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SYSTEMS ANALYSIS OF ARMY MATERIEL REPORTING FOR THE MIDDLE TIER OF ACQUISITION PATHWAY

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MONTEREY, CALIFORNIA

SYSTEMS ENGINEERING CAPSTONE REPORT

SYSTEMS ANALYSIS OF ARMY MATERIEL REPORTING FOR THE MIDDLE TIER OF ACQUISITION PATHWAY

by

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December 2022

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The Acquisition Modernization Integration (AMI) team within the ASA (ALT) office is critical in the Army decision-making process. The AMI creates reports that include actionable knowledge rendered to Army strategic leaders. These reports include vital data on critical Army programs integrated into the modernization efforts. Part of this necessary data are the First Unit Issued (FUI) and the First Unit Equipped (FUE) dates. These reported dates directly affect Army units' training, deployment, and logistics support timelines as they become part of the data-driven analytics on reports provided to decision-makers. Because of the initiatives to improve efficiency in the acquisition process, realignment, and creation of new organizations, the AMI needs a system that facilitates accurate and consistent FUI and FUE dates reporting.

This research used several systems engineering (SE) concepts and methods such as stakeholders' analysis, functional analysis, mapping of functions to systems' parameters, modeling-based systems engineering, and analysis of alternatives. The application of these SE tools resulted in identifying a system/process that will accurately and consistently facilitate FUI and FUE date reporting to meet the AMI's needs. This system/process provides a reporting capability for current and future acquisition programs and could be implemented across the DOD and all other government agencies and departments.

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ABSTRACT

The Acquisition Modernization Integration (AMI) team within the ASA(ALT) office is critical in the Army decision-making process. The AMI creates reports that include actionable knowledge rendered to Army strategic leaders. These reports include vital data on critical Army programs integrated into the modernization efforts. Part of this necessary data are the First Unit Issued (FUI) and the First Unit Equipped (FUE) dates. These reported dates directly affect Army units' training, deployment, and logistics support timelines as they become part of the data-driven analytics on reports provided to decision-makers. Because of the initiatives to improve efficiency in the acquisition process, realignment, and creation of new organizations, the AMI needs a system that facilitates accurate and consistent FUI and FUE dates reporting.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	Adaptive Acquisition Framework
ABAC	Attribute-Based Access Control
AI	Artificial Intelligence
AMI	Acquisitions Modernization and Integration
AMPV	Armored Multi-Purpose Vehicle
API	Application Programming Interfaces
ASA(ALT)	Assistant Secretary of the Army (Acquisition, Logistics and Technology)
BOIP	Basis of Issue Plan
CAC	Common Access Card
CFT	Cross-Functional Team
CTA	Common Table of Allowances
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DODAF	Department of Defense Architecture Framework
DPAS	Defense Property Accountability System
ERCA	Extended Range Cannon Artillery
EVM	Earned Value Management
FCS	Future Combat Systems
FUE	First Unit Equipped
FUI	First Unit Issue
FY	Fiscal Year
GCSS-A	Global Combat Support System-Army
HHS	Health and Human Services
IAMS	Integrated Army Modernization Schedule
LCS	Littoral Combat Ship
LIN	Line Item Number

LRIP	Low-Rate Initial Production
LRPF	Long Range Precision Fires
LUT	Limited User Test
MAR	Monthly Acquisition Report
MBSE	Model Based Systems Engineering
MCA	Major Capability Acquisition
ML	Machine Learning
MTA	Middle Tier of Acquisition
MTOE	Modification Table of Organization Equipment
NDAA	National Defense Authorization Act
NGCV	Next Generation Combat Vehicle
NLP	Natural Language Processing
NPS	Naval Postgraduate School
OT&E	Operational Test and Evaluation
OMFV	Optionally Manned Fighting Vehicle
OSD	Office of the Secretary of Defense
OV	Operational Viewpoint
PEO	Program Executive Office
PLIN	Prototype Line Item Number
PMRT	Project Management Resources Tool
PNSLIN	Prototype Non-Standardized Line-Item Number
PrSM	Precision Strike Missile
RBAC	Role-Base Access Control
RCV	Robotic Combat Vehicle
RPA	Robotic Process Animation
SLAMIS	SNN-LIN Automated Management & Integrating System
STP	Soldier Touch Point
SV	Systems Viewpoint
TDA	Table of Distribution and Allowances

TRAC	The Research Analysis Center
U.S.	United States
ZLIN	Developmental Line Item Number

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EXECUTIVE SUMMARY

The Acquisition Modernization Integration (AMI) of ASA(ALT) is responsible for gathering and reporting the First Unit Issued (FUI) and First Unit Equipped (FUE) timelines to DOD decision makers. This information has a direct impact on the training, deployment, and logistics support timelines of Army units; therefore, the accuracy of the information is vitally important. An inaccurate understanding of modernization efforts' FUI and FUE dates has led to a breakdown in communication and a desyncing of priorities for senior Army leadership. AMI is looking for a standardized process that will drive accurate and consistent reporting for FUI and FUE across all program offices responsible for new equipment modernization.

This research project began with data collection and modeling of the internal processes utilized by the Next Generation Combat Vehicle (NGCV), and Long-Range Precision Fires (LRPF) Cross Functional Teams (CFTs) for reporting the FUI and FUE dates for their modernization efforts. The team conducted a thorough systems analysis to identify drivers, problem areas, and potential solutions to friction points identified. The team then developed a functional decomposition of the ideal process. While data collection and analysis were limited to only two CFTs, the goal is for recommendations to be applicable to other CFTs across the modernization spectrum.

Our research sought to analyze the reporting processes individually and then do a comparative analysis of the three current systems. We identified the functions that are critical for a successful FUI/FUE reporting system using a functional decomposition from stakeholder meetings. We completed a comparative analysis of the three current reporting system using the identified critical functions that are needed in a reporting system. The team scored each system on auditability, fitness, credibility, accessibility, and timeliness and then ranked them in order of precedence utilizing a modified Pugh Matrix to determine the most suitable reporting platform.

Our findings and recommendations support the FUI and FUE reporting process, successfully complete the functional requirements outlined in this study, and satisfy the

FUI/FUE reporting needs of all stakeholders Army-wide. Our research led the team to conclusions that incorporate the selection of a reporting system, recommendations aimed at solving current issues, improving existing capabilities, and recommendations for potential future developments.

REPORT FINDINGS

- Inconsistent definition of FUI
- Data quality issues exist in all three reporting systems
- PMRT / MAR reporting system is the most suitable system

REPORT RECOMMENDATIONS

- ASA (ALT) AMI provides the Army acquisition enterprise a standard definition of FUI.
- Establish the MAR as the FUI and FUE authoritative source for the Army acquisition enterprise.
- Update the interface of the MAR system to accept, optimize, and mandate FUI/FUE reporting.
- Create PMRT FUI/FUE Application to meet the data fitness needs of the user.

Through our research we identified that multiple different reporting methods and mediums have created siloed data pipelines, leading to barriers to information sharing and collaboration across the departments tasked with Army modernization. These information barriers led to unreliable data when aggregated at the enterprise level, greatly hindered efforts in data analytics, and weakened confidence in the data reported. This report presents facts and opinions on some of the current reporting processes being utilized to facilitate a future standardized reporting method to the Army modernization enterprise. Until the reporting process is standardized or an information technology solution is integrated at the

enterprise level, the data being reported will continue to be inconsistent when aggregated by ASA (ALT).

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I. INTRODUCTION

The Acquisition Modernization and Integration (AMI) department of the Office of the Assistant Secretary of the Army (Acquisitions, Logistics and Technology) is responsible for gathering and reporting the First Unit Issued (FUI) and First Unit Equipped (FUE) timelines to Department of Defense (DOD) decision makers. This information has a direct impact on the training, deployment, and logistics support timelines of Army units; therefore, the accuracy of the information is vitally important. An inaccurate understanding of modernization efforts' FUI and FUE dates has led to a breakdown in communication and a desyncing of priorities for senior Army leadership, creating a need for a standardized process that will drive accurate and consistent reporting for FUI and FUE across all program offices responsible for new materiel modernization (AMI Manager, meeting, April 7, 2022).

This research project began with data collection and modeling of the internal processes utilized by the Next Generation Combat Vehicle (NGCV) and Long-Range Precision Fires (LRPF) Cross Functional Teams (CFTs) for reporting the FUI and FUE dates as part of their modernization efforts. The team then conducted a thorough systems analysis to identify drivers, problem areas, and potential solutions to friction points identified. While data collection and analysis were limited to only two CFTs, the goal is for recommendations to be applicable to other CFTs across the modernization spectrum.

A. BACKGROUND

The Secretary of the Army recently named the Army's top objectives and how force modernization will support her priorities (Wormuth 2022). To support a shared understanding of Army modernization efforts, AMI first needs the data on these modernization efforts to be visible, accessible, and trusted. Once AMI can effectively understand and utilize the data from these programs, this information can be optimized to allow leaders to dynamically set the environment to improve future modernization efforts under the constraints of time, funding, and risks to future missions.

Records show that AMI is currently focused on compiling and tracking the status of each signature modernization effort that has been approved by Army Futures Command (AMI Manager, meeting, April 7, 2022). These initiatives fall under each of the eight CFTs designated to the eight modernization efforts. These eight modernization efforts include: Network, Long Range Precision Fires (LRPF), Air and Missile Defense, Future Vertical Lift, Assured Positioning, Navigation, and Timing/Space, Soldier Lethality, Synthetic Training Environment, and Next Generational Combat Vehicles (NGCV). While all data on the status of these efforts should be shared across stakeholders to best foster cooperation and progress across the Army enterprise, the ASA(ALT) primarily requires visibility and accuracy on dates for important gates and milestones in order to have a clear picture of the progress in the initiatives.

Regarding the Adaptive Acquisition Framework (AAF) pathways, AMI's lack of visibility is primarily a problem for initiatives utilizing the Middle Tier of Acquisition (MTA) pathway. This is due to rapid prototyping, rapid fielding, and the lack of standardization in how program offices communicate the status of their prototypes. Army logistics primarily tracks equipment by assigning line-item numbers (LINs), and then inputting that equipment into a database according to its corresponding LIN. That database is shared with all logistics officers and organization across the Army. Prototypes are not assigned LINs, so that means of convenient tracking is not applicable. ASA(ALT) established temporary "Prototype Line Item Numbers (PLIN)" for program offices to utilize in tracking prototypes, but no standard for recording or reporting data on prototypes utilizing "PLINs" has been successfully established. This reporting process is further convoluted by a lack of terminology standardization for the term "first unit issued" (FUI). This term refers to a critical control gate during the acquisition process, but when project managers define FUI differently, status-tracking for these efforts can be very difficult and confusing for ASA(ALT).

This problem crosses multiple Army departments and commands. These organizations include, but are not limited to, HQDA G8, HQDA G3, Army Materiel Command, Army Futures Command, FORSCOM, Program Executive Offices (PEO), and operational units. There are a multitude of organizations contributing to the data, which all

track the data utilizing different methods and systems. The data is also not standardized in terms of what is recorded or in the format it is recorded. Data is often reporting in one of two ways, either in the Day, Month, Year format or in a fiscal year (FY) quarterly format. This causes issues when not only directly comparing data between progress reports, but also in recording and monitoring how dated the information is. The variations in reporting format cause considerable strain on the individuals designated to bring together and report the information.

Additionally, there is currently no reliable system in place to "pull" information from the different modernization initiatives into one repository. Agencies lack tooling to consolidate the information, making the collection process tedious for the small number of human resources allocated to complete the task. The lack of a reliable data pool results in variation in when the data is provided and when it is collected. This variation results in a lack of ability to look at the status of multiple projects in a single time frame, causing a further lack in viability of the reports presented to decision makers.

B. PROBLEM STATEMENT

PEO and ASA(ALT) lack a standardized process to drive accurate and consistent reporting for FUI and FUE across the modernization initiatives. This project will focus on the FUE and FUI timelines for LRPF and NGCV.

C. PURPOSE AND OBJECTIVES

This project applies a tailored systems engineering approach to data collection, systems modeling, systems analysis, and recommendations. The project will focus on the modernization initiatives in the NGCV and LRPF Cross Functional Team portfolios. The purpose of this research is to assist AMI in determining a standardized process that will drive accurate and consistent reporting for FUI and FUE across all program offices responsible for new materiel modernization. The objectives of the project are as follows.

- Conduct systems modeling of reporting processes within the NGCV and LRPF modernization initiatives.

- Conduct systems analysis of reporting processes within the NGCV and LRPF modernization initiatives.
- Provide recommendations on how to standardize the reporting process for FUI and FUE across the Army enterprise.

This approach will be focused on modernization initiatives utilizing the Middle Tier of Acquisition (MTA) pathway. The MTA pathway utilizes rapid prototyping and rapid fielding, leading to the most discrepancies in reporting FUI and FUE. The modernization initiatives utilizing the MTA pathway within the NGCV portfolio include the Armored Multi-Purpose Vehicle (AMPV), the Optionally Manned Fighting Vehicle (OMFV), and all variants of the Robotic Combat Vehicle (RCV). The modernization initiatives utilizing the MTA pathway within the LRPF portfolio include the Extended Range Cannon Artillery (ERCA) and the Precision Strike Missile (PrSM).

D. CAPSTONE REPORT OVERVIEW

The remaining chapters of this report first cover the team's review of literature, the team's approach and research methodology, systems modeling and systems analysis, and the team's conclusions and recommendations. Chapter II establishes an understanding of similar research in the field. Chapter III describes the team's approach in executing data collection, systems modeling, systems analysis, and in drawing their conclusions. Chapter IV consists of the systems models and the team's analysis of collected data. Chapter V is the conclusion and recommendations.

II. LITERATURE REVIEW

The team built a better understanding of the stakeholder's problem through an extensive review of literature. The Naval Postgraduate School Dudley Knox Research Library served as the primary vehicle for finding and researching relevant journalistic articles and books. Each team member focused on a different aspect of the problem and then shared their findings with the team to ensure each member had a holistic view of the team's discoveries. The team then came together again in one collaborative effort.

The team dissected the literature review into the following concentrated efforts. The first effort was to do a review of literature pertaining to DOD and commercial data management best practices. The second effort was a focus on developing a firm understanding of the DOD's Data Strategy and Efforts. The third effort was a focus on the DOD's challenges in data sharing and decision-making. The fourth effort was in reviewing the future of acquisition data management. The fifth effort was an in-depth look at how to develop a "data-driven culture."

Our team has identified that data management across DOD acquisitions is largely unstructured. The literature review also revealed how internal measures of performance and data models can be difficult to track and even more difficult to visualize. We discovered that information management models must accommodate diversity and adaptability to be successfully implemented in DOD acquisitions.

A. DEPARTMENT OF DEFENSE AND COMMERCIAL DATA MANAGEMENT BEST PRACTICES

Through a thorough review of literature, the team developed a foundational understanding of data management in the DOD and commercial sectors. The goal of this effort was to identify some of the best practices while distinguishing between government and commercial strategies. The literature depicted a government with siloed data, a seemingly chaotic data management strategy, and a lack of viability in enterprise data analytics. The literature also provided models that could be applied by the government to improve data management and aggregation for more effective analytics.

The literature review began with a report published by Rand in 2017 entitled "Access to Acquisition Data and Information." This research paper was a great starting point in researching how the DOD manages data, and the report summarized its applicable findings in one succinct paragraph:

> The data elements within these information systems vary. The time frames for the various data elements are nonstationary, meaning, for example, that one information system has data from 1960 to current, while another may have data only from 2010 to current. Acquisition data are stored on differing platforms and hardware; architectures, software, and interfaces; vendors; and databases. The systems' accessibility and security requirements (depending on the data being stored) also vary. (McKernan et al. 2017, 5)

The opinion that the DOD's data management is, essentially, chaotic with very little standardization was shared by Congress. In the 2017 National Defense Acquisition Act Conference Report the conferees stated that, "many major policy decisions were being make without the benefit of being informed by substantive data" (U.S. House of Representatives 2017, 1125). The conferees then went on to state that a lack of data can lead to misleading conclusions and that, "the result may be policies that squander resources, waste taxpayer dollars, and undermine the effectiveness of government programs or military operations" (1125).

By 2019 the DOD had established the Federal Data Strategy Development Team who established a maturity model for the DOD to use in assessing the maturity of their data management strategy (Anton et al. 2019). The model provides a framework for measuring the DOD's data management maturity, but it cannot be properly applied to the DOD as a singular entity, and therefore requires adoption by organizations within the DOD to be properly applied. This bottom-up approach to adoption therefore requires a workforce that is knowledgeable in applying data management techniques and can work together in a collaborative effort. Sadly, the DOD's acquisition data community utilizes siloed data teams for maintaining data instead of establishing agency-wide best practices and training (Anton et al. 2019, 49).

There are various maturity models utilized by private industry to characterize an organization's data management. In reviewing literature, the team identified two prominent

ones to compare to the DOD's data management maturity model. The first one reviewed was the Gartner maturity model. This model's focus is on an organization's data analytic practices and utilized six levels that begin with the first level called "basic" and ended with the sixth level "transformational" (Anton et al. 2019, 45). The second maturity model reviewed by Anton et al. (2019) was IBM's maturity model for big analytics. This maturity model broke the assessment of the organization into six categories measured in five levels (46). IBM's model is also unique in that it considers technology and business factors (Anton et al. 2019, 46).

While the maturity models reviewed were originally aimed at measuring an organization's data analytic capabilities, they provided a good reference for the development of a maturity model the Army Acquisition community could adopt in measuring success in data management. The models also demonstrated some lessons learned and best practices that are included in our recommendations. These best practices include having an all-encompassing data vision shared by the entire organization. This means no more siloed data. Data contributors and leaders must buy into the vision for it to work effectively. Responsibility for data tracking and reporting should be enforced by the lowest echelons of Army Acquisitions, but standardization guidance and organizational adherence should come from the enterprise level.

B. DEPARTMENT OF DEFENSE DATA STRATEGY AND EFFORTS

The DOD makes clear that data will support all its processes and acquisition programs in a more efficient way. As stated in the DOD Data Strategy, "Data underpins digital modernization and is increasingly the fuel of every DOD process, algorithm, and weapon system" (Norquist 2020, 11). The DOD Data Strategy supports the digital modernization vision as the DOD heavily relies on data, placing it at the center of the organization. The increased use of data requires an improved speed, flow, and volume of information to improve to maintain this technological edge. This strategy aims to effectively respond to the current and future data needs to support senior leaders' decision-making and business analytics through the use of data as a driving factor for informed decisions at all echelons (Norquist 2020, 1).

The DOD strategy stresses the need from the beginning with those operational individuals that will be using the data, including the warfighter (Norquist 2020). This direct relation will facilitate data accuracy and relevancy through immediate feedback. The fluency of this process supports the initial DOD data strategy's areas of focus: senior leader support and business analytics (Norquist 2020, 1). The forementioned areas of focus coincide with our capstone project's objectives.

The DOD's strategy has eight guiding principles serving as the foundation for all actions related to data management: (Norquist 2020, 3).

1. Data is a Strategic Asset—Leveraging the data as a resource that produces immediate and long-term sustainable military advantage.
2. Collective Data Stewardship—Assigning two levels of data management to ensure data accountability from creation, permanent storage, and reuse.
3. Data Ethics—Applying ethics to data collection, transmission, use, and storage.
4. Data Collection—Enabling electronic collection of data at the point of creation and maintaining data traceability at all times. Ensuring when data is created, it is tagged, stored, and cataloged; and when the data is combined or integrated, the resulting product must also follow the same process. To expedite these processes and minimize the risk of human error, these steps should be automated to the maximum extent possible.
5. Enterprise-Wide Data Access and Availability—Ensuring maximum amount of DOD data must be made available for use by all authorized individuals and non-person entities through appropriate mechanisms.
6. Data for Artificial Intelligence Training—Creating data sets for inputs to AI processors and algorithmic models as the most valuable digital asset. Developing a framework to manage and further develop its use and applicability.
7. Data Fit for Purpose—Considering the challenges of data collection, data sharing, and the speed of its integration to achieve a goal without unintended consequences.
8. Design for Compliance—Creating a solution that incorporates automation in the processes of data collection, management, and storage, maintaining proper data security (Norquist 2020, 3).

Data visibility is a primary objective of this strategy. The DOD strategy enables authorized users to identify the existence of data that fits their interests and adds specific value to their efforts. All levels of data managers share the responsibility and the obligation of making data visible to the authorized users by properly completing data identification, registration, and exposure. Data managers should aim for making data easily discoverable to those with a valid need for its use. This is a challenging task because it requires the classification of data sets, defining the location of these categories of data sets, the pathway to them, and the means to access through these pathways. This level of complexity is conducive to efficient organization, and exponentially increases the effectiveness of data. Data effectiveness increases as it becomes a valuable input, not just to humans but to the automated systems. These automated systems, paired with human input, drive an incredibly fast series of processes supporting better decisions and solid business growth (Norquist 2020, 6).

These levels of access to data sets—provided by the data managers to all data users—require security controls to limit access to credentialed personnel with a legitimate need for these inputs, justified and in compliance with the law, the department regulations, and local policies (Norquist 2020, 7). More than data access, the understanding of these data sets—created by the data managers—is the enabler to a decision-making process that is timely, accurate, and sustained. These data sets must be organized in such a way that they provide a rich context to facilitate interpretation and analysis. This context will enable aggregation and proper integration of the data sets, to facilitate inferences as a response to the question that originated the need for data. To this end we need to involve our customers and stakeholders to better depict all the details of the data context, its correlation, and what conclusions it facilitates (Miller 2015, 4).

The data being created must be purposely linked to requirements to support decision-making. This decision-making process must show dependency on those data sets being produced. These data sets and decision-making linkage needs to objectively show some value-added in the area where those decisions are made. Here we need to determine what to collect and understand its purpose and limitations in supporting decision making (Miller 2015, 4).

> Achieving semantic as well as syntactic interoperability using common data formats and machine-to-machine communications accelerates advanced algorithm development and provides a strategic advantage to the Department. (Norquist 2020, 8)

Regarding data protection and data security, the DOD strategy uses Attribute-Based Access Control (ABAC), which allows for a highly targeted approach to data security. This authentication method allows for sufficient assurance for the access request. Authentication and its associated attributes are used to facilitate an access decision, these access decisions are recorded in the system and provide attribution to the subject placing the request. By using ABAC, we ensure an extra layer of safety is added to the legacy Role-Based Access Control (RBAC) (Hu et al. 2014).

> Using a disciplined approach to data protection, such as attribute-based access control, across the enterprise allows DOD to maximize the use of data while, at the same time, employing the most stringent security standards to protect the American people. (Norquist 2020, 9)

Security using ABAC is greater than that provided with RBAC because the access decisions are made based on attributes about the user requesting access, the resource to be accessed, what the resource will be used for, and the environment (location, time, network, etc.) or context around the access request. ABAC establishes the policies to be used by defining the combinations of attributes from the user, the resource, and the environment. These combinations are the requirements to gain access to the resource (Hu et al. 2014).

The DOD data strategy supports acquisition reforms aimed at improving the speed of delivery of capabilities and supports faster oversight processes. Oversight conducted by senior DOD and congressional leadership is fundamental to ensuring the acquisition system timely addresses the warfighter needs (Norquist 2020). The DOD is committed to conducting data-driven oversight of acquisition programs, including those managed at the services level. This is a considerable challenge because with the use of the AAF some programs are managed using one or more of the six pathways within this framework. With each pathway governed by different policies for milestones, cost and schedule goals, and reporting, this challenge of capturing accurate and timely data to support decision making processes is extremely difficult. The program managers occasionally tailor the programs

by combining pathways and transitioning between them in the most beneficial way, supporting the program goals and mitigating the risks associated with the program (Oakley 2021).

The current DOD program reporting initiative to facilitate Congress oversight and access to data as close to real time as possible, also offers the possibility of incorporating more complex data sets and its analysis. The challenge on this new reporting initiative is the identification and capture of required data to evaluate program performance. Plans have been developed to capture this required data associated with performance metrics for Major Capabilities Acquisition (MCA) and MTA pathways. All other pathways—within the AAF—require more work in this effort of identifying performance metrics to continuously capture the status and progress of those programs under these pathways. A more complete analysis is required to identify more data markers on all programs under the AAF pathways other than MCA and MTA. This information will allow tracking cumulative cost, schedule compliance, and overall performance on those programs with multiple efforts requiring the use of multiple pathways (Oakley 2021).

Because these performance indicators are not being captured in all programs, the DOD cannot effectively assess whether the strategic goals supported by these efforts have been met. Until these performance metrics have been established and accurately tracked, the DOD would be limited in conducting internal oversight. This situation also affects DOD external reporting and accountability to Congress. Multiple efforts are being developed to solve this problem in program data collection and reporting requirements. All Armed Forces departments—which are the Army, Air Force and Navy—are involved in these efforts as they manage a vast majority of these programs, and their transparent input is critical to facilitate a complete understanding of whether current initiatives effectively support the acquisition process (Oakley 2021).

The Armed Forces departments fully support the DOD data and analytics strategy to facilitate data-driven oversight. This support is not optimal and requires a level of commitment resulting from mutual agreements yet to be reached. These agreements on data reporting are related to the amount of data that the DOD requires from the departments (Oakley 2021).

Detailed and consistent reporting is vital to any DOD program because it tells the story of the work being done. Both DOD and the Departments are required to document these initiatives to ensure that progress is being made. Unfortunately, excessive details or the frequency of reporting requirements hinder management and growth efforts (Oakley 2021).

A determination on a threshold for what is considered enough reporting needs to be made by the DOD in the near future. The time required to pull and analyze data and write the reports should be adequate—not excessive—leaving ample time to make program optimizations. In some programs where closer monitoring is required, and the program manager cannot satisfy the reporting requirements, the program scope needs to be re-examined, or the department's reporting needs must be reassessed (Oakley 2021).

The reporting requirements should be different for each program. Also, automation efforts are a game-changer for data processing and reporting within the DOD. In the automation of processes, the limitation in reporting is greater than what it might be in processing data sets, as there is always at least a section of the report that must be run manually, therefore requiring a tailored user interface (Tsai et al. 2015). Reporting is unique to each program, and that will not change. Because of this uniqueness, the data threshold for reporting purposes should fit the program it supports. We need to create adaptative solutions that accounts for programs with different reporting requirements, and track efforts across multiple pathways (Oakley 2021).

C. DOD CHALLENGES IN DATA SHARING AND DECISION MAKING

Data analysis and analytics are a growing resource used in developing information to make the highest level of decisions in acquisition processes. The process of implementing relevant data into the formula has not been without issues as the access to information has improved as technology has been developed. The 2017 National Defense Authorization Act (NDAA) reads, "a widespread recognition that DOD does not sufficiently incorporate data into its acquisition-related learning and decision making…. These polices are sometimes based on assumptions, and program reviews do not always sufficiently incorporate relevant data against which to evaluate success" (U.S. House of

Representatives 2017, 1125). The poor implementation of data analysis to drive decisions has been identified in multiple sources and include an environment of data restriction, lack of trust that data will be used appropriately, security concerns, and an overall increase in work to report the data (Anton et al. 2019). Research indicates that information is not being applied appropriately to decisions-makers, or simply not applied in favor of other metrics (Under Secretary of Defense, Acquisition, Technology, and Logistics 2016).

Security of data remains a top concern for acquisition personnel as the cyber threat continues to rise. As weapon systems have begun to rely more heavily on software development, to include data management, the DOD has only made limited progress in addressing cybersecurity vulnerabilities (Oakley 2021). Cyber security measures have generated complex security policies that regulate the information systems and can inhibit data flow to DOD leaders (Drezner et al. 2020). This information shows there is a valid risk of consolidation of DOD acquisition data, and limited data availability is prudent in the current environment. The potential risk is high for a single source for all DOD acquisition information, a single breach could release all information regarding system developments to our adversaries. New technologies and policies have attempted to address current limitations, but no current solution exists (Drezner et al. 2020). The development of new cyber protection policies and technologies has increased the difficulty of the user in both managing and reporting their data for various weapon programs.

Organizing and reporting data to decision makers is more difficult than ever before. Currently there is no common data environment for all acquisition information and no common agreement on what data is needed at different levels (Drezner et al. 2020). This has created a problem in that no guidance has been issued for staffs to frame currently available data in a way that it can be viewed and interpreted by decision makers. This coupled with issues that serve as a lack of common definitions for key acquisition terms cause confusion and ultimately degrades the capability that data can potentially bring to decision makers (Drezner et al. 2020). Existing accounting standards do assist to a common language for understanding between programs. This is because there are no metrics or standards established or understood across the community (Anton et al. 2019). The large

range of unstructured data has made it difficult to evaluate even with advanced analytic tools resulting in only limited application (Anton et al. 2019).

When data for assisting in making decisions is available, studies have found that the data has not always been followed by decision makers. A metric that has been used to evaluate if correct managerial decisions have been made is looking at the programs that have broken the Nunn-McCurdy threshold (Schwartz and O'Connor 2016). The Nunn-McCurdy threshold is a statue that requires notification to the United State Congress if a program goes beyond 25% of what was originally estimated and calls for termination of a program if it exceeds 50%. The Office of the Secretary of Defense (OSD) conducted an analysis of breaches since 2010 and found that three of 16 breach programs involved reasons that were linked to root causes where decisions were made that ran opposite of available data available (Under Secretary of Defense, Acquisition, Technology, and Logistics 2016, 28). Additionally, OSD's research shows that 26% of root-cause breach analyses involved in cases, but not fully acted on upon by current leadership (Under Secretary of Defense, Acquisition, Technology, and Logistics 2016). This information provides a context to even when information is available, it is not always fully used in the decision-making process.

Two examples of when data analysis might have been undervalued compared to other factors are the development of the Littoral Combat Ship (LCS) and Future Combat System (FCS). In the development of the LCS, the estimated costs for the ship were known, but a leadership decision was made to drive for lower cost ships (Anton et al. 2019). Based off calculations from the ships' expected weight, the expected cost was going to be much higher than what the leadership was expecting due to the low-cost initiative (Anton et al. 2019). The data was available to predict what the LCS was going to cost but ignored by leaders in favor of other unspecified motivates for changing the expected cost of the ship (Anton et al. 2019). A similar case occurred in the development of the FCS. The leadership responsible for development of the FCS pushed for a lower overall weight for the vehicle, which at the time was technically available and feasible (Anton et al. 2019). The leadership did not follow the data analytics available at the time that showed how difficult the

development of a platform with immature technologies available would be to obtain and failed at procuring a new vehicle.

D. FUTURE OF DEPARTMENT OF DEFENSE ACQUISITION DATA MANAGEMENT

Understanding the future of acquisition data management requires drawing upon facets across industry, government, and researchers. This section reviews both DOD and private industries' outlook on data management, best practices for the future, and possible applications for the future of acquisition data management.

The Rand Corporation published a report in 2019 titled Assessing Department of Defense Use of Data Analytics and Enabling Data Management to Improve Acquisition Outcomes. In this article, the Rand Corporation conducts an in-depth look at how the DOD manages data and applies data analytics in support of acquisition programs. The Rand Corporation identifies that the DOD is lagging the private sector in multiple areas, "Access to data for both internal government analysts and nongovernment analysts needs continued and significant improvement" (Anton et al. 2019, xxi). The DOD acquisition enterprise recognizes that the need for proper oversight and data sharing throughout the different levels of acquisition, but the "belief is that current levels impose burdens on time and resources that are better spent in direct management" (Anton et al. 2019, xxi).

Throughout the report, the Rand Corporation works to inform Congress of the status of data sharing in the acquisition field through multiple differing viewpoints and maturity models. When comparing the DOD acquisition data analytics with private sector companies the DOD consistently falls short (Figure 1).

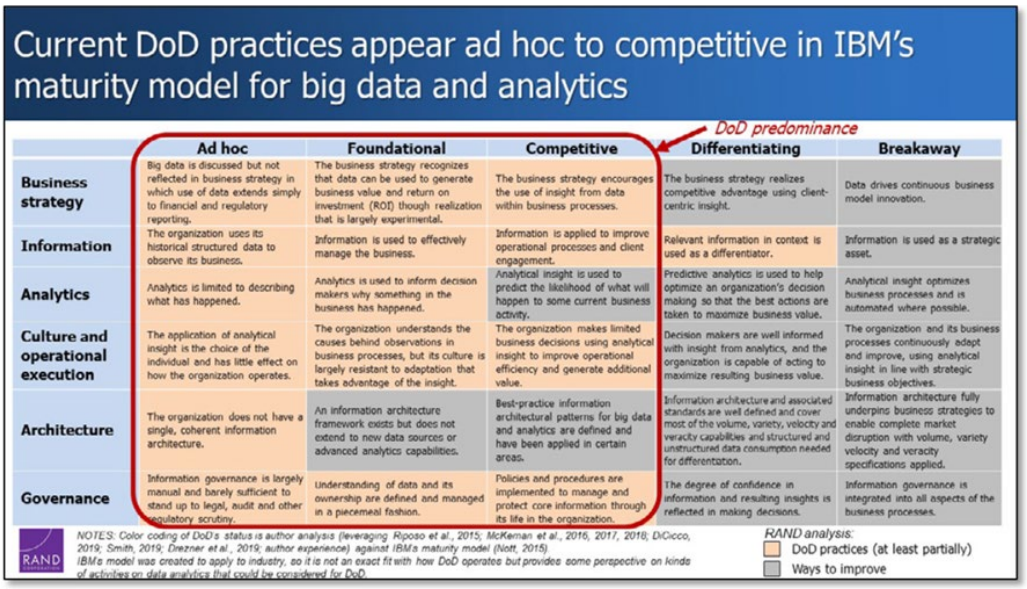

Figure 1. IBM's Maturity Model for Big Data and Analytics.
Source: Anton et al. (2019, 46).

Although the DOD is falling short in multiple data management categories, the acquisition enterprise has acknowledged private sector best practices and is actively pursuing:

> Reduced burden through more-efficient data extraction directly from operating functions, standardized data definitions, designation of the authoritative information source for each data element (to avoid arguments or misleading analysis or decisions), open interfaces to share authoritative data efficiently and to minimize data entry to once (or less, if automatically pulled), selection of which data to make available in each system based on key decisional needs, and provision of integrated software analytic and visualization tools for general-purpose data analytics. (Anton et al. 2019, xxii)

Even though the DOD is making strides in these categories, the Rand Corporation further identified ways the DOD can improve its data analytics in the future. The first recommendation was to delineate internal and external factors in the acquisition data. Improving data analytics capabilities and separating the internal vs. external cost drivers will help to inform decisionmakers in the acquisition enterprise (Anton et al. 2019, xxiii).

The next area that the Rand Corporation identified was the need to shift from siloed program-level performance to an integrated set of programs that field mission-level

capabilities (Anton et al. 2019, xxiii). Viewing each program individually can be problematic, especially at the highest levels in the acquisition enterprise and lacks the perspective of the integrated capability and effects of the overall system. Using "Integrated analysis could help decisionmakers better understand dependencies between systems so that technical, budgetary, and schedule decisions can be made to maximize the integrated warfighting capability" (Anton et al. 2019, xxiii). Essentially Rand Corporation determined that reporting the capability and the program would be beneficial in the future.

Another area that the Rand Corporation identified as needing future analysis was framing assumptions and the need to properly communicate those risks to leadership (Anton et al. 2019, 110). The DODI 5000.02, Adaptive Acquisition Framework (Figure 2), was implemented to help Program Managers access and properly select the right acquisition pathway and risk model to acquire new systems. The Rand Corporation states, "tracking these risks could be made more explicit so that early indicators of fundamental conceptual risks are detected as soon as possible" (Anton et al. 2019, 111).

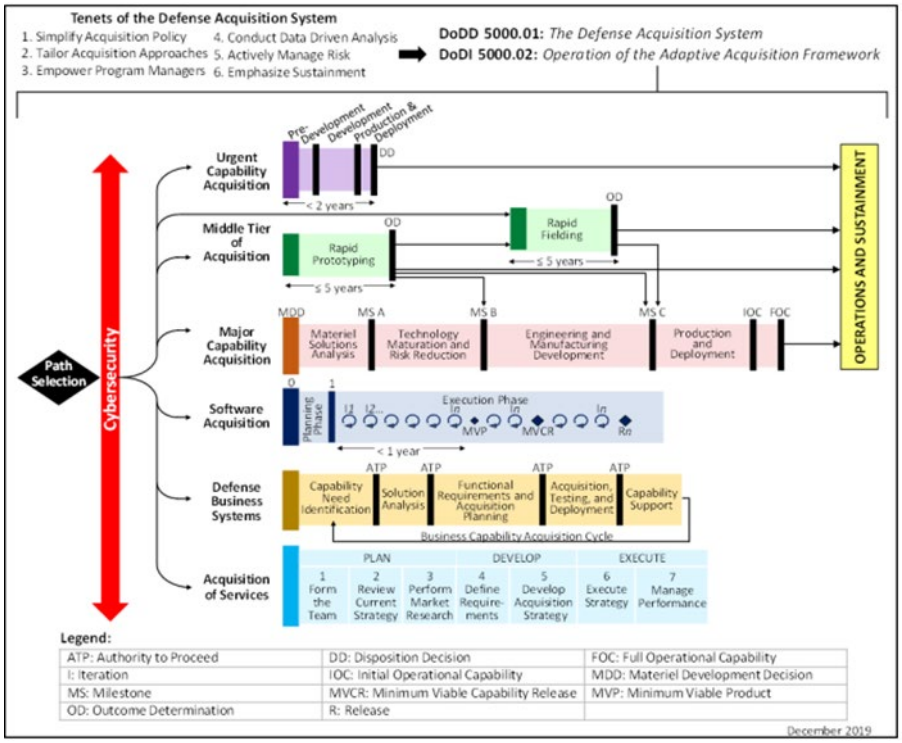

Figure 2. The Adaptive Acquisition Framework.
Source: DODI 5000.2 (2020).

The Rand Corporation also identified performance analysis as another topic that has potential to improve acquisition outcomes (Anton et al. 2019, 111). The Rand Corporation identified that acquisition performance indicators are generally descriptive and lagging in nature. Contractor risks indicators, earned value, and cross-program performance are a few leading indicators, but collectively there are not sufficient leading indicators to identify future acquisition performance problems (Anton et al. 2019, 111)).

Lastly, the Rand Corporation identified the need to conduct "analysis to better understand which data is needed to inform acquisition efficiency efforts and ensure that key data to inform decisions and data analytics are available" (Anton et al. 2019, 111).

The future of data management is not an easy task. Examining large collections of data from many programs of record in various categories to help drive decision making will always be a complex endeavor. But researchers at The Naval Postgraduate School (NPS) are working with Lexical Link Analysis (Figure 3) to improve acquisition visibility (Zhao, Gallup, and MacKinnon 2013, 2). The team at NPS "explored an analytic and visualization of Lexical Link Analysis, to link warfighter requirements with acquisition programs and program elements (Zhao, Gallup, and MacKinnon 2013, 4). Lexical Link Analysis (LLA) can be used to "identify data dependencies that might be indicators for program or investment performances and risks" (Zhao, Gallup, and MacKinnon 2013, 12). Using LLA to assist humans through data mining and discover inside the acquisition enterprise has proven to be useful. Using this methodology and incorporating LLA to discover data connections and gaps of programs may prove helpful in our efforts to synchronize and identify risks.

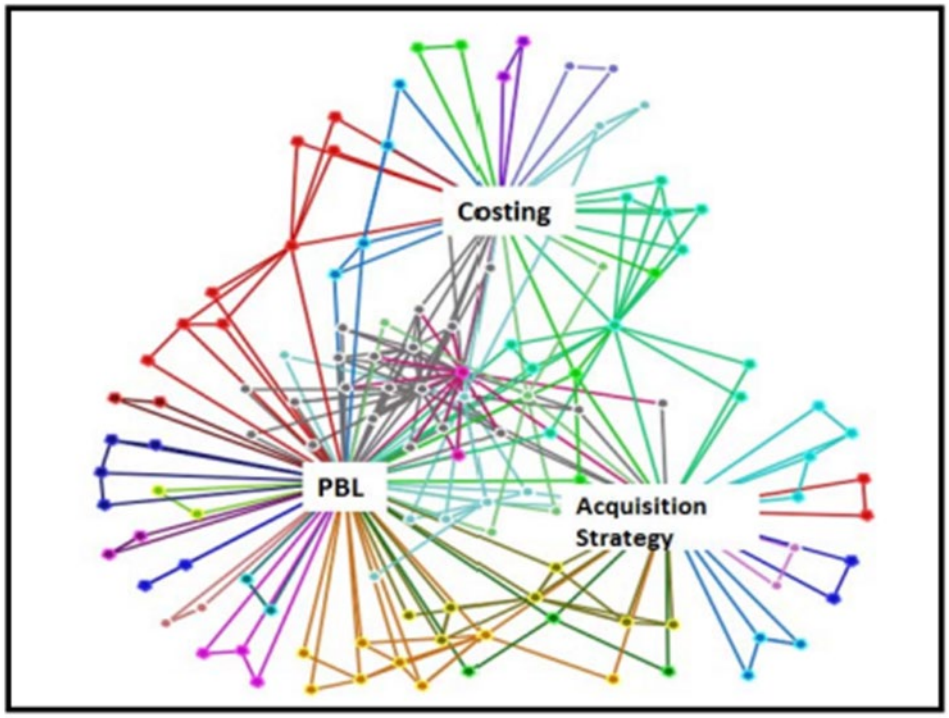

Figure 3. Lexical Link Analysis of Costing, PBL, and Acquisition Strategy and the Links between the Systems. Source: Zhao, Gallup, and MacKinnon (2013, 7).

Acquisition internal measures of performance can be difficult to track and usually even more difficult to visualize. Jammie Downer, an NPS student, did address this through his thesis, Operating Metrics that Effectively and Efficiently Measure Contract Performance Operations Within an Organization (2019). In his research, he identifies a lack of internal performance controls resources within the Naval Acquisition System (Downer 2019, 42). He further encourages the Navy to procure a civilian industry dashboard and adopt a universal web-based system for contracting departments to allow standardized and measurable metrics quickly on one platform (Downer 2019, 42). His research was unable to produce a baseline of internal measuring practices, but he does suggest it as a topic of future research. Downer's recommendation to move to a web-based system for contracting and standardize definitions across the Navy contracting spectrum (Downer 2019, 42). Downer's research can be applied to the future of Army Acquisitions. The Army can benefit from a standardized, web-based dashboard that allows engineers, at

the lowest level, to decisionmakers at the highest level to view synchronized data and measure internal controls in the organization.

Another future potential application of technology is integrating the use of AI capabilities in the acquisition enterprise. Kory Krebs researched this theory in June 2020 in his thesis "How Can the DOD Adopt Commercial Style Artificial Intelligence for Process." He identifies, through interviews with key stakeholders, that artificial intelligence is anticipated to, "save significant time and money, improve speed and agility, streamline processes, and automate tasks" (Krebs 2020, 31). Krebs recommendations for implementing artificial intelligence in procurement were summarized into five parts: "Make it a priority, start with data, treat it differently than traditional software, start small, and monitor similar projects at other government agencies" (Krebs 2020, 40). As of the writing of this thesis, no current efforts had been made to integrate artificial intelligence (AI) into the acquisition enterprise (Krebs 2020, 40). The only case study that was able to be observed was Health and Human Services (HHS) integration of AI (Krebs 2020, 36). Krebs showed that AI can be built quickly and relatively cheap. "Starting small can work well; HHS began with a proof of concept that cost them $175,000 and took them four weeks to build" (Krebs 2020, 36). Krebs goes on to say identify the two largest challenges to bringing AI on in the DOD are data integrity and change management (Krebs 2020, 39).

Another NPS student, Vladislav Skots (2019), conducted research on the application of AI to enhance the contracting process timeline. He identified the most appropriate types of AI for procurement, "which are Machine Learning (ML), Natural Language Processing (NLP), and Robotic Process Automation (RPA)" (Skots 2019, 38), as shown in Robotics Process Automation. He further shows how Microsoft, a company of comparable size to the DOD, successfully implemented AI to help "reduced contract administration costs by 40%, improved speed of contracting by 60%, improved customer, partner and employee satisfaction, and improved auditable contracting compliance and administration, while taking only 12 weeks to fully deploy the system across the entire company" (Skots 2019, 58). Ultimately Skots concluded that the DOD is ready to, "explore AI as a solution to multiple issues that an increasingly connected and technologically evolving reality develops" (Skots 2019, 67).

A joint team from the Air Force Research Lab built a model of information management that applied to DOD Acquisition in 2005. Although this article is quite dated, the assumptions that the team made may still hold true for future acquisition data and information management. "The goal of Information Management is to maximize the effectiveness of an enterprise" (Linderman et al. 2005, 2). The first assumption they made was that acquisition data, "should not be standardized or synchronized" (Linderman et al. 2005, 3), as doing so could produce unacceptable delays in fielding and unacceptable high costs. The second assumption was universal data standards are unrealistic (Linderman et al. 2005, 3). The team conceded that high-level data standards can be productive but relaying on a universal model would be counterproductive (Linderman et al. 2005, 3). In summary, the team identified that the Information Management model must accommodate diversity and adaptability. These concepts may prove to hold true as we develop a solution to our problem for future acquisitions.

E. DEVELOPING A DATA-DRIVEN CULTURE

A data-driven culture is a culture in which data is used to make decisions at every level of the organization, as opposed to making decisions by gut instinct, past action, or belief. In data-driven cultures, data is embraced and used as a strategic asset for growth and innovation. In recent decades, researchers across a myriad of disciplines have grappled with understanding the relationship between organizational culture and the use of data to make decisions. Researchers have failed to uncover a direct link between organizational culture and data-based decision making, however the combined body of research in this area reveals the practices and traits shared by organizations with a data-driven culture. Many of these commonalities are rooted in the people who make-up the organization and their attitude towards data and information. A 2017 study published in Procedia Computer Science found a correlation between the extent to which a workforce values data and the prevalence of data in decision making within the organization. "There is some evidence that the perceived value of data analytics influences the configuration of the decision-making process, and in organizations that believe in the reliability and accuracy of the information available, managers tend to use more of that information to support their decisions" (Thirathon et al. 2017, 775).

Or, as Randy Bean, author and CEO of NewVantage Partners put it in a 2022 *Harvard Business Review* article, "As noted, this is not a technology issue. It is a people challenge" (Bean 2022). Bean's research further reveals that despite many organizations wanting to establish a data-driven culture, 91.9% of executives cited obstacles as the greatest barrier to becoming data driven and only 40.2% of organizations polled reported that the role of the chief data and analytics officer was successful and well established within their organization. To paraphrase the September 2018 McKinsey Quarterly Report: data culture cannot be imported or imposed—it must be developed to achieve engagement with employees and stakeholders, cultivate a sense of purpose and support operations (Díaz, Rowshankish, and Saleh 2018, 2).

This problem is also as prevalent in the public sector. A 2016 study by PwC, the world's second largest professional services firm and research house, found that only 21% of government organizations described their decision making as being highly analytical or significantly based in data (Lawton 2021, 38). The same study also revealed that while nearly all organizations had invested in systems and/or technology to make data-driven decisions, only about 33% of them were utilized those tools to help forge a data-driven culture and to make decisions rooted in data. These studies illustrate just how difficult it is to foster an environment of data-driven decision making, but they also evince the importance and benefit of developing this type of culture, particularly in government organizations. Lawton's 2021 research went on to showcase how the City of Boston used data to reduce school bus mileage by one million miles per year and reduce carbon dioxide emissions by 20,000 pounds annually (38).

The DOD recognizes that developing a data-driven culture today is imperative to meet long-term objectives and build, support and sustain the military of tomorrow. The 2020 DOD Data Strategy outlines the numerous benefits to fostering this type of environment. "Improving data management will enhance the Department's ability to fight and win wars in an era of great power competition, and it will enable operators and military decision-makers to harness data to capitalize on strategic and tactical opportunities that are currently unavailable" (Norquist 2020, I). The 2020 strategy further points out that by embracing data, the DOD will not only be able to improve military operations and

outcomes, but also gain trust with the U.S. Congress, private sector partners and the American public.

Based on the breadth of available literature on the topic in conjunction with the 2020 Data Strategy, we've determined six key issues that the DOD must address to facilitate a data-driven culture. These include Data Policy & Management; Standardization of Data; Accessibility of Data; Data Interoperability; Data Interpretation; and Data Sharing.

The DOD's data policy should outline the principles, policies, procedures, criterion, and governance for data use within the organization. It should be designed in such a way to promote the use of data in decision making at all levels of the organization and provide the framework for how data should and should not be used or shared while simultaneously providing an organized and structured system through which all stakeholders have the ability to share input and be heard (Norquist 2020, 5). The DOD's data policy should be based off the current DOD standards for the management and utilization of data assets. Governance, or management, of data within a government organization can and should take many forms. Lawton suggests empowering a data governance council or designating data stewards to oversee data policy, make decisions, research, and recommend new technologies, investigate data misuse, and develop initiatives to create an environment of accountability and stewardship around data within the organization (Lawton 2021, 39).

For data to be effectively used by DOD staffers and decision makers at all levels of the organization it must be standardized. The lack of standardization or uniformity in DOD data is one of the key hurdles the organization faces in developing a data-driven culture. Standardization is essential to determining the meaning of data, matching related data records, and compiling relevant information for decision making. All data within the DOD system should be standardized and formatted to provide end users with a consistent presentation and to ensure that the placement of information has a context that can be used to determine the meaning of individual pieces of data, such as name, date, stage, group, type, or location (Taylor n.d.).

The reason data accessibility is so important is because it gives users the flexibility to find the information they need to find, when they need to find it and based on the terms

or values through which they need to analyze it (Norquist 2020, 7). The Department's 2020 Data Strategy outlines three valuable objectives for data accessibility: the accessibility of data and information through application programming interfaces (APIs); uniform platform services for creating, retrieving, managing, and sharing data; and the ability to manage data controls on reusable APIs.

Data interoperability is how data is shared and utilized between organizations, departments, programs, and teams. The interoperability of data is another key hurdle the DOD must overcome in becoming a data-driven culture. This obstacle is not unique to the DOD. Organizations struggling to find value in their data analytics tend to develop data in isolated pockets, creating poorly coordinated silos of information and resulting in data models that do not line up or connect (Díaz, Rowshankish, and Saleh 2018, 6). This describes the current data situation at the DOD well. To remedy this situation and to maintain the level of semantic understanding needed for successful joint operations and decision making, the 2020 Data Strategy lists five targets for data interoperability. The aim of these objectives is to ensure the responsibility for creating a data-tagging system, mediating differences in data standards and formats, and ensuring uniform specifications for data system within and outside the organization, falls under the DOD.

All DOD employees should be trained in data interpretation to develop a workforce that understands what and how data is used to make different decisions. This training should be offered in tiers, with a basic briefing on the benefits and possibilities data presents, as well as how to read data at the lower level and working its way up to more difficult data manipulation and computations involving numerous data sets. Following training, all DOD employees should at a minimum have a general knowledge of the five-step process for making data-driven decisions. The steps are as follows: one, identify the question you are trying to answer; two, identify the common variable you must find in the data sets you are working with; three, collect the data you need, organize it, and hide or remove un-needed data; four, analyze your data; and five, draw conclusions based on the data you have collected (Miller 2015).

Data sharing offers the potential of big rewards, but those rewards do not come without risks. To reap the benefits of data sharing, the DOD must find the right balance

between uninhibited information sharing and the protection of sensitive data. To strike this balance the DOD must: identify sensitive data; construct a data policy detailing how to use different types of data and how that data can be shared; implement controls on sensitive data to restrict access; and monitor sensitive data through its life cycle and disposal (Divatia 2020). Ensuring the safety of information in data sharing requires significant and ongoing effort and expense, but when done properly, it is worth it. A recent McKinsey report found that the potential economic value that could be generated from open data was more than $3 trillion annually and that government organizations were key to realizing this economic boon (Díaz, Rowshankish, and Saleh 2018). "Government plays a critical role in enabling value creation from open data. This value primarily accrues in three ways: decision making, new offerings, and accountability (Exhibit 4). These levers produce benefits for the government itself and for other stakeholders, including private sector organizations and consumers" (Chui, Farrell, and Jackson 2017, 9).

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III. RESEARCH DESIGN

A. OVERVIEW

This chapter describes the team's approach to conducting research for the project. The team utilized a tailored systems engineering approach in defining and scoping the problem. They conducted data collection from multiple sources to support an in-depth systems analysis, including a comparison of alternative reporting processes. This chapter presents the team's systems analysis results before offering its recommendations. It also describes the assumptions and limitations that influenced data collection, systems analysis, and recommendations.

B. RESEARCH METHODOLOGY

The team utilized a tailored systems engineering approach. The activities were broken into the following five phases: Problem Identification, Data Collection, Systems Modeling, Systems Analysis, and Recommendations. These phases are demonstrated in Figure 4.

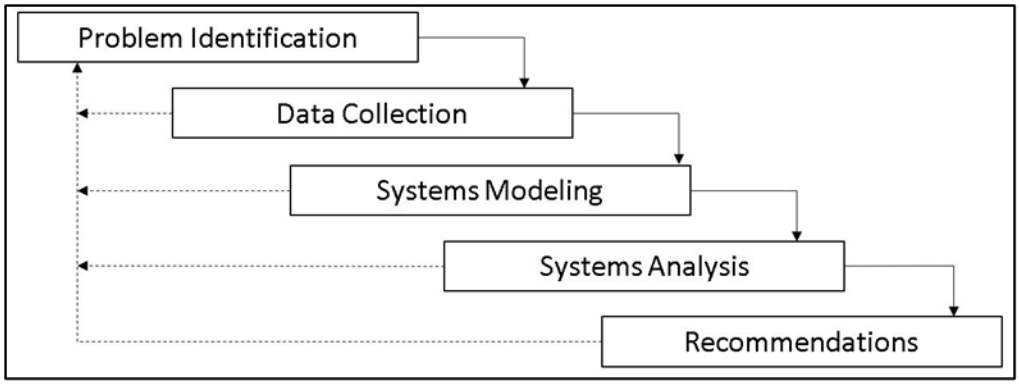

Figure 4. Tailored Systems Engineering Approach

C. PROBLEM IDENTIFICATION

1. Stakeholder Needs Analysis

Blanchard and Fabrycky (2011), in their fifth edition of *Systems Engineering and Analysis*, state that, "the purpose of system design is to satisfy the customer (and stakeholder) needs and expectations." Satisfying diverse needs presents the greatest challenge for the research team in defining and bounding the problem as they turned the unrefined needs identified during stakeholder engagement into objectives for the project. This was initially done through consistent engagement with AMI and The Research Analysis Center (TRAC)-Monterey as the primary stakeholders. Once the team had the needs of the primary stakeholders identified, they began engaging with the Army program offices responsible for the modernization efforts. As they continued with data collection and systems analysis, they continuously engaged with stakeholders to ensure they would satisfy their needs as represented in Table 1.

Table 1. Stakeholders' Needs and Concerns

Priority	Stakeholder	Needs	Concerns
1	AMI ASA(ALT)	• Forecast FUE and FUI for modernization efforts • Visibility of modernization program data • Accuracy of modernization program data	• Synchronization of modernization efforts • Needs forecasting • Risk picture
2	TRAC-Monterey	• Visibility of modernization program data • Accuracy of Modernization program data	• Complete Data Sets
3	Army Program Offices	• Visibility of modernization program data • Accuracy of Modernization program data	• Needs forecasting • Risk Picture
4	Army Futures Command	• Forecast FUE and FUI for modernization efforts • Visibility of modernization program data • Accuracy of modernization program data	• Synchronization of modernization efforts • Needs forecasting • Risk picture
5	NPS	• A Systems Engineering Analysis and Solution	• Research Project Must Complete by December 2022

2. Problem Illustration

Following the initial bounding of the problem through engagement with primary stakeholders, the team began illustrating the data flow and communication processes with systems modeling using the Innoslate Model-Based Systems Engineering (MBSE) Tool. Utilizing models and illustrations was the team's means of conducting "experimental investigation" to yield design decisions in less time and at less cost than direct manipulation of the systems themselves (Blanchard and Fabrycky 2011).

The MBSE Tool provided a common picture as the team opened their engagement to stakeholders within the LRPF and NGCV. The visual aids were vital to effective communication and assisted stakeholders in walking through scenarios with the research team. Visual illustrations were a significant contributor to achieving greater understanding of stakeholder processes, the identification of friction points in their data and communication flows, and in comparing the modernization initiatives.

3. Assumptions and Limitations

The team made certain assumptions and worked under limitations that had a significant impact on their approach, conclusions, and recommendations. The following is a list of those assumptions and limitations:

- The study assumes that FUI and FUE reporting is required and beneficial.
- The study is focused only on the modernization efforts within the LRPF and NGCV portfolios, but the conclusions and recommendations will have applicability across the entire Army modernization enterprise.
- The models and conclusions were developed from the limited available data sources provided by AMI and the program offices.
- The research project was completed within 6 months.

D. DATA COLLECTION AND SYSTEMS ANALYSIS

1. Approach to Data Collection

The team began data collection by gaining access to the Monthly Acquisition Reports (MAR) hosted on the Project Management Resource Tools (PMRT), the Consolidated Signature Efforts Enterprise Data Tracker (CSET), and the Integrated Army Modernization Schedule (IAMS) the product offices utilize to share data on their modernization efforts. These resources assisted the research team in determining their initial assumptions, creating their initial models and illustrations, and in narrowing their questions for the program offices. The team then took those assumptions and questions to the program offices with a more focused approach in their ongoing dialogue. Data collection became more refined and focused once the team began engaging with the program offices. This stakeholder engagement was focused on understanding the processes utilized by the program offices and was driven by the illustrations, assumptions, and questions presented by the research team.

2. Approach to Systems Analysis

The team's data analysis was informed by all raw data gathered from the MAR, the CSET, and the IAMS, followed by stakeholder engagement. The team collectively analyzed the collected data to isolate all relevant information that could inform their illustration of the processes utilized by LRPF and NGCV. As the team refined their illustrations and assumptions, they continuously engaged with stakeholders for feedback. Once they had all relevant information separated and had completed their informed illustrations of the processes utilized by the modernization efforts within LRPF and NGCV, the team began their systems analysis.

The intent of the systems analysis was to review, compare, and contrast the processes and procedures of the modernization initiatives within LRPF and NGCV. This analysis focused on the processes utilized in reporting FUI and FUE and the quality of the data produced by the processes. The processes were reviewed with the intent to identify inefficiencies, best practices, and to potentially inform the development of a new process that could be used as a standard for the modernization enterprise. To conduct a comparison

of the alternative process solutions, the team first conducted a functional analysis of the desired process, beginning with the identification of functional and nonfunctional requirements, and ending with a decomposition of the functional requirements. The functional analysis was vital to determining the proper solution and to mapping evaluation criteria to the solution's functional and nonfunctional requirements. Following the functional decomposition, the team utilized a criteria-based decision matrix, called a Pugh Matrix (Pugh 1981), to evaluate and compare the alternative processes.

In determining criteria to utilize in the comparative analysis, the team decided to focus on data quality. They established criteria based on data quality metrics found in an article published in Data Science Journal. The article entitled "The Challenges of Data Quality and Data Quality Assessment in the Big Data Era" outlines fourteen elements of quality data that are divided into five dimensions (Cai and Zhu 2015). The fourteen elements of quality data are accessibility, timeliness, authorization, definition, documentation, credibility, meta data, accuracy, integrity, consistency, completeness, auditability, fitness, readability, and structure (Cai and Zhu 2015, 5). Those fourteen elements are divided into the five domains, including availability, usability, reliability, relevance, and presentation quality (Cai and Zhu 2015, 5).

The team reviewed the fourteen elements outlined in the article and selected the five elements they deemed to be the most valuable criteria in determining which reporting process best supported the sharing of quality data, mapping them back to the functional requirements identified in the functional decomposition. The five elements were auditability, fitness, credibility, accessibility, and timeliness. Auditability is an element of reliability (Cai and Zhu 2015). In evaluating auditability, the team reviewed each process to determine the level of difficulty auditors would have in determining if the data meets required standards and if the data could be traced back to origin. Fitness is an element of relevance, and it is a measure of how well the data matches user's needs (Cai and Zhu 2015). Credibility is an element of usability, and it is used to evaluate the believability of the data (Cai and Zhu 2015). Accessibility and timeliness are the two elements of availability, and both were determined to be essential criteria in determining which process facilitated greater data quality. "Accessibility refers to the difficulty level for users to

obtain data, and timeliness is defined as the time delay from data generation to utilization" (Cai and Zhu 2015, 5).

Table 2 illustrates the five evaluation criteria utilized in the Pugh Matrix. Using an ordinal rating scheme, the team evaluated each report on a scale from 1–3, 1 being the best and 3 being the worst. Once all reports were ranked, the team summed the scores, highlighting the total summed ratings of the reports. This was then divided by 5, the total number of evaluation criteria chosen, and averaged. Using the Pugh Matrix evaluation, the team was able to evaluate and compare the three reporting processes.

Table 2. Evaluation Criteria for Reporting Platform Considerations. Source: Cai and Zhu (2015, 5).

Evaluation Criteria	Definition
Auditability	"The degree to which users can fairly evaluate data accuracy and integrity within rational time and manpower limits during the data use phase."
Fitness	"The degree to which the data produced matches users' needs in the aspects of indicator definition, elements, classification, etc."
Credibility	"The measure of the objective and subjective components of the believability of a source or message."
Accessibility	"The measure of the difficulty level for users to obtain data."
Timeline	"The time delay from data generation and acquisition to utilization."

IV. SYSTEMS MODELS AND ANALYSIS

A. OVERVIEW

Chapter IV presents the models and analysis of the reporting processes for FUI and FUE dates utilizing a systems engineering approach. The team performed a functional decomposition of the FUI/FUE reporting process and analyzed the current FUI and FUE reporting processes associated with the LRPF and NGCV programs. The team examined the definition and compared how each organization in the Army acquisition enterprise defines FUI and FUE. The team then provided detailed illustration and analysis of the acquisition communities' three main tracking systems used for tracking FUI and FUE dates. This includes analysis of the Monthly Acquisition Reports (MAR) from the hosting Project Management Resources Tool (PMRT) site, Consolidated Signature Efforts Tracker (CSET), and the Integrated Army Modernization Schedule (IAMS) (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). Specifically, the team analyzed how the current tracking systems present FUI and FUE dates to intended users. Activity diagrams demonstrate the flow of reports completed sequentially across the different reporting platforms. Finally, the team compared our results from the different programs to determine how successful reports were being generated for FUI and FUE across the scope of the research.

In the last part of this chapter, the team used specific data quality criteria combined with a modified Pugh Matrix to evaluate the suitability of current FUI/FUE reporting systems for future use. Evaluation criteria established for this matrix was outlined in Chapter III and is used here to conduct a comparative analysis of the three current reporting systems. Each system is evaluated individually to determine strengths and weaknesses of the system as it pertains to auditability, fitness, credibility, accessibility, and timeliness. The reporting systems will then be ranked, 1, 2, or 3 per evaluation criteria. After ranking each reporting system in all five evaluation criteria, we utilize a modified Pugh Matrix to compare the systems against each other. Utilizing the outputs of the Pugh Matrix, the findings establish the most suitable reporting system out of the current three and provide qualitative data highlighting areas of improvement for future use.

B. SYSTEM CONTEXT FOR FUI AND FUE

The scope of the analysis is established from LRPF and NGCV programs that interact with, report, and utilize FUI and FUE information to support making decisions. Figures in this analysis only illustrate activities and agencies in the FUI/FUE reporting process. Key personnel from different offices across the acquisition enterprise report and update information that is used by Army Senior Leaders to make decisions about funding, fielding, and development in a program. The process diagram (Figure 5) shows how different reporting functions containing FUI and FUE are distributed from each office, and then presented on one of the three current systems that track FUI/FUE.

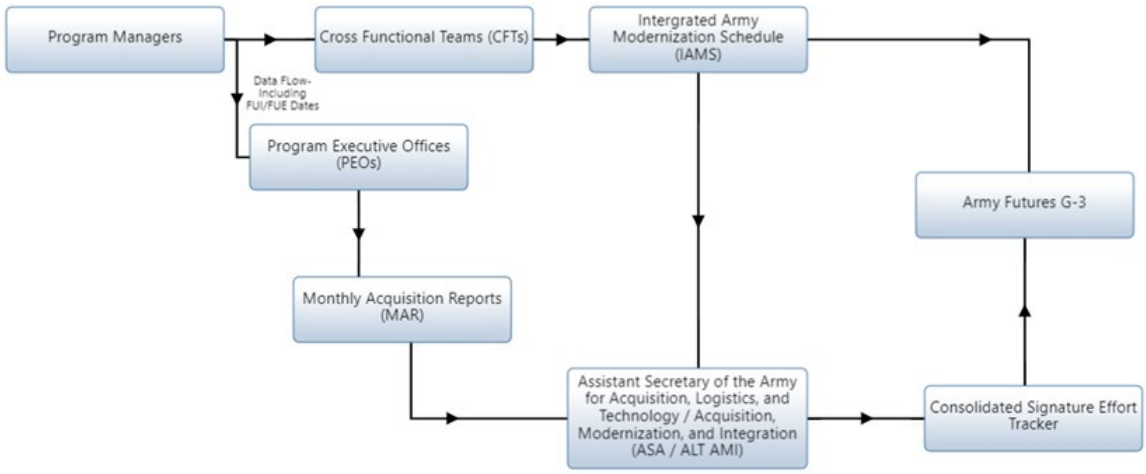

Figure 5. Process Diagram of FUI / FUE System.
Adapted from Flood and Carson (1993).

The projected completion dates for events in the schedule are required to have degrees of accuracy based on the time until execution of that event. The goal is to be within an acceptable tolerance based of the time until event execution as described in Table 3 (AMI Manager, meeting, August 5, 2022). The flexibility in the projection and reality allows for unexpected variances in the project schedule that occur during execution.

Table 3. Program Schedule Variance Tolerance Thresholds. Source: AMI Manager (2022).

Time Until Event Execution	Acceptable Tolerance
Less Than a Year	3 Months
Less Than 2 Years	6-9 Months
More than 2 Years	9-12 Months

C. FUNCTIONAL DECOMPOSITION

The team completed a functional decomposition of the FUI/FUE reporting process. In this phase, the team decided what functions were necessary to provide accurate reports for FUI and FUE. The functional decomposition was laid out in a hierarchical fashion, as shown in Figure 6. There are four functions that support the production of actionable information on each of the systems analyzed. The functions are:

- Upload FUI/FUE Data
- Control Access to FUI/FUE Data
- Report Current FUI/FUE Data
- Maintain Quality Control

The functional decomposition facilitated greater insight into the identity of the constituent processes required to support the reporting process and provide actionable information. The function of Maintain Quality Control has two sub-functions:

- Trace Data
- Record Historical FUI/FUE Information

The functional analysis is also shown in Table 4. The composition level and function/subfunction shown in the first two columns match the functions identified in the hierarchy in Figure 6. The descriptions under the Requirements heading explain what the system is required to do to complete each of the desired function.

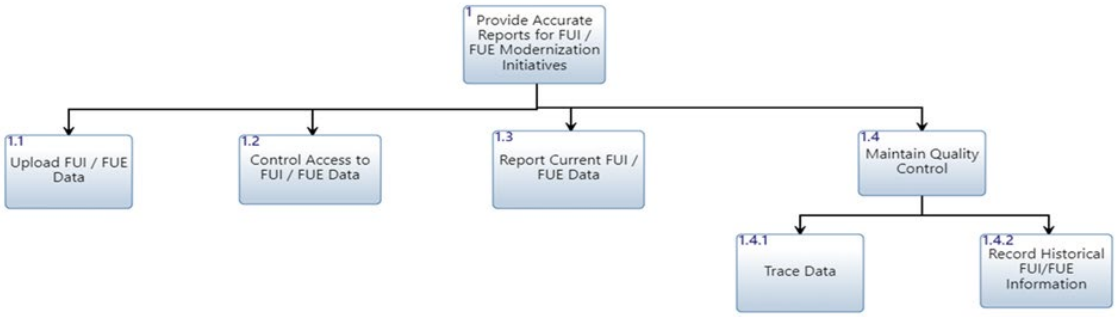

Figure 6. Functional Decomposition of First Unit Issued (FUI) / First Unit Equipped (FUE). Adapted from Buede and Miller (2016).

Table 4. FUI/FUE Reporting System Functional Analysis Requirements. Adapted from Blanchard and Fabrycky (2011).

Composition level	Function/Subfunction	Requirements
1.0	Provide accurate reports for FUI/FUE	The system shall provide reports with accurate FUI/FUE
1.1	Upload FUI/FUE data	The system shall allow the upload of FUI/ FUE to the supporting platform
1.2	Control Access to FUI/ FUE Data	The system shall control the access to FUI/ FUE data
1.3	Report on current FUI/ FUE Data	The system shall report FUI/FUE data in real-time
1.4	Maintain Quality Control	The system shall allow for maintaining data quality control
1.4.1	Trace data	The system shall allow tracing data provenance
1.4.2	Record Historical FUI/ FUE Information	The system shall record the access to FUI/ FUE data

The functional requirements created the baseline to understand the system design that can appropriately address the needs of the stakeholders. After establishing a shared understanding of functional requirements, the team conducted a comparison of existing alternatives. The existing alternatives were compared utilizing five evaluation criteria derived from the functions listed in Table 4.

D. FUI AND FUE DEFINITION ANALYSIS

The research sought to better understand what the current definitions to be, and if any of the definitions were established through policy or law. Key to understanding the inconsistent reporting of FUI and FUE is in the individual definitions that each population uses to understand the terms. Throughout the study we identified that different populations were using the terms FUI and FUE differently and applying different meanings.

1. ASA(ALT) AMI Definitions

ASA(ALT) AMI describes First Unit Issued (FUI) as "Date first unit is issued prototypes to support Soldier Touch Points, Demonstrations or Experimentation" (AMI Manager, meeting, August 5, 2022). The term prototype is defined in the DoDI 5000.80 (2019) as "a model built to evaluate and inform its feasibility or usefulness. Non-physical models are acceptable if the non-physical model is the residual operational capability to be fielded" (Department of Defense 2019). Residual Operational Capability is defined as "for rapid prototyping programs, residual operational capability will be considered any military utility for an operational user that can be fielded" (AMI Manager, meeting, August 5, 2022).

Key to the definition of FUI is the understanding that the prototype has been completed at the time of testing, not iterative testing of individual subcomponents. Soldiers are trained on the equipment through Prototype Equipment Training. Prototype Equipment Training is usually performed on-site at the unit's location, with a team of subject matter experts that lead Soldiers through the training needed to properly operate the newly fielded equipment. Property accountability for FUI equipment is maintained through hand receipts and accountable property systems of record. During our research, the team discovered there was no formal documentation or official definitions of FUI outside of AMI's definition. Soldier Touch Points (STP) is another key term to understanding the issues with misreporting FUI. STPs are defined by the United States Army Acquisition Support Center (USAASC) as "immersive testing and feedback mechanisms through which Soldiers can provide valuable insights on how certain tools or equipment undergoing development will be used practically in the field" (Thompson 2022). The term Soldier Touch Point (STP)

can also be used when conducting FUI, as conducting FUI fulfills the requirements of a STP. The events where STPs are not testing the completed prototype results in a STP that does not meet the threshold for FUI. Not all STPs meeting the criteria for FUI, and FUI is distinguished separately from the term STP.

ASA(ALT) AMI references the Defense Acquisition University definition of FUE and is defined as "The scheduled date a system or end item, and its agreed-upon support elements, are issued to the designated Initial Operational Capability unit, and training specified in the new equipment training plan has been accomplished" (Defense Acquisition University n.d.). The term FUE is not established in Army specific regulations and is currently distributed through informal means through briefings or one-to-one conversations between ASA(ALT) AMI and PEOs.

The definitions of FUI and FUE have evolved, and ASA(ALT) AMI gave the basis of criteria for FUI and FUE (AMI Manager, internal presentation, July 12, 2022). The basis for the criteria for FUI and FUE is described in Table 5. The criteria clarify detailed gates for a program to meet the terms FUI and FUE. The first FUI gate is cleared when the equipment is fielded under a LIN or Developmental Line-Item Number (ZLIN). The property is also accounted for under SLAMIS and the unit's official property system of record, for example GCSS-A or DPAS. Soldiers are trained through new equipment training program prior to test use. FUE gates are completed when equipment is supported through the documented Basis of Issue Plan (BOIP), which provides applicable authorization documents: Modification Table of Organization Equipment (MTOE), Table of Distribution and Allowances (TDA), and Common Table of Allowances (CTA). This event happens after MCA Milestone C in the AAF, and typically larger unit formations are fielded with the equipment. Soldiers conduct the testing on the equipment through OT&E, and assessment on full rate production of the equipment is made.

Table 5. ASA(ALT) AMI FUI and FUE Criteria. Source: AMI Manager (internal document, July 12, 2022).

	Type Classification	Materiel Release	Soldier Touchpoint	Support Equipment	PPBE Designation	Property Accountability
First Unit Equipped.	Standard or Limited Procurement.	Full Material Release (FMR), Conditional Material Release (CMR), or Software Material Release (SMR).	New Equipment Training.	Documented on the BOIP which provides applicable authorization documents: MTOE, TDA and CTA.	LIN or ZLIN.	SLAMIS and Accountable Property System of Record, e.g. GCSS-A, DPAS, or LMP. .
First Unit Issued.	Not Applicable.	Less than FMR, CMR, or SMR. Possibly less than UMR (Urgent Material Release).	Prototype Equipment Training (T&E).	Determined by the PM and documented on the unit hand receipt. To support Test & Evaluation of the prototype, not Data Interchange.	Prototype NSLIN (PNSLIN).	Hand Receipt, SLAMIS, and Accountable Property System of Record, e.g. GCSS-A, DPAS, or LMP.

2. FUI Definition Analysis

The lack of standardized terminology causes multiple program offices to interpret FUI differently. The term "FUI" has been implemented by ASA(ALT) AMI within the last two years and used for tracking the progress of MTA program. The definition has shifted over time through several unofficial publications of the term, from high level definitions to detailed criteria-based descriptions. These different definitions have appeared to cause a disconnect between stakeholders and potentially caused misreporting. PEOs provided general definitions that would place the FUI date somewhere between MCA Milestone B and Milestone C in the AAF, but lacked the specific characteristics defined by ASA(ALT) AMI. This resulted in FUI dates being reported differently or not at all by different program offices. The PEOs did not have a definitive answer for the lack of understanding of the definition of FUI between the different program offices. Some offices did not use the term FUI to report their first unit issued date, but instead would use terms "Limited User Test (LUT)" or "Soldier Touch Point (STP)." Reporting FUI data points under other names does not provide insight to ASA(ALT) AMI of the program's progress or maturity during its development.

3. FUE Definition Analysis

ASA(ALT) AMI definition of FUE is well understood by the PEOs. ASA(ALT) AMI accurately accept reported FUE terms from PEOs as all parties had the same definition for the term.

E. CURRENT FUI / FUE REPORTING PLATFORMS

1. Consolidated Signature Efforts Tracker on Microsoft Teams

The program's official schedule is reported starting from the program manager's office to the program executive office through routine reporting. This information is then passed to the ASA(ALT) AMI through data calls (AMI Manager, meeting, August 5, 2022). These data calls are a quarterly synch that is completed when updated information is needed. This reporting technique produces near-real-time information to ASA (ALT) AMI at the cost of additional resources to conduct the data calls individually to the separate PEOs. ASA(ALT) AMI consolidates this information and confirms the CSET contains the certified FUI and FUE dates for the Army's modernization efforts (AMI Manager, internal document, April 7, 2022). The CSET is a Microsoft Excel document that is saved and updated in Microsoft Teams A365. The tracker currently maintains situational awareness of 99 of the Army's signature efforts in one location as of June 2022 (AMI Manager, meeting, August 5, 2022).

The CSET provides the authoritative source for the most up-to-date FUI and FUE dates for the Army's senior decision makers (AMI Manager, meeting, August 5, 2022). The tracker contains FUI, FUE, system availability start, system availability end, quantity provided for test events, MTA quantity provided for rapid fielding/prototyping, and MCA/ MTA production quantity information. No additional information exists to provide context within the program's schedule (AMI Manager, internal document, April 7, 2022).

Users log into Microsoft Teams A365 using their Common Access Card (CAC) credentials. Since, the CSET file currently is accessed through the Microsoft Teams A365 application, new individuals must be given permission to the file's location by a current member. Anyone that has access to the Microsoft Teams file can view and edit this tracker. This unrestricted access potentially allows someone to make accidental changes to the document in fields they do not have the authority to alter. This format for sharing also allows for easier accessibility, making updating and maintenance easier, but lacking control, security, and traceability.

2. Monthly Acquisition Report on PMRT

The MAR, hosted on PMRT, contains monthly reports on the status of acquisition programs submitted by the program offices (U.S. Army n.d.). The MAR is the Army's current reporting system to collect program data, cost, schedule, and performance metrics to meet these requirements (AMI Manager, meeting, August 5, 2022). The reports build on each other incrementally as the program mature throughout their life cycle. The MAR is the current system that meets the regulatory requirements for reporting program cost, schedule, and performance metrics for major defense acquisition programs on the Selected Acquisition Reports submitted to the Committee on Armed Services of the Senate and the House of Representatives in accordance with Title 10 United States Code § 4351 (2022).

PM's can input data about the program to include, issues, cost breaches, risks, schedule, test and evaluation timelines, funding, contracts, and earned value management (EVM) metrics in the MAR (U.S. Army n.d.). The input boxes allow customization of labels to meet individual program requirements but are not standardized. The MAR reporting system was made to submit Acquisition Category (ACAT) I program data and can support multiple other ACAT programs.

Users log into the PMRT website using their CAC credentials. This is the first layer of security. Users must then be approved individually through a system administrator to gain role access to view, create, or edit MAR reports for their specific program. This double layer of authentication creates a high level of security, ensuring users are given a roll that can easily restrict what is visible to different types of users. This process helps ensure the provided information is reliable for senior decision makers.

Labels for reporting landmarks events during the program are used to quickly determine progress. It was found that most programs do not utilize all the available reporting fields and they instead focus on reporting issues, risks, accomplishments, cost, schedule, and test and evaluation timelines (U.S. Army n.d.). The schedule portion is the area of most interest for this research as it contains the reported dates for FUI and FUE. Users are given the flexibility to label program dates in the schedule as seen fit by the program office. This variability increases complexity for understanding and comparing

data across multiple reports. Common variances include whether a program chooses to use acronyms or write their entire descriptions for events. One example we found was the AMPV program chose to describe "Soldier Touch Point," compared to OMFV program which chose to describe the same event simply as "STP" (U.S. Army n.d.). The variations in the data causes issues when comparing data from adjacent or dependent programs because the data is not labeled the same across similar programs.

The MAR provides historical records of previously submitted reports (U.S. Army n.d.). Programs sometimes cancel, roll-back, or even suspend development of the effort. The MAR does not provide the clarity of events when these program altering events happen and can cause confusion in the timeline. This results in discrepancies or multiple reports of the same event. Additionally, if a program does not report an event, the program schedule lacks the completeness to understand the comprehensive history of the program (U.S. Army n.d.).

3. Integrated Acquisition Modernization Schedule on Microsoft Teams

The IAMS tracker, developed and updated by Army Futures Command, is a verification and validation-based document that is used to manage the testing schedule for a program (Manger PEO Ground Combat Systems, meeting, August 5, 2022). The IAMS tracker is maintained by the program office and reports FUI and FUE timelines. The IAMS tracker provides the most detailed look of the program's schedule from the three discussed trackers, reporting all program dates and events available. The tracker is held in a Microsoft Project file making the schedule easily digestible with the program's many different associated events.

The tracker is maintained in the Army Futures Command Microsoft Teams Group. The Microsoft Project file limits the ability for team members to adjust and update the tracker inside Microsoft Teams, resulting in an individual having to "check-out" the file to update it. Additionally, there are licensing issues with Microsoft Project and data loss in converting to Microsoft Excel. The need for expensive licenses in excess causes potential version control issues as many different personnel from different programs are required to update and validate the file. The extra requirement reduces the chances that the file will

contain the most up-to-date information as many different people will be waiting to update their portion of the document.

F. FUI / FUE REPORTING PROCESS

The team then conducted analysis of each program and modeled their reporting processes using activity diagrams to demonstrate the sequential flow of reports. The maturity of modernization initiatives is determined based upon their reporting of FUI and FUE dates. Although the CSET is currently the authoritative data source, all three reporting pipelines report FUI and FUE dates intermittently. It was identified that the naming of each effort varied from tracker to tracker, with some reporting pipelines more successful than others.

The inconsistencies between the various data trackers lead to the existence of data discrepancies when looking at FUI/FUE dates. These data discrepancies ranged from dates being different, format changes, and naming conventions of reported events, which resulted in data quality issues. The four data quality issues of duplication errors, version control issues, naming convention problems, and past events not being reported. Staying within the scope, the team chose to focus on the primary four data quality issues related to FUI and FUE. Not all the identified discrepancies are visible on the presented activity diagrams. The team decided to instead focus on the reporting of FUI dates and not the discrepancies of other programmatic data outside of FUI/FUE dates. Once the team understood the definitions of FUI/FUE and the process of reporting those dates, the team started to identify discrepancies in the three reporting systems. The flow diagram (Figure 5) shows the FUI/ FUE reporting process and does not show the data quality issues. The data quality issues that will be identified and explored in further detail are described in Table 6.

Table 6. Data Quality Issues by Program

Data Quality Issues Present in Program by Type					
Data Quality Issues	ERCA	OMFV	AMPV	RCV	PrSM
Duplication Errors	X			X	X
Version Control Issues	X	X		X	X
Naming Convention Discrepancies				X	
Past Events Not Reported		X	X		

G. BY PROGRAM ANALYSIS

1. Extended Range Cannon Artillery (ERCA)

The ERCA program team reported both FUI and FUE data. This data was reported using all three reporting processes, as shown in Figure 7 and Figure 8 (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). Reports for FUI data were completed across all three platforms but FUE data were reported through just two of the three platforms. ERCA also utilized different lines in the CSET to report separate events within the same project. There were no date conflicts, but this reporting style causes an issue of fragmented information that could complicate analysis using the authoritative data source, and it means any changes will require multiple updates.

Figure 7. ERCA Reporting Activity Diagrams.
Adapted from Buede and Miller (2016).

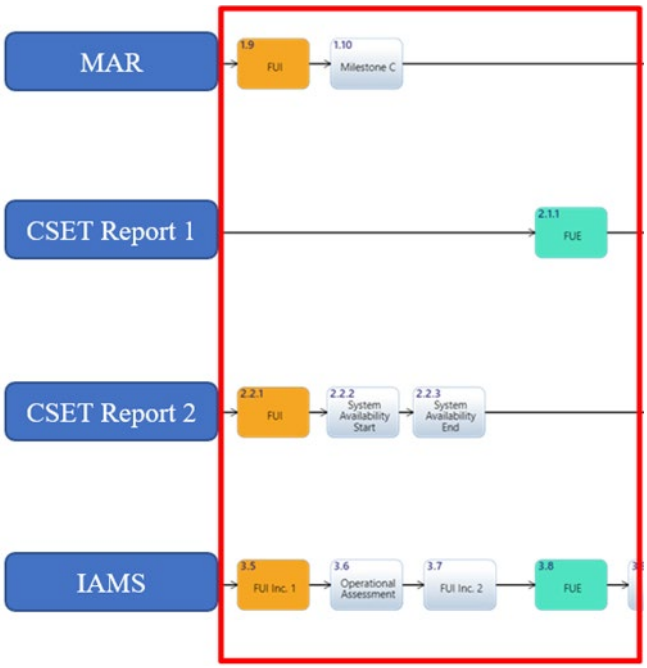

Figure 8. ERCA Reporting Activity Sub-diagram. Adapted from Buede and Miller (2016).

2. Optionally Manned Fighting Vehicle (OMFV)

The OMFV program currently reports through the IAMS, CSET, and MARs (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). OMFV reports forecasted dates for the completion, across all three trackers in Figure 9 and Figure 10. These results show that the information from the project management office is reliable and understood across all stakeholders. OMFV does not report any of the expected FUI timelines for the project. OMFV provided the expected FUE timeline in the reports to help provide better situational awareness to ASA(ALT). No data was available during our research of the OMFV program's intention on conducting a FUI event.

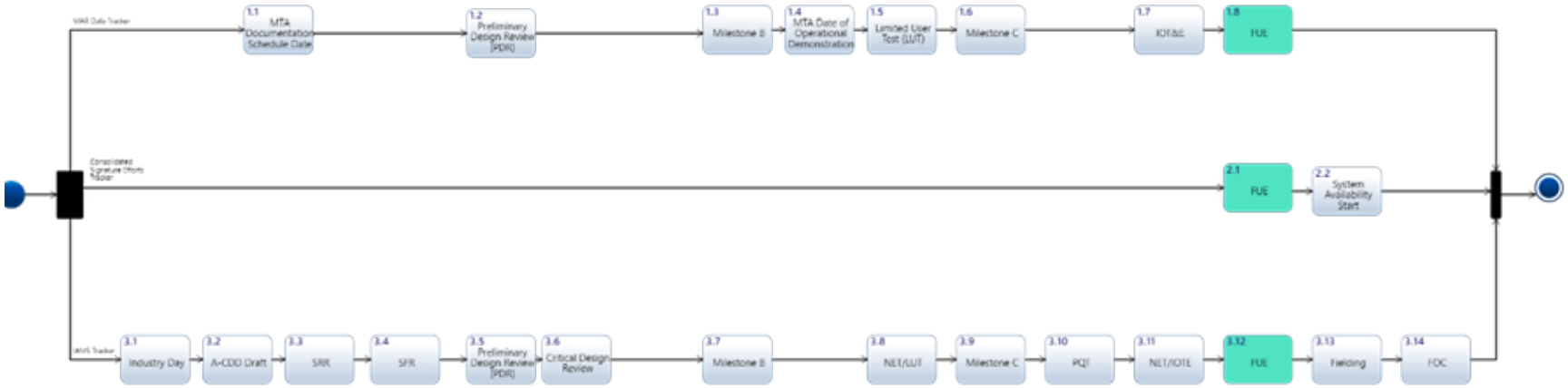

Figure 9. OMFV Reporting Activity Diagram. Adapted from Buede and Miller (2016).

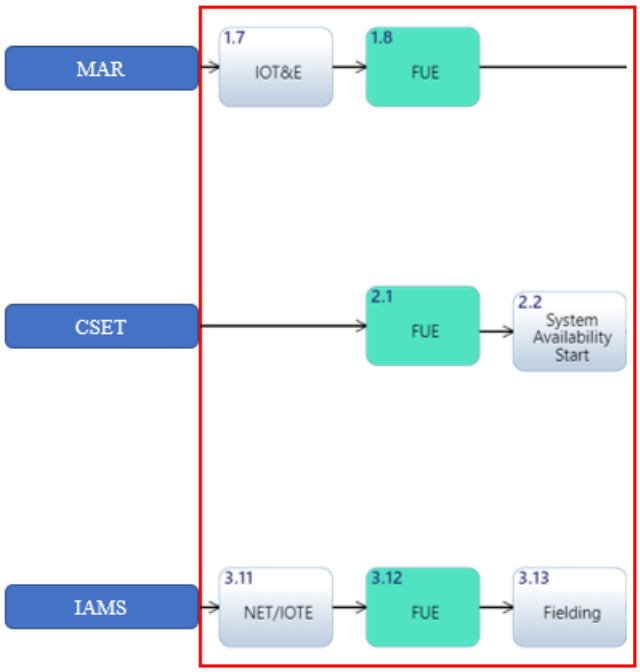

Figure 10. OMFV Reporting Activity Sub-diagram. Adapted from Buede and Miller (2016).

3. Armored Multi-Purpose Vehicle (AMPV)

The AMPV program reports FUE through all three reporting processes in Figure 11 and Figure 12, but FUI is not reported in any of the three (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). The MAR report identifies Limited User Tests (LUT), which could meet the definition of a FUI, but they are not listed as such in the report. The lack of FUI data will reduce the ability of ASA(ALT) to identify and track the progress of this program.

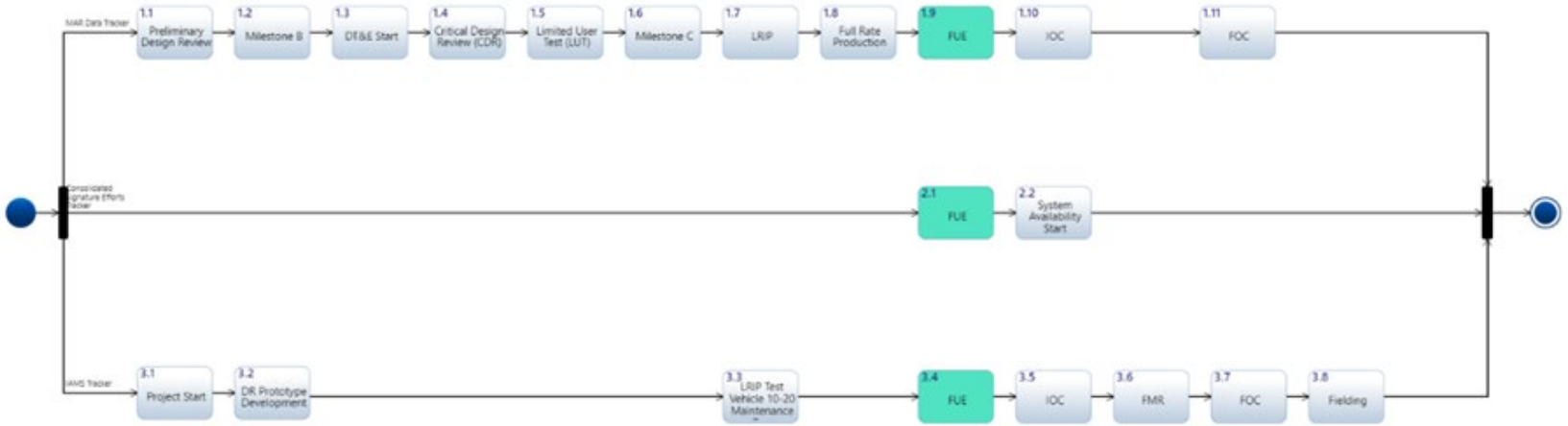

Figure 11. AMPV Reporting Activity Diagram. Adapted from Buede and Miller (2016).

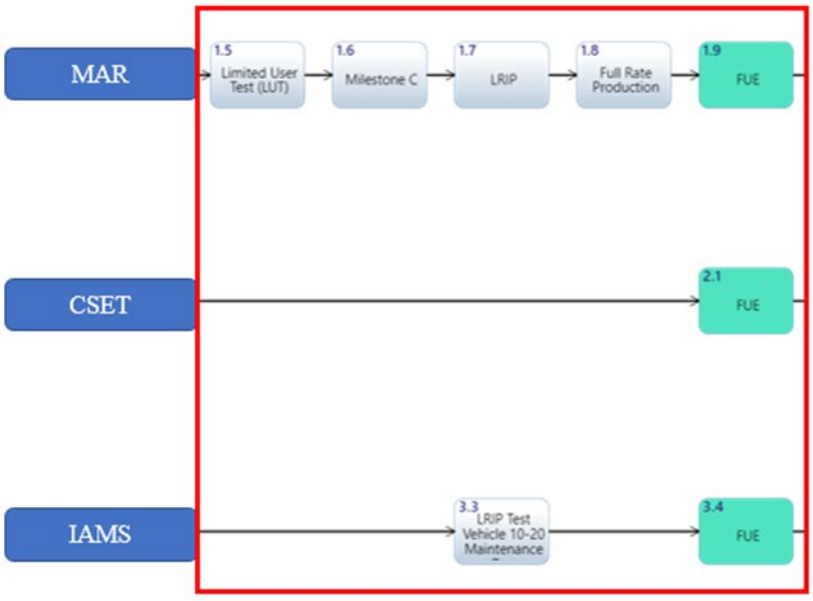

Figure 12. AMPV Reporting Activity Sub-diagram. Adapted from Buede and Miller (2016).

4. Robotic Combat Vehicle (RCV)

The RCV reporting activity diagram in Figure 13 and Figure 14 is more complex than other programs due to the presence of sub-programs underneath the greater RCV program. The RCV currently has a light and medium vehicle being developed in parallel with a software pathway. All three sub-programs are required to develop the RCV capability. The RCV program only reports FUI in one of the lines in the CSET, and FUE is only reported on the IAMS tracker for both the light and medium vehicles (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). Not having all the information in one tracker results in the user having to verify through multiple sources that the information is current and correct. Due to this study's focus reporting requirements for the MTA pathway, this study will not model or analyze the software pathway. The IAMS tracker does not use this three-pathway reporting style, and this can cause confusion when trying to understand the projected progress of the different variations of the program.

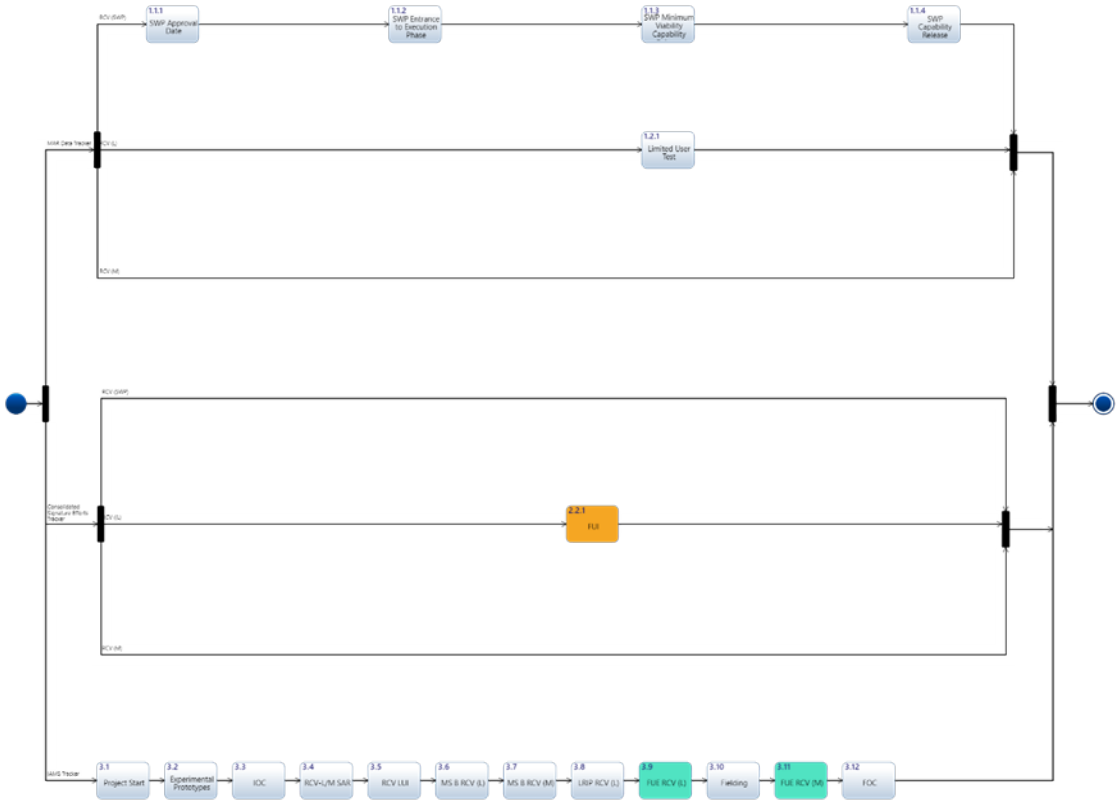

Figure 13. RCV Reporting Activity Diagram.
Adapted from Buede and Miller (2016).

5. Precision Strike Missile (PrSM)

PrSM is different than the other programs due to its nature as a disposable projectile compared to other platform-based programs. The CSET was the only tracker to report FUE (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). The IAMS tracker displayed extensive testing timelines as seen in Figure 15 and Figure 16. On the CSET, the PrSM was broken down into three different lines showing the fielding of the first three iterations of the missile to different units (AMI Manager, internal document, April 7, 2022). By listing the FUE as three separate units and dates, this report does not meet the criteria of "First" unit equipped, but instead also reported the second and third unit as FUE. The multiple reporting timelines can cause confusion as to when the product is in the first unit's inventory. Additionally, FUI was not reported in any of the other two reporting processes.

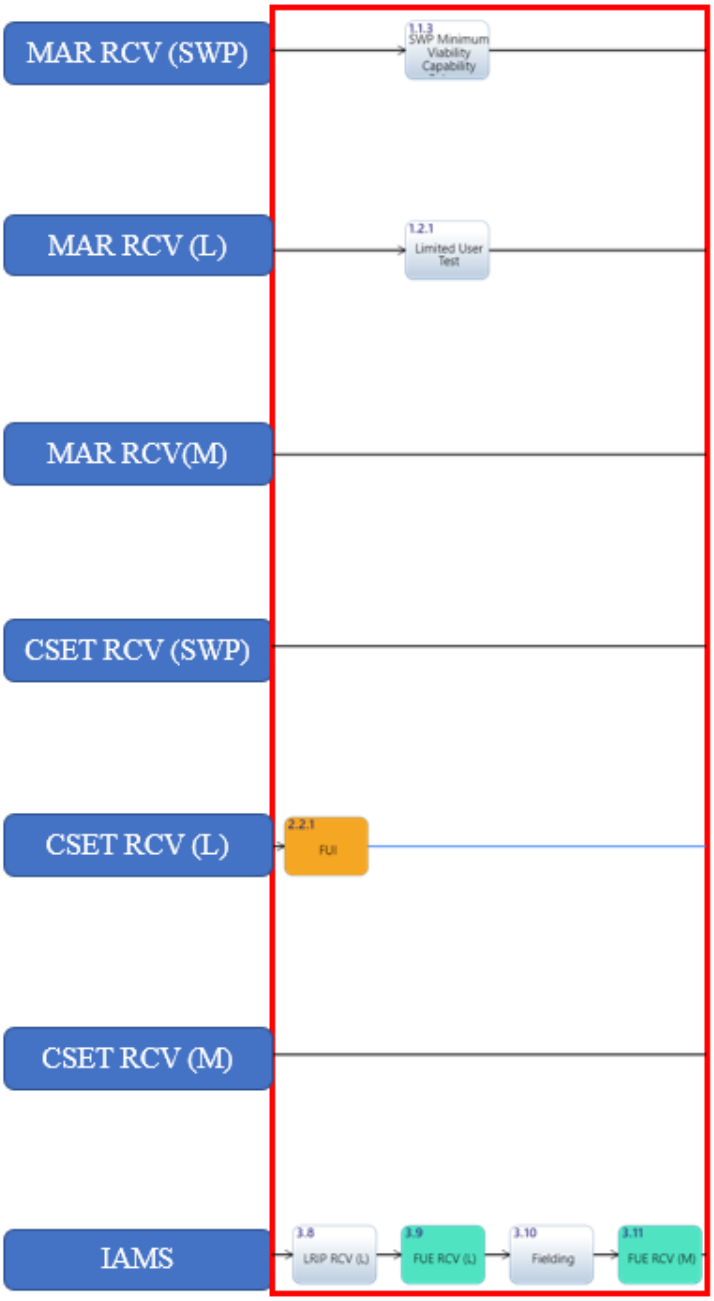

Figure 14. RCV Reporting Activity Sub-diagram. Adapted from Buede and Miller (2016).

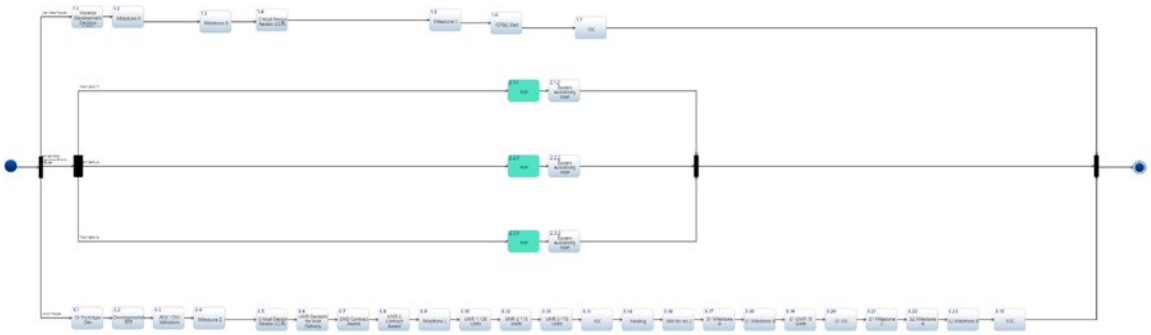

Figure 15. PrSM Reporting Activity Diagram. Adapted from Buede and Miller (2016).

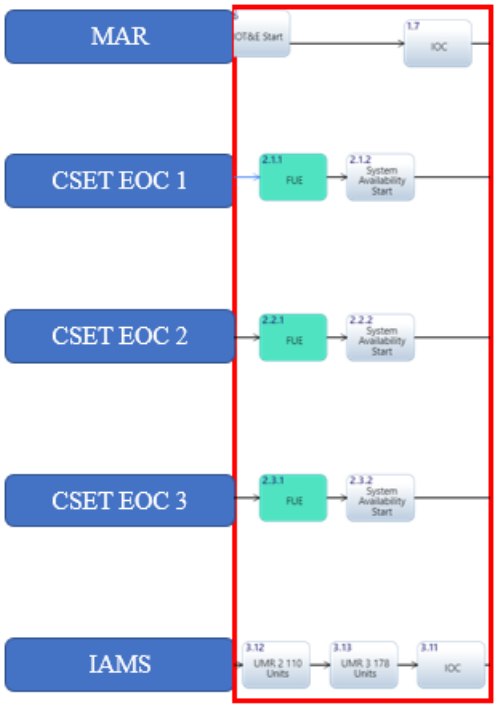

Figure 16. PrSM Reporting Activity Sub-diagram. Adapted from Buede and Miller (2016).

6. Summary of Analysis of FUI and FUE Reporting

FUI and FUE were not reported consistently across the three reporting processes, causing several data quality issues hindering the benefit to decision makers (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). The prominent issues were duplication

errors, version control issues, naming convention problems, and past events not being reported. The duplication errors were from sources of programs reported multiple times in the same platform, which would require additional efforts to accurately track progress. The version control issues were defined when multiple reports with the same name caused confusion when they contain different data or timelines. Naming conventions were not standardized across the platforms, where terms with similar definitions to FUI and FUE were being used as replacements to the official terms. Finally, there was evidence of events that occurred in the past not being report on current reports, resulting in a lack of situation awareness about an efforts timeline.

The CSET had the most consistent data regarding FUI and FUE dates than any of the three platforms consistent with it being the authoritative source. Often the other reporting platforms had additional data that was not available in the CSET not relevant to FUI and FUE (AMI Manager, internal document, April 7, 2022; U.S. Army n.d.). The CSET was originally built for tracking FUI and FUE dates, so it makes sense that this tracker would host the most relevant FUI/FUE data. These data quality issues represented in Table 7 show the success rate for a report of FUI and FUE from the program. The issue that we discovered lies in the platform and aggregation of information. Since the CSET is a spreadsheet in a Microsoft Teams channel. Anyone in the group of 168 members can access all lines of the spreadsheet (AMI Manager, August 5, 2022). While this may allow for quick editing across multiple lines of effort and programs, it has no tracking capability or time stamps of information editing. There is no way of knowing how current any of the information in the tracker is without confirming that data with each program. The intent of the CSET was to bring together the key information on the FUI/FUE dates for each program. The tracker is consistent at capturing key data for quarterly reviews but can be accomplished more efficiently on a different platform.

The current reporting systems that distribute FUI and FUE data are not effective at reporting accurate and reliable information to key decision makers. All current reporting systems have inherent issues that present risks in the information being limited in quality due to the system in place. In the next part of this chapter, we analyze each reporting system

using a Pugh Matrix for comparative analysis to identify the most suitable reporting system that could eventually fit the requirements for ASA(ALT) AMI.

Table 7. FUI / FUE Reporting and Data Quality Issues by Program.

	MAR		CSET		IAMS		
	FUI	FUE	FUI	FUE	FUI	FUE	Data Quality Issues Per program
AMPV	N	Y	N	Y	N	Y	1
ERCA	Y	N	Y	Y	Y	Y	2
PrSM	N	N	N	Y	N	N	2
OMVF	N	Y	N	Y	N	Y	2
RCV	N	N	Y	N	N	Y	3

H. COMPARATIVE ANALYSIS

Utilizing a Pugh Matrix (1981), the team was able to evaluate the suitability of the three reporting systems. The evaluation criteria used in this matrix was outlined in Chapter III and will be used to conduct a comparative analysis of the MAR, IAMS, and CSET reporting processes. Each system was evaluated against each other to determine strengths and weaknesses of the system as it pertains to auditability, fitness, credibility, accessibility, and timeliness. Scoring of each criterion in Table 3 was based on an inverted score, where the lower numbers indicate higher suitability of the reporting systems. The findings in Table 8 establish the most suitable reporting system out of the current three and further analyze areas for improvement for future use.

1. Evaluation Criteria

An analysis of each criterion—considering all relevant parameters within each criterion—was conducted for the three reporting processes to support the systems

engineering method selected to determine the best solution to support FUE and FUI reporting to ASA (ALT) AMI. The evaluation criteria were selected through analysis of the functional decomposition of the desired reporting system. Each functional requirement was translated into an evaluation criterion for measure in the Pugh Matrix (1981).

Auditability was selected for the ASA(ALT) AMI to be able to track the changes conducted in the system (Cai and Zhu 2015). ASA(ALT) AMI needs to track when timelines were updated, who updated them, and how the timelines have shifted. This enables ASA(ALT) AMI to evaluate the presented data's accuracy and integrity without further increases to resources required to validate the data available. The data source with the highest level of auditability will reduce the amount of time users spend trying to trace how the users obtained the current set of data. A system's data auditability is poor if it provides no information regarding historical program dates and cannot show changes of FUI and FUE dates or who made them.

Fitness describes the data's ability to meet ASA(ALT) AMI's need for understanding FUI/FUE dates (Cai and Zhu 2015). A highly rated system will have the capability to accurately represent both FUI and FUE dates with the correct terminology. Representing FUI and FUE timelines using the correct labels and antonymous terms is important for ASA(ALT) AMI to be able to understand the represented data. Conversely, a poorly rated system will only represent partial information for either FUI or FUE to use similar terms to describe the information such as STP. A system that provides a high level of data fitness would fill the needs of ASA(ALT) AMI.

Credibility in the data provides ASA(ALT) AMI the ability to trust in the quality and accuracy of the reported data (Cai and Zhu 2015). Data with high credibility will be presented with date and time stamps and digital signatures of who completed the report. The time stamps and signatures allow users to understand who reported the information to verify they are authorized to make the report and know how current the information is and still valid. This background information allows ASA(ALT) AMI to quickly use the available FUI and FUE information for reporting purposes. A data set that has poor credibility will have no background information outside of the FUI and FUE dates

themselves. If ASA(ALT) AMI has no information about who is making the report additional resources must be utilized to validate the information.

Accessibility of the FUI and FUE is important to ASA(ALT) AMI (Cai and Zhu 2015). The data should be quickly and easily available to allow for rapid information sharing to enable decision makers. Data that is highly accessible will not have many different levels of authorization to access, be available any time of day, and be available to computing devices that do not have specialized software. Systems that do not have highly accessible data will require specialized software and multiple forms of authorization to access. While requiring multi-tier authorization increases data security, it constrains the speed at which information is available. Platforms using specialized software, such as Microsoft Project, are limited in number and will ultimately limit the users that have access to the data.

Timeliness is important to ASA(ALT) AMI to understand the delay from when the information is reported until it is used to inform decision makers (Cai and Zhu 2015). Timely data provides decision makers with an accurate data sample. This increases the chances of a decision maker making informed decisions about the future of the investigated effort. Outdated FUI and FUE data does not provide accurate information to a decision maker and therefore does not provide much value. Data is considered timely if it is reported and updated routinely and contains timestamps for each update. Data in the studied platforms is considered untimely if is reported infrequently or does not include timestamps for each update.

2. Systems Analysis

Auditability—The result of auditability favors the MAR as best fit to the criterion. The MAR requires CAC access, user rights to manipulate data within assigned roles, and the system can log and report updates (US Army, n.d.). Effectively, all data can be timestamped and traced to the editor of that data for auditability. CSET and IAMS both lack the ability to identify and log changes by user without creating a standard operating procedure to self-report logs or sending data through a single user (AMI Manager, internal document, April 7, 2022).

Fitness—The result of fitness favors the CSET as best fit to the criterion. Given the CSET is the only report designed for tracking FUI/FUE, it is unsurprising that this is the best fit. IAMS contains a lot of programs, but the aforementioned version control creates issues with validating the document. The MAR places last in this category as it allows program offices to control what they report. This lack of standardization can lead to gaps in important program reporting requirements being met (US Army, n.d.). However, the MAR maintains the ability to tailor the system to meet data fitness needs.

Credibility—The result of credibility favors the MAR as best fit to the criterion. The MAR requires authentication to access and report data in the system allowing sources of data input to be validated by user (AMI Manager, internal document, April 7, 2022). The IAMS system that utilizes Microsoft Project relies on a singular person to control inputs, data manipulations, and validate the data. The CSET allows for any user who has access to the Microsoft Teams channel to manipulate the data without a logging function which requires a single person to validate all data points.

Accessibility—The result of accessibility favors the CSET as best fit to the criterion. The CSET remains accessible to personnel in the Teams channel. The MAR has an access request process and upon approval, assigned roles, which can cause access delays (US Army, n.d.). The IAMS system has a similar access process to the CSET, however given the previously mentioned licensing issue that forces users without licenses to convert the project file to an excel file (with data loss), the team determined this to be the least accessible.

Timeliness—The result of timeliness favors the MAR as best fit to the criterion. In the MAR system, user data updates are completed monthly and can increase and decrease data updates based on the needs of system manager (AMI Manager, internal document, August 5, 2022). The CSET is validated only at quarterly meetings that remain sensitive to calendar disruptions. The IAMS system also lags as Microsoft Project is only accessible for updates for a single user at a time and the document requires version control to ensure authenticity.

Overall Results—The MAR scored the best when compared against the alternatives for its suitability. The MAR auditability, credibility, and timeliness are currently ahead of its alternative systems with the most potential to facilitate reporting needs in the future. Accessibility to the MAR does take additional time to conduct the double verification process for first-time users, but this provides the missing security element that CSET does not. This process does provide a long-term infrastructure that allows system administrators to assign user roles and log live updates. The MAR scored lower in fitness due to it lacking data reporting standardization, but it can achieve desired reporting metrics by updating the interface of the system. Overall, the MAR can create the best long-term solution for facilitating FUI/FUE reporting requirements, when measured against the evaluation criteria, and could be improved upon with suggestions in Chapter V. No swing weights were used during our evaluation. ASA(ALT) AMI valued all criteria equally with none more important than another (AMI Manager, August 5, 2022). This ranking resulted in all criteria affecting exactly 20 percent of the total score.

Table 8. Pugh Matrix. Adapted from Pugh (1981).

Evaluation Matrix	Best suited reporting process for FUI/FUE Tracking		
Criteria	Monthly Acquisition Report (MAR)	Integrated Army Modernization Schedule (IAMS)	Consolidated Signature Efforts Tracker (CSET)
Auditability	1	3	2
Fitness	3	2	1
Credibility	1	2	3
Accessibility	1	3	2
Timeliness	1	3	2
Net score	7	13	10
Rank	**1**	**3**	**2**

V. CONCLUSION

The purpose of this research is to assist AMI in determining a standardized process that will drive accurate and consistent reporting for FUI and FUE across all program offices responsible for the Army Modernization Initiatives. The scope of the research was limited to only programs utilizing the MTA pathway with a focus on the NGCV and LRPF initiatives, but the goal is for the findings and recommendations from the research to be applicable to all programs in the Army acquisition enterprise. This chapter discusses the findings leading to the selection of a reporting system, recommendations aiming to solve current issues and improve existing capabilities, and recommended future studies.

A. FINDINGS AND RECOMMENDATIONS

1. Finding #1—Inconsistent Definition of FUI

No official, standard, or commonly understood term for FUI was identified. Documents containing definitions of the term FUI presented different levels of interpretation of the term without an authoritative document. These documents described the term FUI well, but without a central definition established. This caused stakeholders from different offices to provide dissimilar understandings for the term FUI.

There was also evidence of several terms in use that partially met the definition for FUI. The example of these terms includes Soldier Touch Points (STP) and Limited User Tests (LUT). These terms were substituted for the term FUI in some reports yielding a reduced capability to track FUI dates. The term FUI does not replace the need for continued use of STPs and LUTs, as they have different definitions that are needed to describe the key events throughout the MTA process.

2. Finding #2—Data Quality Issues Exist in All Three Reporting Systems

The CSET, IAMS, and MAR reporting processes all had data quality issues in at least one of the programs. The presence of the data quality issues directly reduces the credibility of the information presented and requires additional resources to verify

presented data. Across the three reporting processes, it was identified that the presence of duplicate reporting, version control issues, naming convention issues, and past events not reported contributed to the limited success of any reporting system. Many of the data quality issues were created through non-standard data entry processes across the platforms that resulted in difficult to directly compare information. The reporting platforms themselves contribute to the data quality issues as they do not establish standardized reporting processes.

3. Finding #3—The PMRT / MAR Reporting System Is the Most Suitable System

The PMRT / MAR reporting system, based off the team's analysis, is the most suitable reporting system to track FUI and FUE dates. The PMRT / MAR showed the highest potential to meet the evaluation criteria of audibility, credibility, accessibility, and timeliness. High rankings in four of the five evaluation criteria show the greatest potential for the PMRT / MAR system to provide accurate and relevant information for key decision makers.

B. RECOMMENDATIONS

1. Recommendation #1—ASA (ALT) AMI Provides the Army Acquisition Enterprise a Standard Definition of FUI

A standard and published definition of the term FUI is important to a comprehensive understanding of the status of MTA efforts across the acquisition enterprise. The inclusion of the term "full-scale" provides the necessary description that the FUI requirement does not address with the testing of individual sub-components, but is completed with full-scale prototypes. The recommended definition below offers the high-level description that meets ASA(ALT) AMI's needs:

> When a full-scale prototype, including all sub-components, is issued to the first unit for experimentation, testing, soldier touch points, limited user tests, or demonstrations.

Additionally, the updated definition and reporting of FUI needs to be enforced and be promulgated throughout the Acquisition Enterprise via written policy. The policy should address the following:

- The required conditions for FUI execution
- The procedures generally followed during FUI, including reporting timelines
- The official reporting system for FUI.
- The tolerance for shifting FUI dates in accordance with Table 4: "Program Schedule Variance Tolerance Thresholds."

The Acquisition Enterprise should also provide guidance to program offices on how to complete FUI reporting during the acquisition process on all MTA programs. The written policy will help to ensure that all organizations requiring FUI reporting are aware of the rules and procedures that should be followed. Having a written policy in place will help to prevent misunderstandings and confusion and can help to hold everyone accountable for following the rules.

The updated term should be published with a wide distribution to ensure understanding across the acquisition enterprise. Without official dissemination, the updated term will not be as effective at synchronizing the enterprise and will limit the effectiveness of FUI reporting. Quality of reporting will follow wide-scale adoption of the same terminology. The updated term eliminates confusion over what the FUI terms mean and avoids the misunderstanding and mistranslation observed during our analysis of the three reporting systems.

2. Recommendation #2—Establish the MAR as the FUI and FUE Authoritative Source for the Army Acquisition Enterprise

The findings present the MAR and PMRT as the most suitable system for FUI and FUE reporting. In addition to suitability, the MAR is the current reporting system that is used to communicate cost, schedule, and performance of programs. Not all MTAs are

programs of record; but, consolidating the reporting process down to one system for all categories of acquisitions and efforts would alleviate duplicate reporting issues. Our recommendation is the MAR information should be utilized as the authoritative source for FUI and FUE information. Establishing the MAR as the authoritative report sets the foundation for accurate and reliable reporting for FUI and FUE.

This transition from the CSET into the MAR as the authoritative source for FUI and FUE dates will require several incremental steps that could be easily accomplished, given the robustness of the PMRT as a platform supporting the MAR. The teams research indicates that the MAR application includes a database that meets the needs of the reporting requirements for FUI and FUE. As part of this process, all data within the CSET will be verified, and any conflicts will be addressed by the PM offices that own oversight of the program which data is in question. Once CSET data verification has occurred, the data in CSET will be exported into a format that can be imported into the MAR database. This data in the compatible format will then be imported into the MAR application database. After import, the data will be tested in the MAR database to ensure everything was imported correctly. All required adjustments will take place in order to optimize the MAR and facilitate its interface with the new application providing expedient data visualization to all stakeholders.

After transitioning to the MAR and PMRT, the criteria will be met to transition away from completing the CSET tracker. Currently the CSET only provides FUI and FUE reporting, and continuing completion of the tracker would result in redundant reporting. Eliminating the requirement for the CSET tracker will free up resources from the acquisition enterprise that could be better used in other areas.

3. Recommendation #3—Recommend Updating the Interface of the MAR System to Accept, Optimize, and Mandate FUI/FUE Reporting.

Overall, the MAR would create the best long-term solution for facilitating FUI/ FUE reporting requirements, as found in Finding #3. The current MAR application allows for non-standardized “fill in the blank”–style selection when creating a new event to add. The current drawbacks to the data input for the MAR limits the ability for users to quickly

evaluate the data for FUI and FUE data across the acquisition enterprise. Our team recommends that the input selection be specified based on acquisition pathway. For example, an MTA that is currently following a Rapid Prototype pathway, should be presented with a drop-down selection to select pathway type (Figure 17).

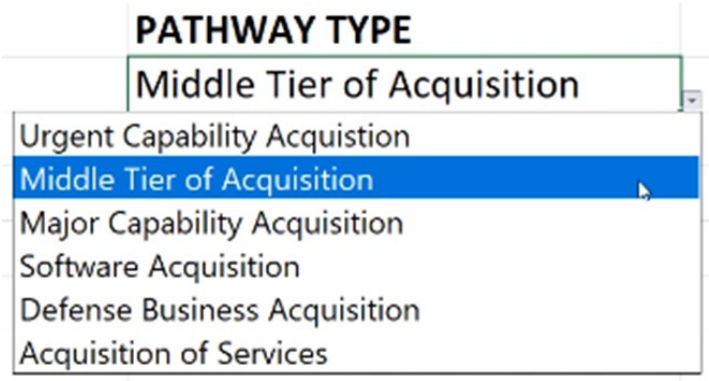

Figure 17. Interface Update Step 1

After selecting the MTA pathway, the system populates another drop down allowing for selection of Rapid Prototyping or Rapid Fielding (Figure 18).

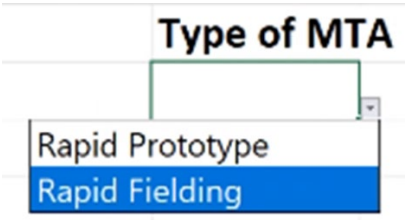

Figure 18. Interface Update Step 2

Once the selection of Rapid Prototyping is made the system should prompt the user to input an FUI date (Figure 19).

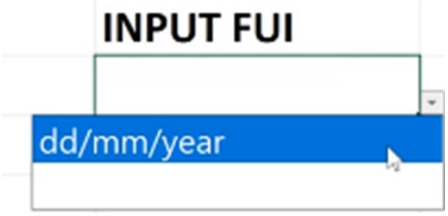

Figure 19. Interface Update Step 3

This is just one example of how the MAR system can be updated to be better suited to receive inputs. Our teams research only views the MAR through the lens of MTA programs, specifically FUI and FUE. Our team stops short of recommending any additional changes outside of the scope of this project.

The following updates should be made to the data input system for the MAR to ensure compliance and tracking needs for ASA(ALT) AMI.

- FUI and FUE fields are mandatory to complete when submitting the MAR for all MTA efforts.
- FUI and FUE categories are established through “drop down” or similar system that ensures correct naming of inputted event
- Accept past completed FUI and FUE events to ensure all past, present, and future events are captured on the report.

Implementing mandated FUI/FUE reporting in the MAR helps to give the PMs and PEOs a streamlined path to input program data. Updating the MAR will facilitate the optimization of this application producing the following advantages:

- Improved performance by updating poorly designed functions and facilitating better integration of these functions.
- Reduced resource usage, which can save both money and environmental resources.
- Better database quality, making it easier to maintain and provide more accurate information.

- Increased customer satisfaction, as all stakeholders will enjoy using a faster, more responsive application.

Updating its architecture to allow robust reporting of all programs pertinent information would make the MAR application the exclusive reporting system to record program information.

4. Recommendation #4—Create PMRT FUI/FUE Application to Meet the Data Fitness Needs of the User

After implementation of recommendation #3, we then recommend that a new application be developed that will specifically pull out the data needed ASA(ALT) AMI from the MAR data files located on PMRT. The MAR reports have a front end user interface that inputs into a database that is accessible to PMRT application and can be exported in pdf reports. This application will specifically pull program's data for FUI, FUE, Initial Operational Capability, and Full Operational Capability. A dashboard is recommended showing previous FUI/FUE with Current FUI/FUE to show are within the specific ranges from Table 4: "Program Schedule Variance Tolerance Thresholds." for changes in estimated dates. This will help ASA(ALT) AMI evaluate acquisition efforts progress and continue to provide information to key decision makers.

The updated MAR reporting system from recommendation #3 can generate FUI and FUE data that meets ASA(ALT) AMI data quality-fitness needs. Further development of an application to provide quick visibility of the programs' FUI/FUE rollup could be completed within the PMRT. This application would allow greater accessibility and meet the security restrictions that normally apply to this type of information.

There are several advantages to creating a new application within the PMRT with specific report formats and modifying the MAR application for a faster and more efficient of data gathering and presentation with this new application. Some of these advantages are the following:

- It will allow tailoring the reports to the specific needs of the organization and to the modernization program being reported.

- It will make it easier to share information between different organizations and within the program office overseeing the program.
- It will help to standardize the way information is presented for specific requirements tracked Army-wide and potentially at the government level.
- It will make it easier to track and manage this huge amount of data over time, as many programs extend well beyond a decade.

C. FUTURE STUDIES

Future studies can further develop the current processes and generate benefits for the acquisition enterprise. The DOD acquisitions process is not designed to effectively manage data. Data management is often seen as an afterthought in the acquisition process, which can lead to issues down the line. This study offers insight into these issues by presenting a very narrow look at how data can become stove-piped, redundant, and inconsistent as it is aggregated, due to the reporting processes utilized. The following issues can be addressed in future studies that would generate value to the entire acquisition enterprise:

- Analyze the best interface dashboard to input/output FUI/FUE data inside PMRT (recommended for Human Systems Integration / Army Acquisition Students).
- Apply the systems engineering process used in this study to all MTA pathway Army Signature Efforts (broadening the scope).
- Incorporate Machine Learning with PMRT/MAR reporting process to improve data quality issues of Army acquisition programs.
- Research and analyze MTA terminology, specifically the term FUI. This study attempted to improve the FUI definition. In doing so we suggested a more constrained FUI definition. A new term may be needed to fill the gap from program initiation to the first time a Soldier touches a minimum viable capability.

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