, p. 29). More companies now are employing a stage-gate model of product development and product supportability has become a considering element in allowing the development effort to proceed to the next phase.

In the Systems Engineering field, “logistics engineering” has also taken on more importance in past years. In Dr. Garett Scott Patria’s “Model-Based Systems Engineering Application to Analyze the Ground Vehicle and Robotics Sustainment Support Strategy” paper, a comprehensive focus on logistics engineering (synonym to DFS) is presented for incorporation into the Model-Based Systems Engineering (MBSE) framework (Patria, 2017). It is stated that MBSE enables the integration of logistics engineering into the acquisition process by presenting sustainment support strategies across multiple platforms. It allows for DFS to be incorporated into the design parameters and for it to be naturally considered by the engineers.

According to Dr. Anagnostopoulos, “Priority of the development objectives, timing and sequence of activities has to be established” in the early planning phase and it must include product support considerations (Anagnostopoulos, Product Support and the New Product Development Process, 2006, p. 13). In the four prominent companies (including HP and Xerox) Product support presented a surpassing importance to customers in all four companies when making decisions. These companies, during the New Product Design (NPD) phase, all placed heavy emphasis on product support and sustainment and try to “design-in” these considerations

during the design phase. DFS is not an afterthought to try to incorporate after the product design is solidified. It is mentioned that in DFS, product service requirements are set before the start of product development "in order to ensure high serviceability" (Anagnostopoulos, Product Support and the New Product Development Process, 2006, p. 29).

There is ample amount of information that supports the notion that DFS must be incorporated at the beginning of product design and it is not just an "accompanying feature" that is a good-to-have. Instead DFS is a must-have if the developer wishes to be able to service customers in an efficient and effective manner as well as allowing the intended function to be utilized to maximum capacity by the user.

D. Questions that are Not Answered

After searching and examining through the available research papers, journal articles, conference transcripts, Government Accountability Office (GAO) reports, and congressional hearing transcripts, there still lacks answers to some of the lingering questions regarding *why* there is a gap between policies, procedures, leader's notions when compared to the actual inclusion of DFS or sustainment/logistics engineering earlier on into the product design process.

While Dr. Goffin's research paper listed out some factors that stand in the way to integrate product support considerations, including (Goffin, Design for Supportability: Essential Component of New Product Development, 2000):

1. Support requirements are considered too late in the product development cycle
2. Field support engineers and managers, who know support problems first-hand, do not have the opportunity to influence product designs
3. Decisions taken to lower production costs may make support more difficult or expensive

4. Product features (performance) often take priority over product support considerations

These "factors" do not answer the question why these factors exist in the first place.

Dr. King's paper listed out additional reasons that contribute to the phenomenon, which is captured in the term total ownership cost (King, 2007):

1. There is a lack of understanding and poor communication of the value of the total ownership cost concept
2. There is poor availability and accessibility of the data necessary to perform total ownership cost analysis
3. There is a lack of long-term systems planning to implement total ownership cost strategies

The field of study have abundantly pointed out the contributing factors to the phenomenon of product supportability being forgotten in early product development stage. However, the root cause of these contributors have not been explored. Why are field support engineers and managers not incorporated into the design team while it is widely accepted that they are the Subject Matter Experts (SME) in this topic? Why programs do not perform comprehensive planning and acquire the right stakeholders into the design team in the first place? Why does poor availability and accessibility of the data hamper engineers to think about supportability? Why is there poor availability of data in the first place?

E. What is lacking in the Research Field?

There lacks a comprehensive research into why there is such a wide gap between notion and action. Normally when one knows he/she is sick, the person will take actions to address that sickness by either going to see a doctor or taking better care himself/herself, or even both.

However, it seem that the incorporation of product supportability design considerations into the actual project management process is an unnatural task that DoD Science and Technology community and the acquisition community needs to be constantly and deliberately reminded of. Despite the confirmed notion that DFS should be done as early as possible and an abundance of policies and guidance to assist the practice, logisticians and product support managers still require extra effort to influence product design pre-milestone A and B in the DoD Acquisition Life Cycle Framework (this statement also applies to AAF).

While the commercial sector is increasingly seeing the value of incorporating product support and sustainment considerations earlier on; for instance, the aviation industry. But this notion is adopted due to high level of competition and high demand from the end-users (airlines) (Goffin, Design for Supportability: Essential Component of New Product Development, 2000). If customers are not taken care of and product support/sustainment cost is not under control, the company will not be able to survive the competitive and dynamic business environment.

The DoD is an organization with its unique structure, culture, funding process, and missions. Could these fundamental and inherent nature of the DoD be contributing factors to the difficulty of product support inclusion? This research paper aims to fill the gap of the study of the root causes that contribute to the lack of execution of DFS and the inclusion of the product support community at the beginning of projects.

III. CHAPTER 3 – RESEARCH METHODOLOGY

A. Research Question – A Review

There are five main research questions this paper is trying to answer. This research methodology section aims to propose a comprehensive structure that lays out the appropriate path that leads to answer discoveries. The five research questions are as follows:

- What is the current logistics supportability analysis and engineering process in the acquisition process and is it adequately executed?
- If it is not adequately executed, why is this happening despite plenty of policies and guidance that encourages to do so?
- If it is adequately executed, how can it be enhanced so the Army's priority to seek "readiness" can be incorporated in the product acquisition process?
- Who are the major direct stakeholders that need to pay attention to this topic?
- What/Who are the distractions that turn projects' attention away from thinking early about product support? And why?

B. Research Design and Validity of the Research

To answer these research questions, a conglomerate of data must be gathered from current DoD Acquisition policies and procedures, academic studies, the United States Government Accountability Office (U.S. GAO), journal articles, and applicable conference recordings. Due to the limitation of conducting interviews or focus group panels, only existing data can be gathered and analyzed and no new data can be generated as a part of this research paper.

To address the current state of supportability analysis and engineering process, current up-to-date DoD acquisition policy and procedures will be thoroughly examined. The level of execution will be examined from U.S. GAO reports, journal articles, and academic research papers.

To analyze the root cause of the lack of early supportability analysis and engineering practices, if any, a mixture of data from various functions need to be examined. This includes not only policy and procedures on the DoD Acquisition level, but will also include specific practices in the following areas:

- Systems Engineering field
- Program Management processes
- Human Resource field
- Programming and Budgeting field
- Data Management processes

The systems engineering field will provide insights to how the current requirements generation and the subsequent technical management process affects the product support analysis and engineering efforts. As Goffin mentioned in his paper regarding the fact that product supportability requirements are considered too late in the life cycle (Goffin, Design for Supportability: Essential Component of New Product Development. , 2000). The reason for this phenomenon may lie within the current systems engineering approach to requirements development and management in conjunction with the current acquisition life cycle framework.

The program management processes will be examined to first compare the past DoD Acquisition Life Cycle Framework and the changes taking place in the upcoming Adaptive Acquisition

Framework. The purpose to examine the program management process, to include the scheduling and performance management doctrines, is to see if the inherent nature of the current program management paradigm actually is conducive to early product support analysis.

The human resource aspect of the acquisition process will also need to be examined. The purpose is to examine if the rotational assignment of military acquisition Program Managers (PM) has an impact on decision making and project planning activities. Military ranking officers rotate in and out of the PM position every few years and its impact on acquisition strategy will be examined through this paper.

The programming and budgeting topic will also need to be examined in order to see if the phenomenon of the lack of early product support considerations is a result of the inherent system and structure of the budgeting cycle.

Finally, the data management topic needs to be examined since it was mentioned by Anagnostopoulos in his paper that a lack of data and information from the sustainment field presents obstacles for in-depth and fact-driven analysis for product support analysis in future development projects (Anagnostopoulos Z. , 2006). This paper seeks to examine whether there is indeed a lack of information feedback loop that allows for sustainment data to be collected, managed, analyzed, and resolution sought for future project considerations.

This research paper will use qualitative method to examine the topics presented above. The qualitative method will include the collection of findings, opinions, conclusions drawn from statistical studies, and U.S. GAO reports to draw conclusions based on this set of information.

Recommendations will be more opinion-based due to the subjectivity of the author and the derived conclusions of the findings. Due to the lack of information that serves as direct answers

to the research questions, certain derived conclusions will be made and presented in the recommendations section.

C. Bias and Error

The main body of this research paper is comprised of information extracted from published research papers, journal articles, the U.S. GAO reports, and various conference recordings. The goal is to examine the desired state presented by the actual DoD policies and procedures and its actual level of execution. The research questions are formulated in a manner that is open to both a positive and negative confirmation on whether or not the state of product support analysis and engineering activities is in a desirable state.

However certain level of bias is still possible due to the existence of non-peer reviewed sources in the library of examined documents. This research paper will strive to balance various viewpoints, if any, and present in a factual manner.

D. Reliability of the Data

Due to the fact that this is a qualitative research paper and data ranges from factual policies and procedures to U.S. GAO reports to research papers to opinion papers; listed in cascading objectiveness. The reliability of the data is not supported by quantitative studies and statistical analysis, however the reliability is supported by well-documented and researched articles and GAO reports.

IV. CHAPTER 4 – DATA COLLECTION

A. Current Department of Defense's Acquisition Process

The United States Department of Defense (DoD) has a formal set of policies, instructions (procedures), and complimentary guidebook that establishes the acquisition process. These set of important documents are the DoD Directive 5000.01 – The Defense Acquisition System (DAS) (Defense, DoD Directive 5000.01, 2020), the DoD Instruction (DoDI) 5000.02 Operation of the Adaptive Acquisition Framework (AAF) (Defense, 2020), and the Defense Acquisition Guidebook (DAG) (Defense, Defense Acquisition Guidebook, 2020) serving as a set of best practices for the acquisition community to execute to.

There are specific section within each of the documents regarding sustainment and product support. In the DAG, the terms "sustainment" and "product support" are used interchangeably. In DoD 5000.01, policy paragraphs "l" and "m" specifically laid out the policy to plan for product support and implement effective life cycle management. In DoDI 5000.02, section 3 lays out the "Product Support Manager" (PSM) role and also the life cycle responsibilities of the Program Managers (PM) and the Program Executive Office (PEO). Along with DoDI 5000.UG "Major Capability Acquisition" paragraph covering the former Enclosure 6 Life Cycle Sustainment from the now obsolete DoDI 5000.02T. As for the DAG, the entire chapter 4 is dedicated to Life Cycle Sustainment.

Starting in the DoD 5000.01 paragraph m, it is stated that "The PM is accountable for achieving program life-cycle management objectives throughout the program life cycle. Planning for operations and support will begin at program inception, and supportability requirements will be balanced with other requirements that impact program cost, schedule, and performance."

(Defense, DoD Directive 5000.01, 2020). It is important to take note that the planning of operations and support should begin at "program inception" and that supportability requirements should be considered along with other requirements. This research paper will come back to this point in later paragraphs.

Following DoD 5000.01, the DoDI 5000.02 further defines the role of the PSM, a key position that drives the entire product support strategy effort. It is stated that "Under the supervision of PMs, product support managers develop, plan, and implement a comprehensive product support strategy…product support managers will make use of data-drive decision making tools with appropriate predictive analysis capabilities to improve systems availability and reduce costs." (Defense, DoD Instruction 5000.02 Operation of the Adaptive Acquisition Framework, 2020).

As a complimentary document to the DoD 5000.01 and DoDI 5000.02, the DAG further provides more detailed best practice to both PM's and PSM's to follow during the acquisition process. To start framing the product support topic, there are twelve Integrated Product Support (IPS) elements categorized into three main sections.

Section 1, Life Cycle Management:

- Product Support Management
- Supply Support
- Packaging, Handling, Storage, and Transportation (PHS&T)
- Maintenance Planning and Management

Section 2: Technical Management

- Design Interface
- Sustaining Engineering
- Technical Data
- Computer Resources

Section 3: Infrastructure Management

- Support Equipment
- Training & Training Support
- Manpower and Personnel
- Facilities and Infrastructure

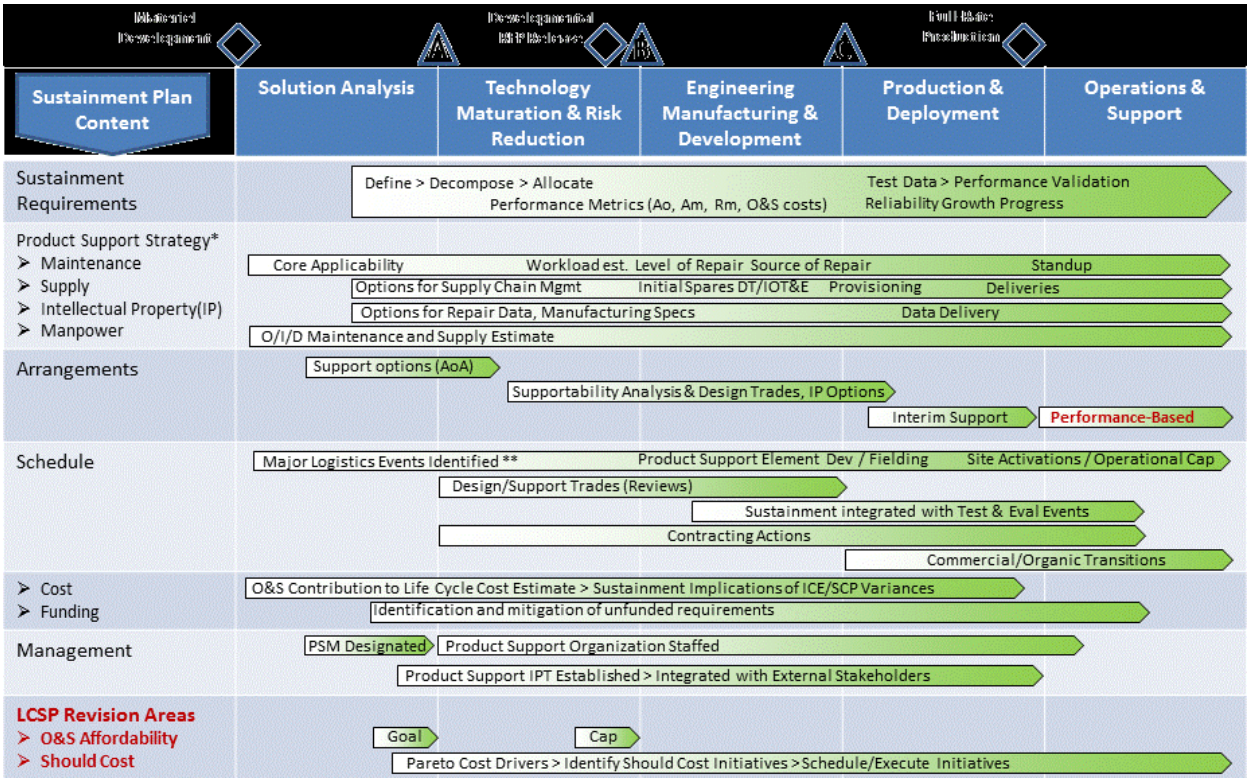
It is specifically stated that "These IPS elements are relatively immature in the Materiel Solution Analysis (MSA) Phase….As the logistics, requirements, engineering, and resource communities mature the program and refine the product support strategy, the PM increases the detail of each IPS element in the product support package to inform the execution of the strategy" (Defense, Defense Acquisition Guidebook, 2020, p. 3).

The Life Cycle Sustainment Plan (LCSP), as the capstone document that records the evolving product support strategy for the system that is being acquired, is described as "an evolutionary management document describing the program's approach to achieve a flexible, performance-oriented product support capability". (Defense, Defense Acquisition Guidebook, 2020, p. 3). The LCSP is to be developed and maintained beginning at Milestone A. The actions to be done to achieve sustainment requirements are to be described by Milestone B. By Milestone C, it should indicate the implementation status of the product support package. For post-Milestone C,

it "describes the plans for sustaining materiel availability and for accommodating modification, upgrades, and re-procurement." (Defense, Defense Acquisition Guidebook, 2020, p. 3)

In the DAG, with the roles of PM's and PSM's and the recording function of the LCSP, they establish the overall framework to ensure product supportability is considered early on and often. The DAG also included an "Overview of Life Cycle Sustainment Activities" (Defense, Defense Acquisition Guidebook, 2020, p. 4), which begins from project conception all the way through Operations & Support (O&S) phase.

FIGURE 1: Overview of Life Cycle Sustainment Activities



(Defense, Defense Acquisition Guidebook, 2020, p. 4)

As indicated in the figure, during the first phase of the acquisition life cycle, the MSA phase, product support strategy, especially the maintenance and manpower elements are to be examined at the inception of the development projects. Analysis of alternatives (AoA) of support arrangements should be examined. Major logistics events should be identified in the schedule. O&S cost estimates are to be conducted, even though much of the actual product design is still to be matured. Legacy system information can be used along with the new product's use case to formulate a draft cost estimate. PSM should be designated and product support organization should be staffed along with a chartered Product Support IPT.

All of the activities listed above should all begin in the MSA phase and should not be obstructed by the fact that a project has not yet become a program of record, thus "PM managed". It is stated in the DAG that "there may be instances where there is no designated person for the role, such as during early capability or concept development. When there is no assigned PSM, trained life cycle logisticians (LCLs) in headquarters organizations or Program Executive Offices (PEOs), or temporarily assigned PSMs, can complete necessary actions. For lower tier programs (Acquisition Category III/IV), a PSM or life cycle logistics (LCL) staff with a portfolio of programs performs the necessary activities." (Defense, Defense Acquisition Guidebook, 2020, p. 4)

Furthermore, during the MSA phase, multiple sustainment related topics should be addressed, including:

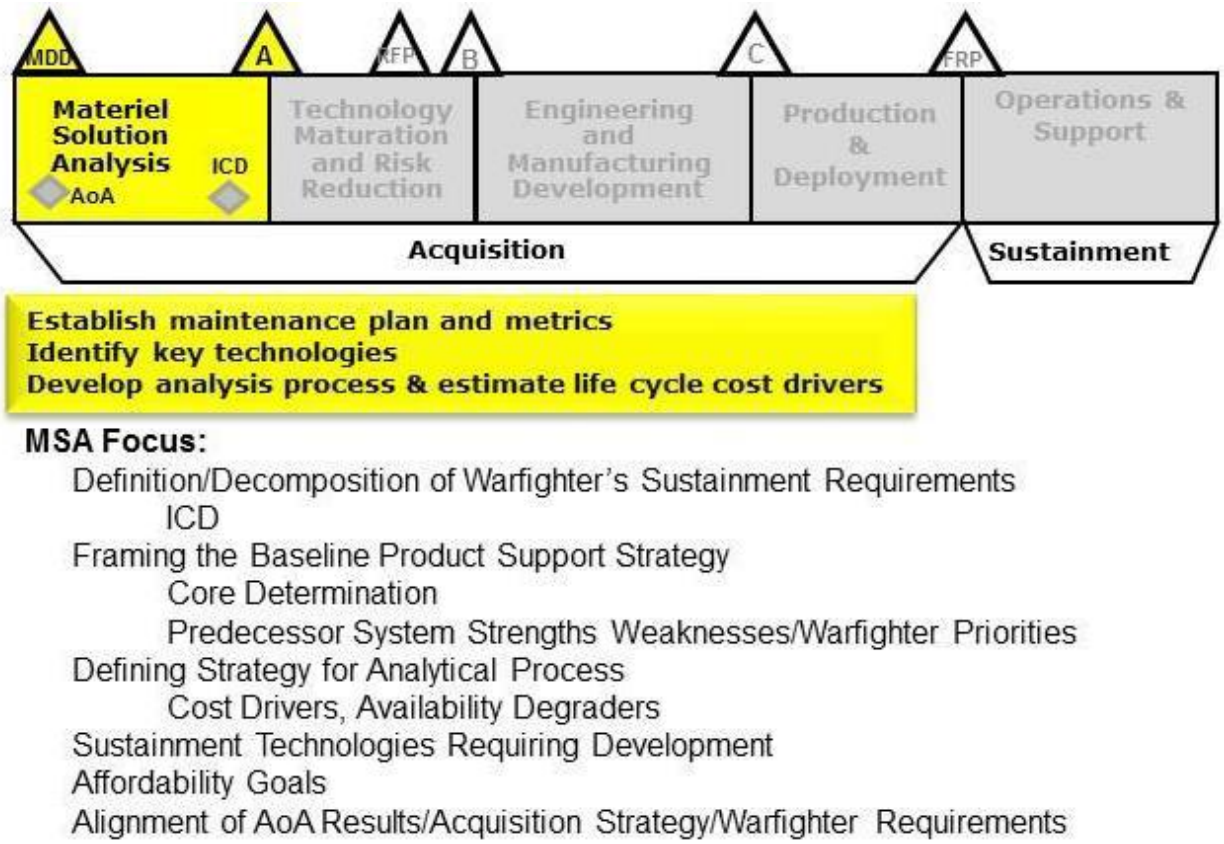
- Requirements Development: Defining/Decomposition of Warfighter's Sustainment Requirements Initial Capability Document (ICD)
- Framing the baseline product support strategy

- Core Determination
- Predecessor System Strengths Weaknesses/Warfighter Priorities

- Defining Strategy for Analytical Process
  - Cost Drivers, Availability Degraders
- Sustainment Technologies Requiring Development
- Affordability Goals
- Alignment of AoA Results/Acquisition Strategy/Warfighter Requirements.

This is graphically represented in figure 2: "MSA Sustainment Planning Activities" (Defense, Defense Acquisition Guidebook, 2020, p. 5)

FIGURE 2: MSA Sustainment Planning Activities



(Defense, Defense Acquisition Guidebook, 2020, p. 5)

It was specifically mentioned that sustainment requirements should be stated in the ICD and it will help determine the sustainment AoA going forward.

It is stated that requirement trade-offs should be balanced between performance-related characteristics and sustainment considerations. In combination with the sustainment AoA, it will ensure that the life cycle perspective of the product is considered.

As sustainment AoA is being considered, O&S cost is an important ingredient that feeds into the AoA. Cost elements such as:

- Maintenance Strategy
- System/Component weights
- Number of systems to be sustained
- Fuel usage/energy consumption
- System complexity
- Operations Temp (OPTEMPO) constraints
- Required manning to operate/maintain/support
- Transportation requirements, including storage and environmental requirements
- Planned/required future upgrades
- Software refresh schedules/licensing agreements
- Hardware refresh cycles
- Projected service life

(Defense, Defense Acquisition Guidebook, 2020, p. 7)

It is further reinforced in the DAG that "DoD Components should begin product support planning as soon as the Milestone Decision Authority (MDA) determines that a materiel solution is needed to satisfy the capability requirements. This timing often precedes formal establishment of a program of record and staffing of a program office." (Defense, Defense Acquisition Guidebook, 2020, p. 8) As mentioned before, in the event where a PM and PSM have not yet been assigned, the LCL will assume the responsibility to conduct early product support analysis during the early stages of product development.

The LCL should participate in various activities including trade studies, cost analyses, and business case analyses. The LCL/PM should also determine whether there is a need to develop sustainment technology to enable the effective use of the acquired system.

By actively participating in the product IPT and also performing all of the sustainment planning activities mentioned in figure 1 and 2, the LCL/PSM and the ICD will inform the Capability Development Document (CDD) that contains all requirements for the system. Sustainment requirements will include the "Availability Key Performance Parameter (KPP), the Reliability Key System Attribute (KSA), and the O&S cost KSA". (Defense, Defense Acquisition Guidebook, 2020, p. 11) The CDD is to be drafted prior to Milestone A, which will eventually mature into the finalized CDD and draft Capability Production Document (CPD) by Milestone B. The CPD is a key decision guide for the program's production decisions and includes the refined sustainment requirements. These sustainment requirements are informed by engineering and test events as well as lessons learned throughout the development process and legacy system.

The aforementioned ICD, CDD, and CPD are the key requirements documents that is matured throughout the acquisition life cycle. It is governed by the Joint Capability Integration

Development Process (JCIDS) in which requirements are reviewed by the Joint Requirements Oversight Council (JROC). Both the JCIDS and JROC is chartered by the "Charter of the JROC and Implementation of the JCIDS" document, instructed by the Chairman of the Joint Chiefs of Staff (Staff, 2018). JROC's title 10 mission and responsibilities include seven main responsibilities that includes the generalized functions of assessing capability gaps to fulfill the National Defense Strategy (NDS), reviewing requirements to ensure gap fulfillment, assess requirement alternatives, and propose joint capabilities to the acquisition community (Staff, 2018). JROC is chaired by the Vice Chairman of the Joint Chiefs of Staff (VCJCS) and the following officers from each service (Staff, 2018, pp. A-3):

- An Army Officer in the grade of General
- A Navy Officer in the grade of Admiral
- An Air Force officer in the grade of General
- A Marine Corps officer in the grade of General

It is also joined by a team of advisors from the DoD, including multiple Under Secretaries, Director of Cost Assessment and Program Evaluation (CAPE), the Director of Operational Test and Evaluation (DOT&E).

Together, with the JROC and JCIDS framework, it forms an iterative process to initiate and mature requirements from project conception all the way through production and fielding.

Overall, it is evident, from the set of DoD acquisition policies, instructions, and guides, that product support elements is to be considered early on. The role and the function of product support management should begin early in the project life cycle. Sustainment requirements and

considerations should be fully balanced with performance related considerations along the acquisition process.

Continuing in the following sections, there are multiple categories of information found that relates to the status of implementation of the set of policies and instructions as well as problems facing the early integration of product support activities into projects.

B. Requirements Development Process and Criteria not Defined

In the journal article "Design for Supportability as a Means of Reducing Technology Transition Risk", it states "When supportability considerations are taken into account early in the design and development phases, key performance parameters (KPPs) such as reliability and operational availability can be optimally met." (Ealy, 2018, p. 1) It is also mentioned in this article that "The intention of the Design for Supportability competency is to catch design issues which may become major reliability or logistical issues early on in the design process so that they do not cause major surprise or delays later in a program." (Ealy, 2018, p. 7)

The Navy and Air Force Case Study

Multiple sources, especially from Government Accountability Office's reports, have found that the requirements development process has both implementation gaps and inherent weaknesses.

For the Navy Ship Building Projects, multiple PMs and PSMs are interviewed and several weaknesses in the current requirements development process is found (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020). It is said that "GAO found that shipbuilding programs' requirements for sustainment reflect weaknesses with how Department of Defense (DOD) policy defines these

requirements for ships." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. Introduction) Sustainment requirements should play a key role during product acquisition but the Navy's sustainment requirements "do not provide key information on how reliable and maintainable mission-critical systems should be and, therefore, cannot adequately inform acquisition decisions." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. Introduction).

With 70% of the life cycle cost of a ship program incurred during the O&S phase, 80% of a program's O&S cost is fixed during the requirements definition and engineering process. The sustainment requirements are defined as "Reliable, available, and maintainable" (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 6) and would require the involvement and communication of multiple key stakeholders including the program manager, requirements officials, ship design managers, engineers, PSMs, and others. To govern its own acquisition process, the Navy has designed a gate review process that each acquisition program needs to go through when it arrives at a major decision point. There are seven gates, with the first three being the requirements setting gates, chaired by the Chief of Naval Operations (CNO). The next four gates are focused on acquisitions and are chaired by the Assistant Secretary of the Navy for Research, Development, and Acquisitions (ASN (RD&A)) and at times co-chaired with the CNO (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 8).

Both DOD and Navy acquisition policies require shipbuilding programs to include sustainment throughout the acquisition process, starting prior to Milestone A. The major planning document being the aforementioned LCSP and sets the foundation for how the ships will be sustained.

However, the GAO report has found that in the shipbuilding programs that were assessed, including major programs such as the DDG 1000 Zumwalt class destroyer, the DDG 51 Arleigh Burke class guided missile destroyer, the (LCS) Littoral Combat Ship, the CVN 78 Gerald R. Ford class aircraft carrier, and various other major programs, that it "identified 150 programs that effected multiple ships in a class…. The Navy's fleet has spent or is planning to spend at least $4.2 billion to mitigate and correct approximately 30% of these problems beyond what was planning for during the acquisition process." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 16)

These 150 problems are all identified as sustainment issues and affects multiple ships in the same class. These problems require more effort and money than what was anticipated which were verified through Navy documentation. These problems have contributed to: (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 18)

- Nearly 5,300 total days of delays to planned maintenance and availabilities since 2012 on ships built during the last 10 years.
- New Ships deferring planning maintenance, and
- Insufficient funding to meet maintenance needs.

It is a costly undertaking if these problems require the replacement of the broken systems. And if a permanent solution is not chosen, it would require "more onerous maintenance approach than expected." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 19). For example, on the new CVN 77 and 78 aircraft carriers, the Navy chose to use commercial grade toilet and sewage systems that were not adequate to serve a crew of 4,000 people, resulting in additional acid flush maintenance actions of $400,000. This acid flush operation will need to be repeated for as long as the ship is in service.

There are three main categories of problems identified for the increased sustainment issues found (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 20):

- Problems maintaining commercial equipment on ships
- Ship designs that did not effectively consider maintainability
- Untested sustainment assumptions that turned out to be incorrect after ships were delivered to the fleet

More sustainment issues were given, including:

- Biofouling inside a titanium pipe on LPD 17 class ship (San Antonio Support Ship)
- Flight I knuckle boom crane on LPD 17.
- Special hall treatment required for SSN 774 (Submarine)
- Commercial systems failure on LHD 8 and LHA 6 machinery control systems (Amphibious Assault)

It is specifically stated that the sustainment requirements directed by DOD and Navy policies "do not capture factors that affect whether ships are reliable and maintainable." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 28)

It is found that there are three main weaknesses related to sustainment requirements development and implementation, including (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 28):

- Setting the sustainment requirements: Poorly defined sustainment requirements that do not represent the availability of the ship during O&S
- Using the sustainment requirements: "Due to problems setting the requirements, shipbuilding programs cannot incorporate the sustainment requirements into acquisition decisions."
- Reporting on the sustainment requirements: Navy has a misleading reporting statue and the reports do not reflect the actual experience of the fleet.

A key issue in the JCIDS process is that "DOD requirements setting policy do not capture all factors that reduce the ability of ships to achieve their missions." Catastrophic failures of mission-critical systems and unplanned maintenance that reduce ship availability is not captured. They two key sustainment related requirements are operational and materiel availability, but these requirements are just a small part of a large amount of key performance parameters that a weapon system has to satisfy. Furthermore, the overall availability requirement for the entire ship, which is comprised of multiple sub-systems, does not reflect the required sustainment actions of each sub-system. "Without a definition for ship sustainment requirements in DOD

policy that accounts for all factors that make Navy ships unavailable for operations, Navy Shipbuilding programs cannot reasonably ensure that they are setting sustainment requirements that will result in reliable, maintainable, and available ships." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 29)

The Navy fleet writes casualty reports that includes 3 casualty categories. Category 4 representing the most severe and along with category 3, these two categories indicate degradation to critical mission capability that needs immediate repair. "Category 2 reports contain failures that are important to the fleet but do not affect the ship's core missions." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 29).

DOD's definition for operational availability accounts for only the category 4 reports and excludes category 3 reports. Category 4 reports are only used when the entire ship is out of commission and category 3 reports actually capture the bulk of sustainment breakdowns of each of the sub-systems. "In other words, there are additional deficiencies that could be mission-critical that may not be captured by category 3 or 4 casualty reports." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 30)

Interestingly, for the 18 ships that GAO reviewed, they represent a near-perfect operational availability when using category 4 casualty reports. However, when category 3 reports are incorporated, 14 of the 18 ships fall short of the operational availability requirements.

DOD requirements setting policy directs that "shipbuilding programs should establish a single metric for the entire ship." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 31). However, if the operational availability is set at the ship-level, then it is very difficult ("improbable", as stated by the Naval Sea Systems Command operational availability manual) to capture the availability requirements for each sub-system, which each ship is comprised of hundreds of sub-systems. Further, the ship-level availability requirement does not reflect which sub-system (or a family of sub-systems) is mission-critical and which ones are not.

Regarding material availability, the GAO report "found that DOD's definition of materiel availability for Navy ship classes in its requirements setting policy does not ensure that ships will be ready when needed." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 33) There are three factors that affect materiel availability which are not accounted by the DOD requirements setting policy (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 33):

- Unplanned maintenance: When the planned ship maintenance "lasts longer than expected or a mission critical failure occurs during deployment that needs immediate attention"
- Unplanned losses: "Instances when a ship is out of commission for an extended length of time due to severe damage or when a vessel was not prioritized for maintenance.
- Training: DOD requirements policy does not address unavailability of ships during training periods.

There is a mixture of different degrees of materiel availability requirements set on these shipbuilding programs. Some have ignored the statue, some implemented it, and some went above and beyond. However, since DOD's definitely for materiel availability "does not include all factors that could result in a ship being unavailable for operations, shipbuilding programs cannot ensure that ships will be ready when needed." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 34)

Due to the current gaps and weakness in sustainment requirements setting, these requirements are inadequate to support well-informed decisions during the acquisition process.

It is found that this phenomenon continues to happen for ongoing and new shipbuilding programs. Acquisition decisions that influence sustainment are being made without better-defined sustainment requirements.

In order for engineers to incorporate sustainment considerations into the design, sustainment requirements must be firm, well-defined, feasible, and affordable. However, with the current inadequately defined sustainment requirements, it is difficult for engineers to fully consider them and building into the design. It is reported that "Navy ship engineers told us that they interpret the requirement to only apply to catastrophic failures that put the entire ship out of commission." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 35). This in-turn, does not allow for a more refined approach to sub-system sustainment requirements development.

As for the Air Force,

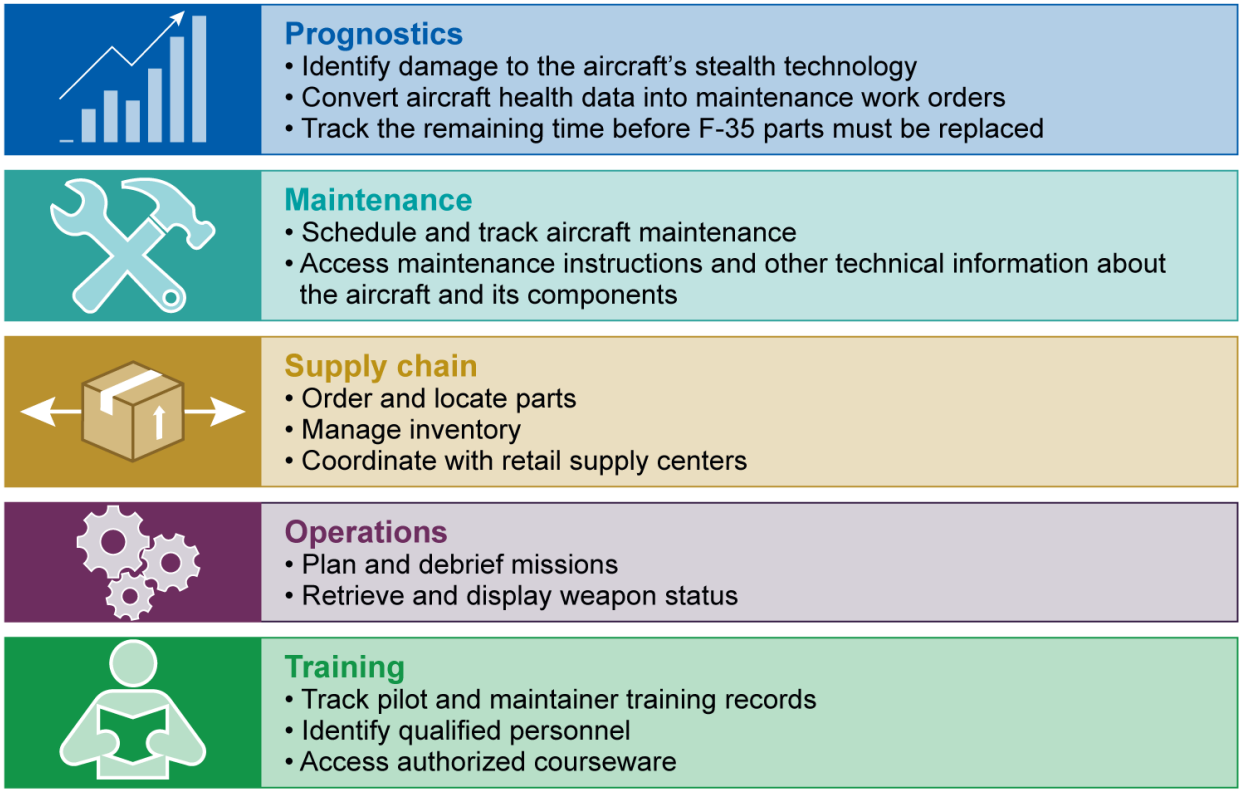
The F-35 program is one of the largest and most expensive ACAT I program in the history of DOD. The central nervous system of its logistics support function is the Autonomic Logistics Information System (ALIS). It is stated that "DOD has experienced significant challenges sustaining a growing F-35 fleet. GAO has made over 20 recommendations to address problems associated with ALIS, spare parts shortages, limited repair capabilities, and inadequate planning." (Maurer, 2020, p. Introduction).

The ALIS integrates multiple key capabilities into one system, including:

- Prognostics
- Maintenance
- Supply chain
- Operations
- Training

A detailed capabilities chart is listed in figure 3.

FIGURE 3: ALIS Capabilities Chart



Source: GAO analysis of Department of Defense documents. | GAO-20-665T

ALIS intends to support many of F-35's key performance parameters:

- Increase sortie generation rate
- Increase mission reliability
- Reduce logistics footprint

However, as ALIS is fielded along with the fielding of the F-35 fleet, it is reported that there are seven challenges presented by the system and requires a system redesign in order to fix all of the reported problems.

- Inaccurate or Mission Data

- Challenges Deploying
- Increasing Personnel Needs
- Inefficient Issue Resolution Process
- Poor User Experience
- Immature Applications
- Ineffective Training

A detailed chart includes the detailed description of the types of issues reported, presented in figure 4 (Maurer, 2020, p. 4).

FIGURE 4: Types of Issues Reported for ALIS

User issue	Types of Issues Reported
Inaccurate or Missing Data	Inaccurate or missing data in ALIS has, at times, resulted in the system signaling that an F-35 aircraft should not be flown even though the aircraft has no issues that require it to be grounded and is ready for flight. Military service leadership then decide whether or not to assume risk and fly an F-35 that ALIS tells them to ground.
Challenges Deploying	Taking ALIS on a deployment can be challenging because the required hardware is bulky to transport, internet connectivity is frequently limited, and significant advanced planning is required.
Increasing Personnel Needs[a]	F-35 squadrons are finding that they need more personnel than originally planned to support ALIS operations.
Inefficient Issue Resolution Process	Solutions to overall F-35-related issues, including ALIS-related hardware and software issues, are not shared in ALIS across the fleet, resulting in a reliance on contractor support to address problems that may have already been resolved.
Poor User Experience	ALIS is not very user-friendly or intuitive, can be difficult to navigate, and standard functions can take more time than users expect to complete.
Immature Applications	The Training Management System application within ALIS does not fit the needs of and remains unused by most users, while the Off-board Mission Support application remains difficult to navigate without the help of contractors.
Ineffective Training	Current training for ALIS generally does not prepare users to operate ALIS, and most knowledge about the system is obtained through on-the-job-training.

Source: GAO analysis of information obtained from 5 U.S. F-35 locations through documentation and/or discussions with pilots, maintainers, and supply personnel. | GAO-20-665T

(Maurer, 2020)

It was reported that at one location, a user reported 400 issues per week within a 6-months period in 2019 that are related to inaccurate or missing electronic records. Users said that they would use their own method to track information outside of ALIS and did not always trust the system.

It is stated in the GAO report, given by Ms. Diana Maurer, Director of Defense Capabilities and Management, to Congress, that the ALIS's primary testing focus during version releases is only on whether or not the new version is performing better than the older version. According to officials "tests are not determining if the ALIS system is performing to a specified standard because DOD has not defined this standard." (Maurer, 2020, p. 7) There was no explicit performance standard developed for the ALIS and thus the system was not designed or tested to performance standards. This in-turn, could affect the overall F-35 fleet readiness. This is backed up by user interviews that stated problems with ALIS were affecting the overall readiness of the F-35 in all five locations that GAO visited. However, the strength of correlation between ALIS problems and lack of fleet readiness is yet to be determined.

The reports states that DOD has limited attention on ALIS over the years and has resulted in a troubled history with the system and that the system itself cannot be sustained into the future.

As DOD tries to determine the path forward for a system redesign, key technical data from the prime contractor presents a challenge as DOD tries to lead software development. "At a November 2019 congressional hearing, the Under Secretary of Defense for Acquisition and Sustainment stressed that many of the challenges with ALIS stem from the fact that ALIS data are fed back through prime contractor computers, and there is resulting ambiguity over the ownership of that data." (Maurer, 2020, p. 11).

Data rights is one of the twelve main product supportability elements that needs to be considered during sustainment planning and it is evident that this was not considered during the acquisition process.

Private Sector Product Support Requirements Weakness

Product Support, or customer service, are the two interchangeable terminologies in the private sector that represents actions necessary to maintain and sustain product functions for customers after purchase. These actions are equivalent to the product support and sustainment actions to the military when equipment is developed and fielded into the soldier's hands.

It is reported through research and studies that product support considerations are lagging behind performance related considerations when designing a new product. In a research paper published by Dr. Anagnostopoulos, titled "Product Support and the New Product Development Process" (Anagnostopoulos, 2006), several project managers and product support managers for new product development from prominent companies were interviewed. These companies manufactures automobiles for both the professional and consumer markets. Case studies for product A and product B were conducted and findings were presented. The answers from the interview "showed that the position of product support in the organization has limited effect when making decisions about new products." (Anagnostopoulos, 2006, p. 45) Product support is often considered second to sales or product functionality design. All managers agreed on the importance of product support elements as customers have provided feedback such as "Extremely important…. Product support is a quite major element of why we choose a product." (Anagnostopoulos, 2006, p. 46).

In the case studies of this research paper, "In the very first steps of the product development process of both products A and B, the Ideation point, the product support department does not have any influence…. At this first stage of product development, the product support involvement 'did not start immediately with the initial concepts, but was considered very early

on'". (Anagnostopoulos, 2006, p. 52). Even though product support representatives were often present at the early stage, but their influence on product design was not evident.

However, with product A of the case study, the "Brand Positioning Document" for the product showed that he Automotive company wanted to achieve cost-of-ownership performance in the market and thus product A's product support design was phased-in to the product design process earlier on. This represents that when cost-of-ownership is the main consideration, product support will be considered more and emphasized earlier on.

Even with the emphasis on cost-of-ownership, product A's product support representatives still faced challenges when competing with other product requirements. It was stated that "the visibility of service within the product development phase is somewhat limited. I think service doesn't always get the priority that maybe it should have." (Anagnostopoulos, 2006, p. 55)

As for product B, there is evidence that the company consciously tried to incorporate more product support considerations into the design. However this is mainly due to the presence of early and competition-based goals presented to the product development team. This can be translated as a better-defined requirements presented to the development team and enabled them to incorporate clearer product support requirements into the design.

In another research paper, "Design for Supportability: Essential Component of New Product Development" (Goffin, Design for Supportability: Essential Component of New Product Development, 2000), it listed out the factors that stand in the way of incorporating supportability considerations into the design. These were presented in chapter 2, literature review as well

(Goffin, Design for Supportability: Essential Component of New Product Development, 2000, p. 42).

1. Support requirements are considered too late in the product development cycle
2. Field support engineers and managers, who know support problems first-hand, do not have the opportunity to influence product designs
3. Decisions taken to lower product costs may make support more difficult or expensive
4. Product features often take priority over product support considerations

It was indicated that "support is often neglected during new product design" (Goffin, Design for Supportability: Essential Component of New Product Development, 2000, p. 42) and that less than 50% of companies fully considered service requirements during design. This situation is worsened by the requirement of faster time-to-market becoming the norm.

Field engineers and technicians are the ones with firsthand knowledge of supportability issues. However they are seldom consulted during the product design process. Leading companies like HP, GE, and AT&T are recognizing the issue and are taking steps to incorporate more voices from field personnel. This can be interpreted as lack of sustainment requirements defined by sustainment personnel.

Production-driven and cost-saving decision making criteria could also result in higher product support cost. For example, non-reprogrammable memory chips may save the company money during production, but it will result in much higher replacement cost if firmware needs to be upgraded and thus requiring a total swap out of the chip. This can be interpreted as lack of consideration for sustainment requirements when compared to other product requirements.

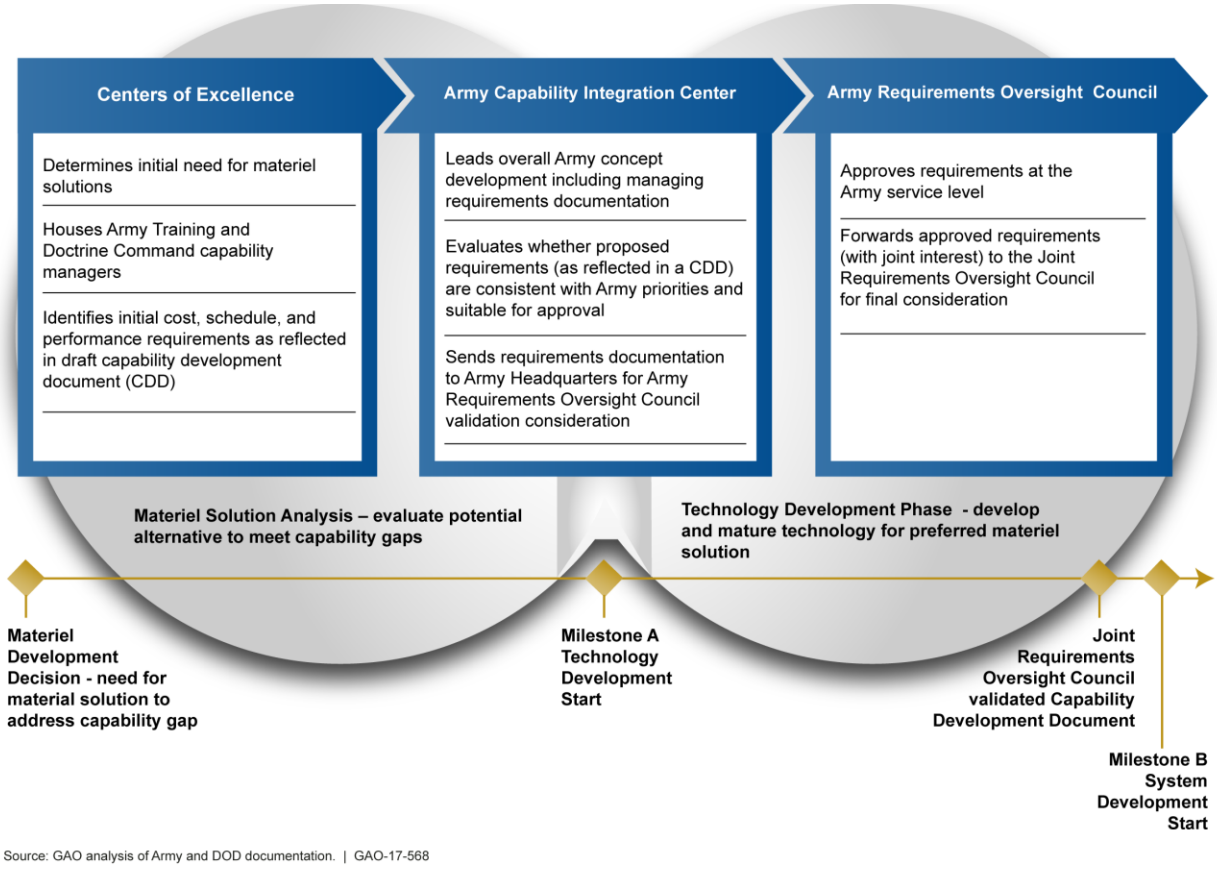
Engineers are found to be more driven to design for product features than for supportability issues. It is considered to be more interesting to focus on features rather than focusing on cost of ownership. Implementing design for supportability may also represent more cost and time during the product development process, thus is less attractive to decision makers.

C. Personnel Structure not Conducive to Early Supportability Consideration

As the US Army reorganizes and establishes the new Army Futures Command to drive modernization and speed up the research and development timeframe, there is a lack of requirements development personnel to accompany the initiative. In the 2017 GAO report "Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements" (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017), it was reported that there is a history of the Army's weapon system programs cancelled due to problems with the requirements. It is stated that "GAO found that the Army is unable to ensure requirements for major defense acquisition programs are well-informed and feasible, as its requirements development workforce is declining" (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017, p. Introduction). From data gathered since 2008, the requirements development workforce decreased by 22 percent and the trend is continuing.

The Army's requirements generation process, starting from the Centers of Excellence (CoEs) to the Army Capability Integration Center (ACIC) to the Army Requirements Oversight Council (AROC), then continuing to the JROC in the JCIDS process, are now a part of the Army Futures Command. The process is presented in figure 5:

FIGURE 5: Army's Requirements Generation Process



Source: GAO analysis of Army and DOD documentation. | GAO-17-568

(GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017)

To improve the requirements generation process, the Army has made multiple improvements including (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017, pp. 9-10):

- Establishment of operations research/systems analyst units at Centers of Excellence
- Implementation of guidance to facilitate early knowledge-based decisions at key milestones
- Increased senior leader involvement in requirements approval process
- Increased coordination with other services

While these initiatives are well-intended, but the Army still lacks the proper personnel to execute the mission. The report states "Workforce shortfalls limit the extent to which requirements are well informed and feasible…prioritized combat readiness….acknowledged the risk to other areas, such as requirements development." (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017, p. 11)

It is reported that there is a shortage of personnel in the CoEs and Operations Research System Analysts (ORSAs) are performing other duties supporting the development acceleration effort rather than focusing on requirements development and analysis.

To compound the issue, while the Army's RDT&E budget has increased from 1994 to 2009, but the acquisition workforce had declined. This condition has continued on and is in contrary to the Army's acknowledgement that early on analysis and development of requirements. ACIC, the main requirements development authority within the Army Training and Doctrine Command (TRADOC) has experienced a workforce decline of 26 percent from 2010 to 2017 and is expected a 19 percent further decline into the near future.

The report interviewed four CoEs (Not all CoEs are interviewed) including Aviation, Cyber, Maneuver, and Fires. One center reported that they are so constrained that they can no longer perform effectively as responsibilities continue to grow and resource constraints tightens. They are only operating with 50 percent of the required personnel and the budget is expected to shrink even more in the future. Another center experienced a 65 percent reduction in workforce and cannot perform sufficient requirements development activities.

Despite the across-the-board decline in workforce, the ORSA workforce has remained steady and this is the reason why some ORSAs are tasked with assisting requirements generation.

A key paragraph in the report states: "Officials across the Army recognize the need for increased systems engineering knowledge early in the requirements development process. However, the Army noted in DOD's annual System Engineering Reports to Congress from fiscal year 2012 to fiscal year 2014 that, historically, systems engineers have been utilized after the start of system development instead of earlier in the requirements development process" (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017, p. 14).

From the Decker-Wagner report, many of the Army's acquisition programs did not have positive outcome due to un-executable requirements. As early requirements development enables for early analysis into the risks associated with the system and mitigation methods can be determined earlier on. Several legacy and current programs are listed as examples of the impact of performing (or lack thereof) early requirements development activities. These programs include:

Early Requirements Development Played a Critical Role in System Development:

- Ground Combat Vehicle (GCV)
- Joint Air-to-Ground Missile (JAGM)
- Improved Turbine Engine Program (ITEP)
- Long Range Precision Fires (LRPF)

System Developed Prior to Fully Considering Systems Engineering and Requirements:

- Armored Multi-Purpose Vehicle (AMPV)
- Common Infrared Countermeasure (CIRCM)
- M109A7 Family of Vehicles (FOV)

Entering System Development with Well-Informed Requirements

- Indirect Fire Protection Capability Increment 2 Intercept Block 1 (IFPC Inc. 2-1 Block 1)
- Joint Light Tactical Vehicle (JLTV)

From these different programs, categorized by their treatment of requirements development, it is evident that early requirements development plays a crucial role in program success. However a lack of requirements development personnel is forcing many requirements development effort to take a back seat against competing priorities.

The rotational system of Program Managers is also not conducive to early supportability requirements considerations. "Program managers are in the job for 3 or 4 years and then move on to a different role. As a result, decisions are made to meet short-term goals, and it is difficult for PSMs to advocate for long-term sustainment considerations and justify the value of this approach to program managers." (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 7)

D. Lack of Suitable Personnel and Resource to Carry Out Mission

Furthermore, continuing with the requirements development personnel issue, DOD has a lack of suitable personnel to effectively carry out the acquisition mission.

DOD's PSMs have expressed that there is severe resource constraints that "hindered their ability to influence sustainment-related decisions during weapon system development." (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 6) Limited funding and available personnel makes it "extremely difficult to perform all of the PSM functions without enough personnel to help."

In 2018, there are 78 major acquisition programs across DOD, including aircraft, missile interceptors, submarines, and space-based sensors. These programs would cost over $1.46 trillion to acquire and that is $484 billion more than was expected from the first full estimate (GAO, GAO 18-217 Defense Acquisition Workforce: Opportunities Exist to Improve Practices for Developing Program Managers, 2018). These programs require expert acquisition program managers to manage and coordinate a multitude of functions and activities, including internal and external stakeholders (DOD and private sector). DOD's talent management process to cultivate and train skilled personnel for these positions is critical in satisfying the monumental acquisition portfolio.

Since Program Managers serve as the life cycle management authority for a system, they play a critical role in determining the sustainment strategy and how it is integrated into the acquisition process.

Typically, when a military officer fills a program manager position, a civilian usually fills the deputy program manager position and vice versa. There exists several "opportunity areas" that could help bolster the current acquisition career field and qualified personnel. A few best practices were identified in the report and they are as follows:

- Practice #1: Training classes that allow program managers to share experiences (More on this in the DOD structure section)
- Practice #2: Rotational Assignments
- Practice #3: On-the-job learning and information repositories
- Practice #4: Mentoring programs
- Practice #5: Career paths that describe skills needed to advance
- Practice #6: Financial rewards for good performance
- Practice #7: Education subsidies
- Practice #8: Recognition
- Practice #9: Identification of high-potential talent by senior leaders
- Practice #10: Assignment based on skills, experiences, and program needs

It is found that for practices 2, 4, 5, 7, and 9, there is at least one military service that is not aligned extensively.

Practice #6, financial reward for good performance is the least aligned practice from all services.

It is found that military services have taken actions to improve their talent management structure but yet they still lag behind the best practices and the "training, mentoring, retaining, and selecting of people for program managers could be improved" (GAO, GAO 18-217 Defense Acquisition Workforce: Opportunities Exist to Improve Practices for Developing Program Managers, 2018, p. 26)

E. DOD Structure not Supporting Early Sustainment Risk Management

In a 2017 report that interviewed the Product Support Managers across DOD, multiple weaknesses in product supportability analysis and planner were found. One of the statement says “PSMs identified skills and institutional support as factors that enhance their ability to influence weapon system acquisition programs.” (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 4) . One of the factors is Teamwork and Collaboration. It is stated that “Army PSMs said that PSMs should have good relationship skills to collaborate with program management, finance, and engineering officials… PSMs need to be assertive to advocate for the long-term supportability of their assigned weapon system program…. It is important to foster peer-to-peer relationships.” (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 4)

Another important factor that enables early influence on sustainment is the Early Assignment of the PSM Position. PSMs are often not assigned to a position until later on in the acquisition process and his/her ability to influence design and program decisions after-the-fact becomes limited.

Another factor is Organizational Support and Emphasis on Sustainment. PSMs stated that if the institution supports the emphasis on sustainment, then it makes their job much easier. Having competing priorities in the acquisition programs does not help this cause. As PSMs expressed that the reason why sustainment was not emphasized is due to the fact that there are other priorities that are considered to be more crucial in the short term, such as performance “because a program’s success is not measured by sustainment.” (GAO, GAO 17-744R Weapon Systems

Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 7) Furthering this point, it is said that "military services are subject to statutory limits on the funds that can be used to contract for depot-level maintenance and repair workloads and also on contracting for core depot maintenance capabilities. According to this Air Force PSM, decisions on product support for individual weapon system programs are influenced by the services' need to satisfy these statutory requirements in the future, even if these product support decision are not advantageous to a specific program." (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 7)

Also, the manner in which DOD has implemented the PSM position resulted in different understanding of the PSM's role, responsibilities, and workload. For example, the Army's PSM stated that "when the PSM position was implemented, Army logisticians were moved into these positions and were not replaced. As a result, when logisticians became PSMs, they assumed all of the PSM responsibilities while continuing to perform their prior duties." (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 7)

Last but not least, in the same report, it is found that the geographic dispersion of program support staff, the difficulty of obtaining the necessary technical data rights, and the burdensome development and approval process for acquisition documents also contributed to the PSM's challenge to influence design earlier on in the acquisition process. (GAO, GAO 17-744R

Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017, p. 8)

It is found in the GAO Report 19-209 "Defense Acquisitions: Information on Workforce, Organizational Structure, and Budgeting for Selected Programs", that "Programs we reviewed relied on support organizations such as the Army Contracting Command for contracting functions, the Aviation and Missile Research Development and Engineering Center for engineering expertise, and others to provide life cycle management support." (GAO, GAO 19-209 Defense Acquisitions: Information on Workforce, Organizational Structure, and Budgeting for Selected Programs, 2019, p. 19). This presents the fact that structure-wise, different acquisition functions are performed by various agencies and coordination and interactions between the agencies is vitally important to the life-cycle view of the program.

According to another GAO report, there also lacks information sharing between PMs and lessons learned from acquisition of one program is not necessarily shared with other PMs (GAO, GAO 18-217 Defense Acquisition Workforce: Opportunities Exist to Improve Practices for Developing Program Managers, 2018)

Army Futures Command was established to oversee the Army's modernization priorities and plays an important role in facilitating the acquisition process. In order to retain a holistic acquisition perspective it is important for AFC to coordinate with other organizations that do not directly report to it. However, in the GAO report "Army Modernization: Army should take steps to reduce risk", it is reported that "As Army Futures Command approaches full operating status, it is important to define not only how the command functions, but how it works with other organizations. In our January 2019 report, we found that Army Futures Command had not yet

established policies and procedures detailing how it will execute its responsibilities in coordination with other Army organizations that do not directly report to it." (GAO, GAO 19-502T Army Modernization Army Should Take Steps to Reduce Risk, 2019, p. 9). In the same report, it also made recommendations to the Army's IPT structure to enable better communication since the current IPT process still requires much improvement to ensure the necessary risks are communicated.

Product support considerations do rely on well performing systems engineering to ensure the product support elements are adequately considered during the acquisition process. One of the key mechanism is through risk management. Incorporating sustainment risks into the program management process can help analyze and track these risks earlier on and provide mitigation methods. However, it is found in several GAO reports that the current risk management process is not adequately executed in the acquisition process.

"Section 804 of the National Defense Authorization Act (NDAA) for Fiscal Year 2016 required DOD to issue guidance establishing tow new acquisition pathways for DOD – Rapid Prototyping and rapid fielding – to create an expedited and streamlined "middle tier" of acquisition programs intended to be completed within 5 years." (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020, p. 7) The Army guidance of middle tier acquisition required the inclusion of risk management in the acquisition plan. However, there is no requirement to provide a detailed schedule in order to expedite prototyping. This results in a lack of consistent information related to how program documentations are tied together and a lack of systems view of the entire program. It is found in the report that "the life-cycle cost

estimates for MPF and OMFV generally followed our leading practices for such estimates, but did not appropriately reflect uncertainty." (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020, p. 20)

There were instances of programs not conducting systems engineering design reviews due to the accelerated schedule for rapid development. This in turn, limits risk management performed on the technology. (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020). Furthermore it was found that "other Army programs that began system development before fully considering systems engineering and requirements resulted in a mismatch of available technologies with program requirements, and ultimately schedule delays." (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020, p. 31)

Similarly, lack of early risk management, which resulted in significant increase of sustainment cost for the Navy's shipbuilding programs, are also presented in a Navy's report. (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020).

F. Information Gap and Weakness in the Reporting Mechanism to Congress and other Oversight Organizations

There is consistent reporting that DOD also lacks coherent and accurate information reporting up and down the chain. This information gap reduces the ability for oversight and management

entities to grasp the true status of acquisition programs as well as properly capturing and monitoring risks throughout the acquisition life cycle.

The Navy shipbuilding programs are reporting to Congress that the assessed shipbuilding programs are meeting or surpassing their sustainment requirements. "The Navy's reports to Congress do not reflect the actual availability of ships in the fleet." (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020, p. 37) The major sustainment issues experienced by the fleet are not reported due to definitions of reporting requirements.

It is found in a 2017 GAO report that DOD's budget accounts for almost half of the discretionary spending and that "DOD remains one of the few federal entities that cannot demonstrate an ability to accurately account for and reliably report its spending or assets." (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017, p. 2) Furthermore, it stated that DOD needs to implement best practices in order to control the cost of its weapon systems. It is found that the planning and budgeting process results in misalignment between the acquisition programs and available resources. Unsustainable cost estimates are submitted and requires "significant funding commitments". (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017, p. 4) Due to the deficiencies with DOD's financial management process, Congress has been receiving inconsistent and sometimes unreliable reports on weapon systems' operating and support (O&S) costs. "This inconsistent and unreliable reporting limits the visibility that Congress needs to effectively oversee defense programs, and impairs its ability to make cost-effective choices." (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission

Challenges , 2017, p. 4) The report also pointed out that “We have reported that DOD could achieve significant cost savings by consistently employing acquisition best practices in its weapon systems programs, such as early systems engineering, analyzing alternatives, managing changes in system requirements; and applying prototyping early in development testing…. It has not uniformly implemented acquisition best practices and reforms across the portfolio, which has resulted in some programs that realized significant cost growth and delays in delivering needed capabilities”. (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017, p. 29)

Figure 6 below displays several major programs’ knowledge-based practices at system development start: (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017)

FIGURE 6: Knowledge-based Practices at System Development Start

Knowledge-based practices at system development start	Columbia Class SSBN	F-15 EPAWSS	IFPC Inc 2-I Block 1	PAR	Other 41 programs ●	Other 41 programs ○	Other 41 programs ––
Demonstrate all critical technologies are very close to final form, fit, and function within a relevant environment (TRL 6)	○	●	––	––	23	11	7
Demonstrate all critical technologies are in form, fit, and function within an operational environment (TRL 7)	○	○	––	––	3	29	9
Complete system functional review and system requirements review before system development start	○	●	●	○	15	25	1
Completed preliminary design review before system development start	●	●	●	○	19	21	1
Constrain system development phase to 6 years or less	––	●	●	––	27	6	8

● Practice implemented

○ Practice not implemented

–– Practice not applicable or information not available per the program office response

(GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017)

As shown, the lack of complete system functional review and system requirements review before system development start is still a weakness in some programs. Preliminary design review before system development start is also something that is not consistently implemented across the board.

Another report states that across the services, data on O&S cost estimates is lacking and the "actual" O&S cost information is also absent in five of the seven assessed programs. "Without

historical life-cycle O&S cost estimates and complete data on actual O&S cost, DOD officials do not have important information necessary for analyzing the rate of O&S cost growth for major weapon systems, identifying cost drivers, and developing plan for managing and controlling these costs." (GAO, GAO 10-717 Defense Management: DOD Needs Better Information and Guidance to More Effectively Manage and Reduce Operating and Support Costs of Major Weapon Systems, 2010, p. 2) As a matter of fact, it was concluded by the report that DOD lacks the information needed to plan and manage O&S costs in an effective manner. Also, the current cost-estimating guidance does not require to retain this information. Furthermore, DOD does not quantify O&S cost growth by using updated life-cycle O&S cost estimates. However, when the updated information is collected, there are instances of significant cost increase that was uncovered. For example, for a major Air Force program, the program office updated the production milestone cost estimate, a 47 percent ($19 billion) increase in life-cycle O&S costs was identified. O&S cost is found to be a result of two elements, reliability and logistics support. If a weapon system is built to be reliable, then the logistics support requirements may not be as comprehensive and vice versa.

Under the current acquisition process, "decision makers at milestone A determine whether to approve a program to enter into technology development…..although very little is known about the system design….. Support concepts… DOD guidance states that rough O&S cost estimates are expected to primarily support plans that guide refinement of the weapon system concept." (GAO, GAO 10-717 Defense Management: DOD Needs Better Information and Guidance to More Effectively Manage and Reduce Operating and Support Costs of Major Weapon Systems, 2010, p. 8) This O&S cost estimate will add on more fidelity as the acquisition progresses

through the life-cycle framework. However the status of the execution of this intent shows inconsistency and it remains as a weakness.

The adoption of MTA also requires better information flow to enable better oversight. However, the current MTA programs are experiencing challenges in terms of cost and schedule reporting. A study of business case elements developed by MTA programs at initiation shows that requirements documents were not approved for multiple programs at initiation. Moreover, cost estimate based on independent assessment and formal schedule risk assessment were absent for most of the assessed MTA programs at initiation.

Figure 7 is a display of the assessed MTA programs (GAO, GAO 20-439 Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight, 2020, p. 65)

FIGURE 7: Assessed MTA Programs

Program name	Approved requirements document		Approved acquisition strategy		Formal technology risk assessment		Cost estimate based on independent assessment		Formal schedule risk assessment	
	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020	Initiation	Jan. 2020
Air Launched Rapid Response Weapon	✓	✓	✓	✓	⊗	✓	✓	✓	⊗	✓
B-52 Commercial Engine Replacement Program-Spiral 1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Extended Range Cannon Artillery - Increment 1C	✓	✓	⊗	✓	⊗	✓	⊗	⊗	⊗	✓
F-22 Capability Pipeline	✓	✓	✓	✓	⊗	✓	⊗	✓	⊗	✓
Hypersonic Conventional Strike Weapon	⊗	✓	⊗	✓	⊗	✓	⊗	✓	⊗	✓
Integrated Visual Augmentation System	✓	✓	⊗	✓	✓	✓	⊗	⊗	⊗	⊗
Lower Tier Air and Missile Defense Sensor	⊗	✓	⊗	✓	⊗	⊗	⊗	⊗	⊗	⊗
Mobile Protected Firepower	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Next Generation Overhead Persistent Infrared-Block 0	✓	✓	✓	✓	✓	✓	⊗	✓	⊗	✓
Optionally Manned Fighting Vehicle-Increment 1	⊗	✓	⊗	✓	⊗	⊗	⊗	✓	⊗	✓
Protected Tactical Enterprise Service-Release 1	✓	✓	✓	✓	⊗	⊗	⊗	✓	⊗	✓
Protected Tactical SATCOM	⊗	✓	⊗	✓	✓	✓	⊗	✓	⊗	⊗
Unified Platform	⊗	✓	✓	✓	⊗	⊗	⊗	✓	⊗	⊗

Legend:

✓= program had business case element

⊗ = program did not have business case element

Source: GAO analysis of Department of Defense data. | GAO-20-439

(GAO, GAO 20-439 Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight, 2020, p. 65)

In an earlier research paper in 2008 by Nicholas J. Anderson, it states that the "Army does not have a logistics Knowledge Management (KM) to manage data and information from the Single Army Logistics Enterprise (SALE)" (Anderson, 2008) This lack of single management entity presents challenges to effectively track and manage the Army's sustainment data and information and leverage them for future uses.

V. CHAPTER 5: CONCLUSION and RECOMMENDATIONS

Through the research and collection of possible topics and contents related to the lack of early product supportability (used interchangeably with "sustainment"), the data collection chapter was organized in the following categories:

1. Current Department of Defense Acquisition Process
2. Requirements Development Process and Criteria not Defined
3. Personnel Structure Not Conducive to Early Supportability Consideration
4. Lack of Suitable Personnel and Resource to Carryout Mission
5. DOD Structure not Supporting Early Sustainment Risk Management
6. Information Gap and Weakness in the Reporting Mechanism to Congress and Other Oversight Organizations

From the available information presented, several conclusive points can be made regarding the causes of the lack of early supportability involvement in the acquisition process:

1. The current requirements development and management framework is not adequate to support early sustainment thinking.
    a. It was reported that many programs are initiated without a well-defined requirements document and there are challenges in further maturing these requirements documents down the road (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020). Product supportability analysis needs the system's requirements to be defined, at least roughly, to conduct initial sustainment analysis. Without a well-defined requirements document, especially documents that do not include

sustainment related elements as KSAs, it is very difficult to conduct product support planning and analysis activities.

b. Furthermore, there is a lack of requirements development personnel to support early requirements definition activities; both in quantity and quality (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017). It takes training and development to produce competent requirements development personnel and this career field is declining, both in budget and available quantity.

c. The adoption of MTA does not improve the situation and rather, it exacerbates the situation by introducing competing priorities into the acquisition planning phase and many program managers choose to revolve around the performance priority instead of other longer-term priorities such as sustainment. Even though it is mentioned in several GAO reports that the requirements development process is now being seen as a priority issue and recommendations were given to ensure mitigation. Examples like the establishment of the Army Futures Command and its emphasis on requirements development provides evidence of improvement. However, accompanied with the MTA rapid prototyping and rapid fielding initiatives, requirements development, and in turn supportability requirements development is still hampered by competing priorities (GAO, GAO 17-568 Army Weapon Systems Requirements: Need to address workforce shortfalls to make necessary improvements, 2017). (GAO, GAO 19-502T Army Modernization Army Should Take Steps to Reduce Risk, 2019)

d. In addition, the reported lack of early systems engineering in major DOD acquisition programs is contributing to the lack of upfront supportability requirements built into the programs. Requirements development is an inherent step of systems engineering. It is the earliest step in a program's life cycle to understand the requirements and allocate requirements to the specific features of the system. Contrary to popular belief, supportability requirements needs to be present in the ICD, even in a draft format, prior to milestone A. If the systems engineering process is not present at the start of the program, it would be difficult to build in supportability considerations into the programs earlier on (GAO, GAO 17-369 Department of Defense: Actions Needed to Address Five Key Mission Challenges , 2017).

2. DOD's inherent structure, program management, and budgeting processes are not conducive to early supportability consideration integration. (GAO, GAO 19-209 Defense Acquisitions: Information on Workforce, Organizational Structure, and Budgeting for Selected Programs, 2019)

    a. One factor is the relatively short-term tenure of the program managers precludes the practice of looking at the long term aspect of an acquisition program. Even though private companies like Boeing also have two to three year rotational assignments, but these assignments are usually rotated within the same division or departments and do not create a rift or total "change of culture" from one rotation to the other . In addition, program managers are not incentivized to think the long term picture, rather, their performance ratings are more emphasized by "tangible" results such as performance and schedule. (GAO, GAO 17-744R Weapon

Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017) (GAO, GAO 18-217 Defense Acquisition Workforce: Opportunities Exist to Improve Practices for Developing Program Managers, 2018)

b. Also, due to statutory requirements, in some cases the discussion of more effective and efficient product support becomes a moot point. It was reported that industrial base facilities need to be kept in operational status and that designing in product support and in turn the benefits of doing so does not necessarily fit with the statutory requirements. This is joined by the fact that the budgeting process for the entire acquisition life cycle have multiple contributing entities in various phases of the life cycle and it is difficult to have a holistic life-cycle view of the entire budget. For example, in the Navy Shipbuilding programs, engineering and design concerns regarding risks were not filtered up the chain and also down the development path and resulted in sustainment increases. (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020)When these sustainment issues surface up, they are not adequately reported to oversight entities and thus no lessons learned or corrective actions were taken to preclude them from happening again. (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020)

c. Another factor in terms of structure is that even though the PMs are put in charge of the “life-cycle management” of programs, but in some cases PMs are not

assigned to programs until later on in the life-cycle and PSMs, in turn, are not assigned until later on. This hampers management's ability to instill supportability elements into system design. (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017)

d. Due to the complex organizational structures and the various roles and responsibilities of each service and entities associated with the services, it requires a large amount of coordination and communication with the various entities to plan and execute the product sustainment activities. On top this, there are competing priorities to overcome with the limited time and budget constraints that each organization faces. (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017)

3. Personnel-Related Issues Need to be Addressed

   a. As mentioned before, requirements development entities are facing a declining workforce and increased workload. Similar phenomenon is also happening in the PSM personnel front. It was reported that many of the PSM were previous logisticians and they have taken on the PSM's roles and responsibilities while continuing to perform the traditional logistician taskers. This increases the workload and also confuses the original intent of the PSM's function. PSMs are supposed to be coordinating and management function to address all twelve Integrated Product Support (IPS) elements. These elements extends well beyond the traditional logistics taskers such as "computer resources" and "technical data".

These elements needs to be coordinated with the PM and the PSM is serving as the lead for all twelve IPS elements while the PM serves as the overall program integrator. (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017)

b. Logisticians and PSMs need to become better communicators to other functional entities when they attempt to drive in product support considerations into engineering designs. They also need to be more adamant when opportunities present themselves to include supportability considerations. This is the more intangible aspects of influencing design but vitally important. (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017)

4. Information gap exist amongst organizations and oversight entities.

   a. There exists a gap in what is happening in the field versus what is being reported to the Congressional Oversight community regarding the state of sustainment of Navy vessels as reporting requirements do not reflect the criticality of multiple sustainment failures. (GAO, GAO 20-2 Navy Shipbuilding Increasing Focus on Sustainment Early in the Acquisition Process Could Save Billions, 2020) (GAO, GAO 20-439 Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight, 2020)

   b. Due to the lack of historical sustainment cost information being retained, it is difficult to update the actual O&S cost and thus produce lessons learned to prevent similar issues from happening. (GAO, GAO 10-717 Defense

Management: DOD Needs Better Information and Guidance to More Effectively Manage and Reduce Operating and Support Costs of Major Weapon Systems, 2010)

c. Even though life-cycle cost estimates are required at each milestone, increasing in fidelity and content in each life cycle phase, but it is evident that there is significant weakness in terms of early life cycle cost estimates. These cost estimates are either absent or inadequate to address the true O&S sustainment issues down the road. This lack of upfront information is a detriment to early program decisions that can impact sustainment efforts and cost down the road. (GAO, GAO 20-579 Next Generation Combat Vehicles: As Army Prioritizes Rapid Development, More Attention Needed to Provide Insight on Cost Estimates and Systems Engineering Risks, 2020)

5. In terms of the research questions posed in chapter one:

   a. What is the current logistics supportability analysis and engineering process in the acquisition process and is it adequately executed? The current logistics supportability analysis and engineering process in the acquisition process is documented in various documents such as the DOD 5000.02, the DAG, and the PSM guidebook. However, they are not adequately planned and executed in the major acquisition programs and inconsistencies in the level of execution is something that still needs to be improved.

   b. If it is not adequately executed, why is this happening despite plenty of policies and guidance that encourages to do so? The various paragraphs in chapter 4 and points 1 through 4 in chapter 5 summarized the causes for the lack of execution.

This question represents the heart of this research paper. More recommendations to answer this question are posed in the chapter 6 "recommendation" paragraphs.

c. If it is adequately executed, how can it be enhanced so the Army's priority to seek "readiness" can be incorporated in the product acquisition process? Readiness of the US Armed Forces depend on not only training and competency of the personnel, but also the availability of the various systems it possesses. Availability is divided into operational availability and materiel availability and both are addressed in the IPS elements and also need to be represented and coordinated by the PSM role. However, as we have seen from the information found, the PSM roles and responsibilities are still in a maturing stage and it is not adequately executed through DOD. This in turn, could impact the overall readiness our Armed Forces. When the Navy's shipbuilding programs are facing significant sustainment challenges and when the Air Force's Autonomous Logistics Information System is not reporting the correct data, this does not help with the overall readiness paradigm that DOD is trying to accomplish. When the requirements development process is not adequate and "readiness" does not serve as a central theme in the early phases of development, it is difficult to steer the developer's perspective away from performance or "features" of the system.

d. Who are the major direct stakeholders that need to pay attention to this topic? As identified, the PM and PSM community, as well as the cost estimation community, systems engineering community, the entire budgeting community, as well as Congressional oversight and other management authorities, all need to have a more thorough understanding of the systemic issue of the high cost of

sustainment of our weapon systems and how it needs to be addressed earlier on rather than later.

e. What/Who are the distractions that turn projects' attention away from thinking early about product support? And why? There is no specific ill-intended organizations or individuals that purposely try to block early product support. Instead, the lack of early product support thinking is a natural phenomenon created by the unique structure, processes, personnel, and information framework of the DOD. This is also attributed to the disjointed decision making processes as well as competing priorities that exist within each organization. (GAO, GAO 17-744R Weapon Systems Management: Product Support Manager's Perspective on Factors Critical to Influencing Sustainment-Related Decisions, 2017) Product supportability thinking requires a life-cycle long term perspective and the PMs, who are in place to look at that life-cycle view are either encouraged to think short term or do not possess enough authority to execute that long term view due to the complex structure of the DOD organizations. (GAO, GAO 19-209 Defense Acquisitions: Information on Workforce, Organizational Structure, and Budgeting for Selected Programs, 2019)

RECOMMENDATIONS

Due to the fact that is research paper cannot generate new information or thoughts not supported by existing information, it is strongly recommended that the following topics to be researched later on in order to answer supportability questions in a more holistic fashion.

1. As mentioned in the research paper, there are many "tangible" factors that contribute to a lack of early supportability analysis in acquisition projects. However, there are many suspected "intangible" factors that are working as forcing functions to ignore product supportability earlier on.
    a. Tangible factors are (including but not exclusively): Policies, procedures, organizational structure, personnel availability, personnel performance rating factors, and information availability.
    b. Intangible factors are (including but not exclusively): The ability of logisticians and PSMs to effectively communicate to relevant stakeholders and the willingness of PMs to look at the long term view.
    c. The ability to effectively communicate with the engineering/technical community is extremely important. Since product supportability does not necessarily produce immediate tangible results or features, it is harder for the designers to consider product support seriously in the midst of work and competing priorities. The ability of the logisticians or PSMs to communicate the importance and impact of product supportability to the development community becomes vitally important. Despite a lack of immediate "rewards" from this effort, the negative consequences of not performing early thinking on product sustainment needs to be fully and clearly communicated. A more in-depth research of this topic could reveal how the communication element can be improved from PSMs (and logisticians) to the acquisition community and vice versa.
    d. Since PSMs are mostly prior logisticians and they are performing jobs in various aspects, sometimes it is difficult for them to understand the intent of the PSM

role. According to the policies and guidance, PSMs are supposed to be able to come up with assumptions or early drafts of the sustainment framework and mature them as the acquisition process progresses. However, a research can be done to examine whether or not logisticians are comfortable and trained to make assumptions in the earlier stages. For example, it is desirable for the Level of Repair Analysis to have the full Technical Data Package (TDP) ready to be fed into the analysis application, but it could also be done earlier in the life cycle when a mature TDP is not yet present. Although packaging design requires the specific dimensions of the system or sub-system, but assumptions can still be made to ensure transportability and storage. However, whether or not the product support community is trained and is willing to make those changes can be a research topic to examine whether or not the product support community itself has become its own hurdles.

2. In-depth research of the relationship between the systems engineering process and product support analysis process: It was reported in multiple places that the systems engineer requirements development process as well as the risk management process are not adequately planned for and executed in major acquisition programs. However, it would be a good fact finding topic to see whether there is disconnect between the systems engineering processes and product support processes. This recommendation seeks to explore the question of "Even if the systems engineering process is adequately planned, will product supportability be adequately addressed?"
3. It was reported that customer requirements and market competition play an important role for product managers to emphasize product support earlier on. A more in-depth research

can be done to examine this market and product relationship and see if this is indeed a contributing factor to the DOD realm. The DOD's "customers" are the soldiers and "competitors" are other adversarial nations or states. The lack of feedback loop of sustainment issues from soldiers could be a contributing factor to the lack of emphasis during the design stage. More intriguingly, could the lack of "competition" be a factor that encourages more short term thinking rather than thinking the long term sustainment when the products are in the soldier's hands? Private sector needs to consider product support because customers have choices and they often choose products that are reliable and require less maintenance/sustainment effort in its life span. Products such as automobiles, cell phones, electronics, and appliances, all have significant product support implications and the more reliable brand usually wins the hearts and loyalty of customers. However, due to the fact that there are virtually no choices given to the soldiers, there is no incentive for the product developers to seek more efficient and effective sustainment elements and drive them into the design. A more in-depth research into this topic could help reveal more facts in this field.

4. Specifically to the Army, DEVCOM is an AFC entity that is responsible for the research and development of the Army's warfighting systems. As a revenue stream, some S&T projects are initiated outside of the ICD/CDD process. These S&T projects are often concept proving projects that rejects earlier supportability analysis. However, when these concepts are proven and ready for further development, supportability is still lacking in the projects. This could be a gap outside of the JCIDS process that warrant more attention since these concept proving S&T projects serve as a pipeline into formal programs later on. A research into the structure and revenue stream of the DEVCOM

centers could be beneficial in understanding the how the lack of early systems engineering and supportability analysis in these early projects impact the long term health of the cost and performance of the systems in the field later on.

5. More examination into DOD's budgeting process, the "color of money", and the industrial base policy could help reveal some more insights as to why product supportability can become a difficult topic to coordinate when done in the earlier product development phase. A legitimate question can be asked: If there is a federal policy that requires the upkeep and sustainment of the national industrial base and funding is already obligated to support the policy, where would the early product support analysis cost benefits come from? It does not matter if a product is designed to require less maintenance since our maintenance depot needs to have the tasker to sustain itself and funding is already allocated for it. This is outside of the typical responsibility of PM's and their oversight authority, therefore early product support analysis' attempt to "save the government money" could become a moot point later on since our industrial base is already staged to support sustainment level of a specific weapon system at a certain service level.
    a. Regarding the "color of money" discussion, since currently the Army PM's funding mostly covers 6.3 and beyond funding, the PM and in turn, PSM's do not have direct oversight on the 6.1 or 6.2 funding being provided to Army's DEVCOM for S&T projects. Even though the PM's are supposed to serve as "full life cycle manager" of the program's cradle to grave life cycle, however the true practical scenario is that the PM's oversight does not kick in until post MS-B

(some exceptions include PM-funded S&T projects, but this is not a mainstream scenario).

b. Therefore the topic of "how can PM's become true life cycle manager of weapon systems?" becomes a real and tangible topic to explore.

6. It is recommended further research to be conducted on the reference to MIL-STD 1388-1A – Logistic Support Analysis, 1991. This was the military standard on product support in the 1980's and 1990's. Further research can be done to analyze the applicability and inclusion of this military standard into the Adaptive Acquisition Framework.
7. Last but not least, it is recommended to perform research in the current PM structure and how it does not encourage "supportability systems" to be developed. DOD has various Program Executive Offices (PEO) and associated PMs to act as owners of various systems. For example, the US Army has PEO Armaments and Ammunition that owns all class V munition and class VII armament systems. There is PEO GCS that owns all ground vehicle systems. However, there is no specific PEO/PM that owns the "supportability systems" or "sustainment" technology. There lacks an advocate to "proactively" develop "enabling" systems that is parallel to the main systems development. Supportability tools and technology is developed on an as-needed basis and it is an upward battle in the fight for funding in the environment of competing priorities and schedule acceleration. A research into this topic could reveal more facts on this aspect of systems acquisition and the importance to think proactively on the creation of product support enabling technologies.

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