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Analysis of Cost Variance within Defense Acquisition Programs

June 2025

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Naval Postgraduate School

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Prepared for the Naval Postgraduate School, Monterey, CA 93943

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ACQUISITION RESEARCH PROGRAM
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ABSTRACT

The Government Accountability Office has published multiple reports stating that defense acquisition programs (DAPs) often exceed original cost estimates, take longer than planned, and produce fewer units with less capabilities than promised. Changes in cost, schedule, and performance within DAPs are captured and submitted to Congress in Selected Acquisition Reports. The data and information contained in these reports has been made available through multiple information systems at the secretary of defense and military department levels. The Department of Defense is currently exploring new approaches to utilizing existing data and systems to improve the effectiveness of the data being reported to Congress and provide better oversight to DAP management. The purpose of this study is to understand, using a text analysis approach, how different factors affect cost variance for DAPs. This research aims to provide the following: (a) a review of policies and reports affecting data collection on DAPs; (b) a data analysis process wherein we imported, cleaned, transformed, modeled, and communicated specific data; and (c) recommendations that may be used to improve data collection and reporting among MDAPs.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAF	Adaptive Acquisition Framework
ADS	Acquisition Datasets
ADVANA	Advanced Analytics
AIR	Acquisition Information Repository
AVDF	Acquisition Visibility Data Framework
C4ISR	Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance
CJCS	Chairman of the Joint Chiefs of Staff
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
DAP	Defense Acquisition Program
DAVE	Defense Acquisition Visibility Environment
DAES	Defense Acquisition Executive Summaries
DoD	Department of Defense
GAO	Government Accountability Office
JSF	Joint Strike Fighter
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MILCON	Military Construction
NDAA	National Defense Authorization Act
O&M	Operations and Maintenance
OUSD(A&S)	Office of the Under Secretary of Defense for Acquisition and Sustainment
PARCA	Performance Assessments and Root Cause Analyses
PMA	President's Management Agenda
PS	Program Submissions
RDT&E	Research, Development, Testing, and Evaluation
SAR	Selected Acquisition Report
TRL7	Technology Readiness Level 7
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment

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I. INTRODUCTION

This chapter provides an overview of cost overruns in Major Defense Acquisition Programs (MDAPs) and explains how this research aims to better understand how different factors captured in Selected Acquisition Reports (SARs) impact cost variances within MDAPs. The chapter includes background information on the issue, the purpose of the research, questions the research intends to answer, the methodology used for the research, the importance of the research, and the limitations of the research. The chapter concludes with information on how the report is structured and a concise chapter summary.

A. BACKGROUND

At the start of each new Congress, the Government Accountability Office (GAO) produces and updates a list of high-risk government programs and operations with "vulnerabilities to waste, fraud, abuse, and mismanagement, or in need of transformation" (Sager, 2023, p.2). Department of Defense (DoD) major systems acquisition was first added to this high-risk list in 1990 and has remained on it since. The most recent update to the GAO's high-risk list, completed in April 2023, identified the following areas within DoD major systems acquisition as needing attention: capacity, action plan, monitoring, and demonstrated progress. The GAO reported that the "DoD has made progress in its efforts to conduct data-driven oversight on the effectiveness of defense acquisition system changes" (Sager, 2023, p.125). Despite progress, the DoD continues to face challenges with using data in the oversight of MDAPs, according to GAO.

Some challenges with the management of data in MDAPs have surfaced with the implementation of the Adaptive Acquisition Framework (AAF), established in 2020. DoD Instruction 5000.2, *Operation of the Adaptive Acquisition Framework*, details general information, responsibilities, program management authorities, and procedures for using the AAF (Office of the Under Secretary of Defense for Acquisition and Sustainment [OUSD (A&S)], 2020). The purpose of the AAF is to support the Defense Acquisition System by "delivering effective, suitable, survivable, sustainable, and

affordable solutions to the end user in a timely manner" (OUSD [A&S], 2020, p.4). The AAF is designed to achieve these objectives by granting "Milestone Decision Authorities (MDA), other decision authorities, and program managers broad authority to plan and manage their programs consistent with sound business practice" (OUSD [A&S], 2020, p. 4).

The AAF is composed of six pathways: the Urgent Capability Acquisition Pathway, Mid-Tier Acquisition Pathway, Major Capability Acquisition Pathway, Software Acquisition, Defense Business System Pathway, and Acquisition of Services Pathway (OUSD [A&S], 2020). Program managers can use a single pathway or develop an acquisition strategy through a combination of these pathways that is best suited to the capability being acquired (OUSD [A&S], 2020). While the AAF has introduced flexibility in defense acquisitions, it has also led to various reporting methods and data collection requirements that differ from practices used prior to its establishment. This has prompted the development of new data systems, such as the Defense Acquisition Visibility Environment (DAVE) and the Advanced Analytics (ADVANA) Portal, to better manage and monitor the cost, schedule, and performance of MDAPs. The datasets used in this research analysis were obtained from DAVE.

Congress has enacted several policies and issued official recommendations to enhance data management and utilization within the DoD and other federal agencies. These policies are embedded in Title 10 of the U.S. Code, National Defense Authorization Acts, federal strategies, and reports from independent oversight bodies such as the GAO. Chapter II, the Literature Review, provides an overview of several of these policies and reports.

Given the impact of cost overruns on budgeting, defense program success, and military readiness, much research on the relationships between MDAP cost variances and independent factors has been conducted. Cost variance, which refers to the difference between the planned and actual costs of an acquisition, can significantly influence resource allocation for service components and the DoD. In a 2011 study, William Griffin and Michael Schilling analyzed how cost variance was affected by contract types, different segments of MDAPs, and early occurrences of cost variance. Also in 2011, the

Center for Strategic and International Studies conducted a study focusing on cost overruns related to "quantity and schedule changes, engineering problems, the extent of competition, contract structure, the lead military service branch, and the identity of the prime contractor" (Haufbauer et al., 2011, p.6). Reviews of these previously conducted studies are provided in Chapter II. This research uses data current as of 2018, along with different data analysis methodologies, to analyze how sources of cost variances differ across service components, commodity categories, funding categories, Joint Capability Area (JCA), and cost variance categories.

The analysis and management of cost overruns in MDAPs have significantly improved due to the integration of new technologies and data resources. The DoD has increasingly utilized data analytics to process and analyze a large range of data, providing insights to cost overruns and potential Nunn-McCurdy breaches (explained in Chapter II). The use of data analytics for observing and predicting trends has become essential in informing decisions within defense program management (Sullivan, 2011). Additionally, the use of knowledge-based acquisition methods has ensured key information about technology maturity, design stability, and completed production trials is certified before moving into full production of a capability. Knowledge-based acquisition methods reduced the associated risks and uncertainties imposed on the DoD as a result of poor schedule and cost management (Oakley, 2022b).

The DoD is exploring new approaches to collecting data on MDAPs and implementing new data systems to improve the quality of information reported to Congress. These approaches to data collection include creating datasets within systems such as DAVE and ADVANA. These datasets contain detailed information on program schedules, performance parameters, budget allocations, and risk factors, all of which are essential for overseeing and managing program outcomes. However, these new datasets present challenges for key stakeholders and policymakers analyzing the data to improve acquisition. For example, one challenge is determining how to analyze data to identify the sources of cost variances in MDAPs. Another challenge is evaluating how much of an impact factors already collected have on cost variance.

B. PURPOSE OF RESEARCH

The purpose of this research is to understand how various factors impact cost variances within MDAPs. To identify these factors, a range of data elements from historical SARs on cost variance are considered. Factors analyzed include Joint Capability Areas, commodity types, appropriation categories, cost variance categories, service branches, and common word phrases within explanation fields. Higher quality information enhances the understanding of key issues and potential risks to acquisition programs for stakeholders, ultimately leading to better oversight of defense acquisition program management. This research analyzes different data elements found within pre-existing datasets to understand how various factors affect cost variance for MDAPs.

C. RESEARCH QUESTIONS

In order to understand if data elements contained within SARs on cost variance exhibit different cost variances, the following questions are asked:

1. Primary Questions

- How do the causes of cost variances differ among factors (e.g., service components, commodity categories, funding categories, Joint Capability Areas, and cost variance categories) in historical cost variance datasets?
- How can text analytics be used to analyze historical cost variance data?

2. Secondary Question

- How do the current datasets lend themselves to machine learning and text analytics?

D. METHODOLOGY

For this research, a literature review of government policies on cost variances in defense contracting and weapon system acquisitions is conducted. A review of past reports and research performed on cost variances within MDAPs is also conducted. To understand what data is currently being used within the DoD to assist key stakeholders with oversight of MDAPs, access to available databases and reporting tools was obtained. The data analysis was performed utilizing cost variance datasets from SARs available through the DAVE web portal. These datasets were then cleaned, transformed, modeled,

and communicated. Finally, the research provides a discussion of the potential use of other factors within MDAP processes that could be used to help predict the impact of cost variances.

E. BENEFITS AND LIMITATION OF RESEARCH

The research highlights currently available data and resources being used for oversight of MDAPs. The analysis of the available cost variance datasets shows whether the data elements being collected affect cost variance among MDAPs and whether the data elements may be used as indicators for future changes in cost variances. The research further assists ongoing efforts to leverage machine learning and the use of text analytics.

However, the analysis is limited to the available SAR data from 1997 to 2018 and Major Automated Information System Annual Report data up to 2016. This research is also limited by the quality of data submitted. This is especially a factor when conducting free text analysis of explanations of reasons for cost variances among MDAPs.

F. ORGANIZATION OF RESEARCH

This capstone report is organized as follows:

Chapter I is composed of background information, the purpose of the research, and the research questions that are being addressed. The chapter then provides an explanation of the benefits and limitations of the research and the organization of the report.

Chapter II begins by discussing current government policies related to cost variances of MDAPs. It then includes a discussion of several findings made by the GAO, the Congressional Research Service, and the RAND Corporation. The chapter concludes with a discussion of previous academic research on cost variance in MDAPs.

Chapter III provides an overview of the information system from which the data was obtained, the process through which the data was cleaned and prepared, and the process used to analyze the data.

Chapter IV outlines various data and text analytics approaches and explains how they were employed to analyze cost variance data and text explanations within the historical Cost Variance dataset. It then presents the findings and provides a discussion of how cost variances were affected by the factors analyzed. The chapter concludes by providing recommendations based on the factors analyzed and how the DoD can benefit from applying text analysis and machine learning to predict cost variances among MDAPs.

Chapter V includes a summary of the research, explanation of the conclusions, and identification of further areas of research that the report may support.

G. SUMMARY

This chapter introduced the research and provided background information on the longstanding issue of cost variances in MDAPs, and the efforts being made to improve oversight and management of defense acquisition programs through new data management practices. It presented the purpose of the research and the problem the research aims to improve by addressing the primary research questions. The chapter concluded with a discussion of the benefits and limitations of the research as well as an overview of how the report is organized. Chapter II provides a literature review that includes a discussion of the relevant policies that were reviewed, an assessment of reports produced by independent agencies, and a review of previously conducted academic research related to understanding cost variances among MDAPs.

II. LITERATURE REVIEW

This chapter presents an overview of the literature used to establish a foundation of knowledge for this research analysis. The literature reviewed includes government policies related to cost variances in MDAPs, reports conducted by the GAO, and previously conducted research on cost variances within MDAPs.

A. POLICIES IMPACTING DEFENSE ACQUISITION

The following overview of government policies emphasizes the impact of DoD acquisitions on senior leadership within the federal government and the mandated changes required to improve controlling costs, schedule, and performance associated with MDAPs.

1. Selected Acquisition Reports

A SAR is a standard, comprehensive, summary status report of an MDAP. Its purpose is to provide information to assist with monitoring the progress of acquisition programs, identify any significant deviations from baseline estimates, and provide explanations about changes in cost, schedule, and performance estimates that may have occurred. Under Section 4351 of Title 10, U.S. Code, the secretary of defense is mandated to submit a quarterly report to Congress on the status of current MDAPs. (SARs, 2023). "SARs submitted for the first quarter of the fiscal year are known as annual SARs. SARs submitted for the second, third, and fourth quarters of the fiscal year are known as quarterly SARs" (SARs, 2023, p.1). Annual and quarterly SARs were required by law to be reported starting the first quarter of fiscal year 1983 (SARs, 2023). This research analysis utilizes historical SAR data from 1997 to 2018.

2. Weapon Systems Acquisition Reform Act

The Weapon Systems Acquisition Reform Act was enacted in 2009 for the purpose of reducing schedule delays and cost variances found in MDAPs (Alexander, 2009). The law addresses required changes to the acquisition organization, acquisition policies, and other areas found to have an impact on the acquisition of major weapons

systems, to include data and information management. The major organizational changes involved appointing a "director for cost assessment and program evaluation," a "director for developmental test and evaluation," a "director for systems engineering," and a "director for research engineering" (Weapon Systems Acquisition Reform Act, 2009). Each of these positions serves as a principal advisor to the secretary of defense and is responsible for developing policies and guidance related to their respective areas of expertise.

In 2014, the Congressional Research Service produced a report titled *Defense Acquisitions: How DoD Acquires Weapon Systems and Recent Efforts to Reform the Process.* The study provides a detailed explanation of the process for procuring MDAPs and highlights the efforts by Congress to improve the performance of the Defense Acquisition System (Schwartz, 2014). In addition to the creation of new appointments mentioned previously, the report also named one key provision of the Weapon Systems Acquisition Reform Act being changes to the Nunn-McCurdy Act that include "rescinding the most recent milestone approval for any program experiencing critical cost growth" (Schwartz, 2014, p.18). The offices and appointments created from the Weapon Systems Acquisition Reform Act have monitored all aspects of MDAPs, implemented numerous policies, and provided guidance to key leaders and program managers. This has led to additional changes that have impacted the Defense Acquisition System, such as the creation of the AAF and new initiatives for the use and management of data in MDAPs, which is the focus of this research.

3. Nunn-Mccurdy Breaches

The Nunn-McCurdy Act, enacted in 1982, was developed to improve oversight and control over cost growth in MDAPs. It mandates that the DoD report to Congress when a program's cost exceeds established thresholds, thus promoting accountability and transparency in defense spending (Cost Growth-Unit Cost Reports [Nunn-McCurdy], 2021). A Nunn-McCurdy breach occurs when an MDAP exceeds its cost baselines by specified threshold metrics. A significant breach occurs when the current unit cost (CUC) or program acquisition unit cost (PAUC) increases by 15% when compared to the current baseline estimate, or by 30% when compared to the original baseline estimate.

When there is an increase in CUC or PAUC of 25% compared to the current baseline estimate, or by 50% compared to the original baseline estimate, the breach is considered critical (Schwartz, 2016).

Program offices for MADPs are required to submit reports containing unit cost data to the senior executives that are responsible for overseeing a service's acquisition portfolio. This occurs regularly and on a quarterly basis. If a cost breach is suspected to have occurred, the program manager of the respective MDAP is required to send the unit cost report to the service's acquisition executive immediately. In the event of a breach, a series of mandatory corrective actions is triggered. One of these actions is the service's acquisition executive determining whether a breach has actually occurred, in which case they are required to notify Congress within 45 days (Cost Growth-Unit Cost Reports [Nunn-McCurdy], 2021). The notification consists of 17 pieces of information that explain the reasons for the cost growth, the impacts on the program, and the planned corrective actions (Schwartz, 2016). In addition to the notification, the DoD must also submit an "SAR for the fiscal quarter in which the breach occurred or in the quarter in which it was determined that a breach occurred. For a significant breach, no further action is required. However, if a program experiences a critical breach, the secretary of defense must also conduct a root-cause analysis of the breach" (Schwartz, 2016, p.8). Programs having critical breaches are required to be canceled "unless the secretary of defense certifies that the program meets certain requirements, such as being essential to national security, and that new cost estimates are found to be reasonable by the director of cost assessment and program evaluation" (Schwartz, 2016, p.9).

Several programs have faced Nunn-McCurdy breaches since 2007, leading to significant reviews and restructuring. In 2009, the VH-71 presidential helicopter was canceled after a critical breach due to unjustified cost overruns (Sullivan, 2012). The F-35 Joint Strike Fighter program and Global Hawk unmanned aerial vehicle both triggered critical breaches, resulting in program adjustments rather than be canceled. In 2024, Congress was notified by the Air Force that baseline cost projections for the Sentinel intercontinental ballistic missile program were exceeded by more than 25% (DoD News, 2024). Following a thorough review led by William A. LaPlante, the undersecretary of defense for acquisition and sustainment, the program was "estimated by the Office of

Secretary of Defense, Cost Assessment & Program Evaluation to cost $140.9 billion, an increase of 81 percent compared to estimates at the program's previous Milestone B decision in September 2020" (DoD News, 2024, p. 1). LaPlante certified the Sentinel program as meeting the statutory criteria to continue. However, he also rescinded the program's Milestone B approval, the point in the acquisition life cycle that allows progression to the engineering and manufacturing phase and directed the Air Force to develop and provide a plan to restructure the Sentinel program and address the root causes of the breach (Department of Defense, 2024).

The Nunn-McCurdy Act plays a crucial role in maintaining fiscal discipline in DoD programs, ensuring transparency and accountability. This information was found to be relevant to the focus of this research, as it relates to cost growth in MDAPs and the actions the DoD is taking to minimize the risk of excessive cost growth that may result in a Nunn-McCurdy breach.

4. National Defense Authorization Act

Congress produces a National Defense Authorization Act (NDAA) annually, with one of the act's purposes being to authorize funding for all MDAPs and specify the quantities to be procured. Section 830 of the NDAA for Fiscal Year 2020, "Modification of Requirements for Reporting to Congress on Certain Acquisition Programs," explains that MDAPs include

> any program that is estimated by the Secretary of Defense to require an eventual total expenditure for research, development, test, and evaluation of more than $300 million (based on fiscal year 1990 constant dollars) or an eventual total expenditure for procurement, including all planned increments or spirals, of more than $1.8 billion (based on fiscal year 1990 constant dollars). (NDAA, 2019)

This language is also found in Section 4351 of Title 10, U.S. Code, which covers the details and requirements for SARs. The historical SAR datasets that are being analyzed for this research are based on this dollar threshold and are considered MDAPs.

The NDAAs additionally provide instructions and requirements for the DoD in the management and oversight of MDAPs. Section 830 of the NDAA for Fiscal Year 2020 directed the secretary of defense to submit a proposal to Congress outlining an

alternative methodology for using SARs to report on all acquisition programs (NDAA, 2019). This requirement was introduced due to updates made to the Defense Acquisition System and the adoption of the AAF (NDAA, 2019).

In response to the reporting requirement for MDAPs that were directed by the NDAA for Fiscal Year 2020, the DoD proposed the use of web-based systems that are "intended to improve efficiency and data transparency by providing real-time access to acquisition information for Congress and stakeholders" (Oakley, 2022a, p. 2). Section 836 of United States Code, Title 10 directs the "secretary of defense to develop and integrate advanced digital management and analytical capabilities consistent with private sector best practices" (Digital Modernization of Analytical and Decision-Support Processes for Managing and Overseeing Department of Defense Acquisition Programs, 2021, para. 1). The new online system for managing and overseeing MDAPs was intended to replace the reporting processes for SARs after fiscal year 2021. However, the DoD experienced delays in implementing the new reporting requirements. As a result, Section 805 of the NDAA for Fiscal Year 2022, "Two-Year Extension of Selected Acquisition Report Requirements," extended the use of SARs and their reporting requirements until the end of fiscal year 2023 due to delays in implementing the new digital modernized reporting system for MDAPs. At the time of this research, the DoD continues to work toward implementing changes to comply with the congressional mandate for reporting on MDAPs. Additional information about the causes of the delays on reporting for MDAPs is presented later in this chapter, alongside a review of a GAO report on the topic.

5. President's Management Agenda

The President's Management Agenda (PMA) is an initiative undertaken by each presidential administration since 2001. The PMA facilitates collaboration among agencies to improve the functioning of government through concrete milestones (PMA, 2022). The PMAs for 2018 and 2022 both address the need for improving acquisition programs through better use of data.

The 2018 PMA, published by the Trump administration, specified that one of the goals was to utilize data as a strategic resource to "grow the economy, increase the

effectiveness of the federal government, facilitate oversight, and promote transparency" (PMA, 2018, p. 15). This effort resulted in the development of the Federal Data Strategy, which is intended to "leverage the full value of federal data for mission, service, and the public good by guiding the federal government in practicing ethical governance, conscious design, and a learning culture." (Federal Data Strategy, 2020, p. 15). The Federal Data Strategy is composed of a mission statement, 10 operating principles, 40 best practices, and was developed by cross-agency teams composed of chief data officers and staff members from 23 federal agencies, including the DoD. One of the Federal Data Strategy's directed actions is for principal agencies to develop and share use cases for artificial intelligence.

A priority of the 2022 PMA, published by the Biden administration, is to improve the management of government operations. One of the strategies supporting this priority is the enhancement of the federal acquisition system through interoperability and sharing of acquisition data and tools. Through a series of milestones, the strategy aims to develop a digital product that will provide detailed and accurate operational pricing and contract information to federal contracting personnel. These milestones include (a) development of a new application named Procurement Co-Pilot, which allows access to government-wide pricing data for market research; (b) establishment of data-sharing agreements between principal agencies to break down data silos; and (c) completion of a Technology Landscape Assessment to identify potential opportunities for creating a more modern, data-driven acquisition environment (PMA, 2022). The public website reporting the status of PMA priority milestones states that these three milestones were completed as of June 2024. Future research into cost variances may benefit from the large datasets that the Procurement Co-Pilot initiative will provide.

B. REPORTS BY THE GOVERNMENT ACCOUNTABILITY OFFICE

The following review of GAO reports validates that the DoD has taken steps to improve the collection, management, and reporting of data for MDAPs; however, it highlights that additional improvements are still needed.

1. Joint Action Needed by DoD and Congress to Improve Outcomes

In 2015, the GAO conducted a study titled *Defense Acquisitions: Joint Action Needed by DoD and Congress to Improve Outcomes* (Francis, 2015). The GAO study on recurring issues with the Defense Acquisition System is important for this research because it suggests there are factors not contained in SARs that may help to better understand the causes of cost and schedule overruns. The study focuses on the Defense Acquisition System to gain insight into recurring issues that include cost overruns, schedule delays, and performance shortfalls in MDAPs, which have been documented in reports, including Weapon System Annual Assessments, dating back to the early 2000s. The study underscores the importance of a sound business case for individual programs and identifies situations where business cases are being undermined.

Francis (2015) stated that defense acquisitions "frequently take significantly longer and cost more money than promised and often deliver fewer quantities and capabilities than planned" (p. 2). While there have been several congressional and senior executives–mandated reforms related to defense acquisitions, Francis states that it is not unusual for time and money requirements to be underestimated by 20–50%. Because the DoD does not have access to an unlimited amount of resources, its buying power is reduced when acquisition programs experience excessive cost and schedule overruns.

Francis (2015) focused on the importance of MDAPs having sound business cases. One element in achieving a sound business case is a Product Support Business Case Analysis, which is required prior to the initiation of an MDAP and is validated throughout the program's life cycle. It is a "structured methodology and document that aids decision-making by identifying and comparing product support alternatives, examining the mission and business impacts (both financial and non-financial), risks, and sensitivities" (Office of the Deputy Assistant Secretary of Defense for Product Support, 2024). A business case consists of 12 integrated product support elements, which fall within three primary categories: life cycle sustainment management, technical management, and infrastructure management (Francis, 2015). Francis suggested that a properly completed business case should provide credible evidence that a desired requirement is valid and that the chosen concept is the best approach, which can be

developed and produced with the available resources. To achieve this, "a good business case should include (a) firm and feasible requirements, (b) mature technology, (c) an incremental, knowledge-based acquisition strategy, and (d) a realistic cost estimate" (Francis, 2015, p. 3).

Francis (2015) identified three cultural incentives within the DoD that undermine business cases for MDAPs. The first incentive arises from the competition for defense funding among program sponsors, who project overly high levels of performance while promising low costs and short schedules. The second incentive relates to the budgeting process, where funding decisions are often made when there is "less verifiable knowledge available about a program's cost, schedule, and technical challenges" (Francis, 2015, p. 5). This creates pressure to advance programs that may have higher levels of risk because funding for these programs has already been approved. Lastly, the third incentive is based on overpromising by programs that receive funding approvals: "If funding is approved for a program despite having an unrealistic schedule or requirements, that decision reinforces those characteristics instead of sound acquisition practices" (Francis, 2015, p. 6). This information is important to consider in this research as there are underlying factors negatively affecting MADPs that program managers are not able to capture within a program progress report or dataset.

2. Additional Actions Needed to Implement Proposed Improvements to Congressional Reporting

In 2022, the GAO published a study titled *Defense Acquisitions: Additional Actions Needed to Implement Proposed Improvements to Congressional Reporting* (Oakley, 2022a). The study focused on the DoD's use of data in reporting on defense acquisition programs (DAPs) to Congress. The study highlighted significant reforms implemented to track and report on acquisitions, as well as some problems encountered with implementing new technologies. The report concluded with two recommendations that the DoD agreed with and has been working on implementing.

In response to the NDAA for Fiscal Year 2020 mandate for the DoD to propose a new method for reporting on acquisition programs, the DoD offered a "web-based reporting approach intended to improve efficiency and data transparency by providing

real-time access to acquisition information for Congress and other stakeholders" (Oakley, 2022a, p.2). The DoD stated that it would use the ADVANA platform for congressional reporting on DAPs. The DoD's response acknowledged that Congress seeks "additional data elements on risk that are not included in current SARs" (Oakley, 2022a, p. 36). It was suggested that "some data elements for cost, schedule, and performance risks could be included in an unclassified ADVANA environment" (Oakley, 2022a, p. 36). However, there is a possibility that risk assessments may become classified if certain details are provided. It was noted that a study was being conducted by the OUSD(A&S) to determine if the services could benefit from having a separate reporting portal for risk assessments containing classified information. This information is important to consider when working with the current datasets in this research, as the true reasons for cost and schedule overruns may not be included in SARs due to the potential negative impact of such information not being publicly available.

Oakley (2022a) pointed out that while the DoD provided a timely response for its proposed changes on reporting for DAPs, the actual implementation of the proposed changes has been limited. There were four open questions that the DoD had yet to address at the time of the study. These questions included the following: "(a) what information to report, (b) what criteria to use for selecting acquisition efforts to report, (c) how to improve reporting timeliness, and (d) how to provide congressional access" (Oakley, 2022a). There are unique issues associated with each of these questions for which the DoD continues to work on finding solutions. The primary takeaway from this report is that the process of improving the collection, management, and communication of acquisition information for the AAF pathways is a large and complicated undertaking.

Oakley (2022a) provided two recommendations to assist with the reporting transformation process. The first recommendation was related to "leadership focus and attention" (Oakley, 2022a, p. 21). Oakley stated that the DoD's planning documentation related to this reform did not specifically identify the responsibilities of the offices with leadership roles. Additionally, DoD officials had not yet determined the resources, such as funding and manpower, necessary to implement the new web-based reporting system. The second recommendation was "related to managing and monitoring implementation" (Oakley, 2022a, p. 23). Oakley highlighted the need to develop a process that would

measure the progress of implementing recommended changes. This would require the creation of key milestones, deliverables, and performance ratings to be given by congressional members (Oakley, 2022a, p. 23).

Oakley's (2022a) study on the DoD's use of data in reporting on DAPs to Congress is important for this research because it suggests that additional data, beyond what is reported in historical SARs, may not be readily available at the time of writing this thesis. It also indicates that the DoD is still working to identify the correct data to use for managing and monitoring MDAPs.

3. Weapon Systems Annual Assessments

Since 2003, the GAO has produced an annual assessment of major weapon programs with the goal of providing "congressional and DoD decision-makers with an independent, knowledge-based assessment of defense programs that identifies potential risks and offers an opportunity for action when a program's projected attainment of knowledge diverges from best practices" (Brock, 2003, p. 2). The assessments use a two-page format to report on major weapon programs, which include "a profile of the product that contains a description, a timeline of development, a baseline comparison of cost, schedule, and quantity changes, and a graphical and narrative depiction of how the product development knowledge of an individual program compares to best practices" (Brock, 2003, p. 2). The information in these assessments benefits this research by providing potential causes for outliers that are found in the analysis but are not identified in SARs; these findings are presented in Chapter IV.

A 2003 GAO report, *Defense Acquisitions: Assessments of Major Weapon Programs*, Brock (2003) explained that product development knowledge is "a process of reducing risk by ensuring high levels of knowledge regarding critical facets of a product are achieved at key junctures in development" (p. 4). The GAO often refers to this process as using a knowledge-based approach to acquisitions. There are three knowledge points that can be aligned with a program's schedule and used to identify whether gaps or shortfalls exist. The first knowledge point is, "Resources and needs are matched. This level of knowledge is attained when a match is made between a requirement owner's need and the developer's technical, financial, and available resources" (Brock, 2003, p.

4). One best practice that serves as a strong indication of resource availability is having a high level of technology maturity at the beginning of product development. The second knowledge point is, "The product design is stable. This level of knowledge is attained when the product's design demonstrates the ability to meet the requirement owner's need" (Brock, 2003, p. 5). It is a best practice that the design of a product is stable enough to commit to production by the system-level critical design review, which should occur near the midpoint of the product development phase. The third knowledge point is, "Production processes are mature. This level of knowledge is attained when it is demonstrated that the product can be manufactured within cost, schedule, and quality targets" (Brock, 2003, p. 5). It is a best practice to have mature production processes in place by the time that production begins. When program managers and MDAs move through acquisition phases with less knowledge than suggested, there is an increased risk of cost, schedule, and performance problems. Adherence to knowledge-based acquisition principles in the management of MDAPs has been a central focus of GAO annual weapon assessments and has inspired independent researchers to study how the use of these principles affects cost overruns. A dataset containing the achievement or non-achievement of the discussed knowledge points at critical milestones in the procurement process was not available at the time of this research; however, future research on such factors affecting cost overruns in MDAPs could benefit from such data being made available.

C. PAST RESEARCH

The following review of previously conducted research on cost overruns in MDAPs provides a basis for how other researchers used pre-existing data to analyze factors affecting cost variances in MDAPs.

1. Cost and Time Overruns for Defense Acquisition Programs

In 2011, members of the Center for Strategic and International Studies conducted a study titled *Cost and Time Overruns for Defense Acquisition Programs* (Hofbauer et al., 2011). The authors examined the cost variance categories of changes in cost estimates, quantity changes, engineering problems, scheduling delays, and support issues.

The in-depth analysis of SARs for MDAPs concluded that inaccurate cost estimates are a key factor contributing to cost overruns, accounting for approximately 40% of the accumulated cost overruns. The research also highlighted the impact of each service component, suggesting that programs led by the Army and Navy exhibit fewer and smaller overruns compared to programs led by the Air Force or managed at the DoD-wide level (Hofbauer et al., 2011). This study assists the current research by enabling a comparison of results from cost variance categories using more current data and different analysis methods.

2. Study of Cost, Schedule, and Engineering Variances

In 2011, William E. Griffin of the U.S. Air Force and Michael R. Schilling (2011) of the U.S. Navy conducted research titled *Analyzing Cost, Schedule, and Engineering Variances on Acquisition Programs*. Their research focused on analyzing cost, schedule, and engineering variances in MDAPs. They used data from SARs to determine whether cost variances identified early in an acquisition program are significantly associated with future program variances. The primary analytical methodology employed was multiple regression analysis, which estimates the effect of multiple explanatory variables on a particular dependent variable. To conduct the analysis, many of the nominal variables in the SARs had to be converted into binary variables, often referred to as dummy variables.

The researchers noted in their summary that the results did not provide definitive conclusions for all the questions tested, but they did offer insights into the relationship between program and contract variance. This finding is particularly relevant to the current research, as it similarly seeks to explore the relationships between data identified in SARs. Although this research also uses nominal variables, the analytical methodologies used do not require the creation of binary variables, a step in the data preparation phase that would have required a significant amount of time to accomplish.

3. Knowledge-Based Approach to Defense Acquisitions

In 2010, Dana Wyman (2010) of the U.S. Air Force conducted research titled *Best Practices in Government Acquisition: A Test of the Government Accountability Office's Knowledge-Based Acquisition Theory*. The research focused on the root causes of cost

and schedule overruns. A key piece of literature used in Wyman's research was a GAO report on an acquisition practice known as knowledge-based approach. The GAO report claimed that acquisition programs would achieve better results by utilizing the industry proven practices that the knowledge-based approach is comprised of. These practices include "developing products using only proven technology, completed product designs, and by having their production processes under statistical control" (Wyman, 2010). Wyman analyzed acquisition program data to compare the performance and success rate of acquisition programs meeting knowledge-based approach criteria thresholds against acquisition programs that did not.

To understand if acquisition programs meeting knowledge-based approach criteria achieved better results than acquisition programs that did not , Wyman tested the following three hypotheses:

> (a) defense acquisition programs that do not reach Technology Readiness Level 7 (TRL7) by program initiation (Milestone B) will experience worse program outcomes than those that do reach TRL7 by program initiation; (b) defense acquisition programs that do not complete 90% of their engineering drawings by Critical Design Review will experience worse program outcomes than those that do; and (c) defense acquisition programs that do not have manufacturing processes stabilized by Milestone C will experience worse program outcomes than those that do (Wyman, 2010)

The results of Wyman's (2010) research indicated that the GAO's claim was correct: programs are more likely to have better outcomes in terms of cost and schedule when knowledge-based principles are adhered throughout the acquisition. This finding is important for this research, as one of the objectives is to identify what information or data that is not currently reported in SARs could benefit the management and oversight of MDAPs if it were included.

D. SUMMARY

This chapter presented a review of literature used to establish a foundation for this research. The overview of government policies emphasized the impact of DoD acquisitions on senior leadership within the federal government and the mandated changes required to control costs, schedule, and performance associated with MDAPs.

The review of GAO reports validated that the DoD has taken steps toward improving the collection, management, and reporting of data for MDAPs. It also highlighted that additional improvements are required. The analysis on previously conducted research provided a basis for how other researchers used pre-existing data to analyze different factors affecting cost variances in MDAPs. The next chapter provides an overview of the data sources used in this research and the methodology for collecting, preparing, and analyzing the data.

III. DATA SOURCES, COLLECTION, UNDERSTANDING, AND PREPARATION

This chapter outlines the methodology used to collect and analyze defense acquisition data to answer the research questions introduced in Chapter I. It begins by providing an overview of the information system used to obtain the datasets for this research. Next, a detailed explanation of how the dataset was prepared for analysis is provided. Finally, the chapter concludes by introducing the software used and the steps performed for conducting analyses of the datasets.

A. DEFENSE ACQUISITION VISIBILITY ENVIRONMENT

The data used in this quantitative research was obtained from the historical SAR repository that is hosted on the DoD information system DAVE.

DAVE is a web portal maintained by the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD[A&S]). It provides the "department with timely access to accurate, authoritative, and reliable data to support insight, analysis, and decision-making. DAVE offers easily accessible front-end applications, data repositories, capabilities, and a well-defined and -managed data framework to offer perspective and context for the use of acquisition data" (DAVE, 2024, p. 1). The six available applications hosted on the DAVE site include the Acquisition Information Repository (AIR), Acquisition Visibility Data Framework (AVDF), Program Cost and Funding Chart, Data Opportunities Visualization, Program Submissions (PS), and Acquisition Datasets (ADS).

AIR stores final approved acquisition documents in a centralized searchable repository. This application makes acquisition information accessible to senior executives, analysts, component staff members, program management officers, and other acquisition personnel. Some of the searchable documents include MDAP Acquisition Strategy Documentation, Milestone Recommendation and Certification Memorandums, Acquisition Program Baselines, and Live Fire Test & Evaluation Reports. Access to this site requires submission of a System Authorization Access Request (SAAR) form, and some information and documents require the submission of a SAAR along with approval

from information owners due to the sensitive nature of the information. Therefore, additional information useful to understanding causes of cost overruns may be available to stakeholders who possess the appropriate access.

The AVDF is the authoritative OUSD (A&S) common enterprise data standard that supports the operation of the AAF pathway and enables data visibility, accessibility, uniformity, transparency, and interoperability. The AVDF site provides users with the data standards for almost 700 discrete data types and 115 active document types (DAVE, 2024). These discrete data types, or metadata, are data elements that provide information such as category, type, and sources for the data being reported. The framework is a living document that is updated quarterly to add new data elements, update current data elements, and retire outdated data elements. Each approved data element has an Acquisition Visibility Identification associated to it. For example, AV0001 is assigned to the data element "Acquisition Full Name," which is defined as the "Official designation and/or nomenclature of the acquisition being reported" (e.g., Joint Direct Attack Munition). This information helped this research by providing definitions and clarification about the data elements and factors used in this research analysis.

The Program Cost and Funding Chart is used to capture the primary acquisition and sustainment program budgets and fund-required estimates. This site provides program managers with a fillable form and instructions to report all research, development, testing, and education (RDT&E), procurement, military construction (MILCON), and system operations and maintenance (O&M) investments supporting the baselined acquisition program. In this research analysis, the changes among these estimates are examined and the fund type category is used to determine the probability and likelihood of an associated change.

The Data Opportunities Visualization is a dataset that provides information about the data being used in the defense acquisition process, allowing users to investigate data opportunities and solve acquisition problems. The dataset contains a list of the various acquisition and business information systems and provides details such as each system's name, an associated acronym, a summary description, the business use case, the site Uniform Resource Locator (web address), and points of contact for those who manage

the data. The site informs users that the dataset is updated regularly. The current dataset, which displayed a last-updated date of June 18, 2024, at the time of publication of this report, contains 73 records.

PS is a website used to view and create all program submissions that exist in DAVE. The site provides users with a list of more than 10,000 results that can be filtered by Program Number, Short Name, Acquisition Type, Lead Component, Submission Type, Responsible Office, Effective Date Range, and Submission Date. Examples of document submission types include Acquisition Program Baselines, Defense Acquisition Executive Summaries (DAES), Mid-Tier Acquisitions reports, and program status assessments. The program status assessments are particularly useful and informative for key stakeholders, as these assessments provide categorized indicators; status icons that are green, yellow, or red; a short synopsis of the assessment; and a more detailed explanation of the assessment. Categorized indicators include cost, schedule, system performance, budget, contract performance, international program aspects, interoperability, management, production, test and evaluation, and sustainment. Program managers and senior executive leadership utilizing this assessment format would likely focus their efforts on assessment categories with a red or yellow status, as these colors signal increased risk of missing established program objectives.

The last DAVE application, ADS, is a repository of minimally processed datasets that may be used for analysis and uploading to analytical tools. The datasets used in this research were obtained from the ADS application. The application provides users access to historical SAR data from 1997 to 2018 and major automated information system annual report data up to 2016. The application also provides links to Data Opportunities Visualization, the Program Cost and Funding Chart, and access to a list of MDAPs that have experienced Nunn-McCurdy breaches from 1997 to 2022.

B. SELECTED ACQUISITION REPORT DATASETS

As indicated in the previous section, the datasets that were used for this research were obtained from the SAR repository found in the DAVE ADS application. The historical SAR repository contains 26 datasets and reports that are current as of 2020. While DAES and SAR data are still submitted through DAVE, data collected after 2018

is now available through the DoD ADVANA portal. ADVANA offers program management personnel, analysts, and stakeholders access to several business area communities with analytic applications designed to display dashboard reports based on the user's filter criteria. Unlike the historical SAR repository, the ADVANA applications and portal do not offer full datasets or a report containing all MDAPs. Users typically select one program or one service component to obtain search results. Therefore, research analysis using program data from all MDAPs cannot be accomplished using the ADVANA portal at this time due to large datasets not being readily accessible to users. For this research, the Program Information dataset and the Cost Variance dataset were found to contain the data elements required to answer the research questions posed in Chapter I.

C. PREPARING DATA FOR ANALYSIS

The process of preparing data for research analysis included the following steps: obtaining the data, cleaning the data, and joining the data.

1. Obtaining the Data

The two datasets used in this research analysis were the Cost Variance dataset (primary) and the Program Information dataset.

The primary dataset used for analysis was the Cost Variance dataset. The columns from the Cost Variance dataset included Program Number, Service Name, Program Name, Program URI, Subprogram Name, Submission Type, Effective Date, Base Year, Funding Category, Cost Variance Category, Explanation, Cost Variance Then-Year Amount, Cost Variance Base Year Amount, and Version. The Cost Variance Table contained 95,782 records.

The Program Information dataset contained 77 columns; however, only six were found to assist with answering the research questions. These columns were the Program Number, Full Name, Type, Acquisition Category, Joint Capability Area, and Commodity Type. The Program Information table contained 2,200 records, many of which were recurring entries from annual and quarterly SARs. To use the Program Information table for the analysis, a one-to-many relationship was established by removing these multiple

entries for individual DAPs. After this process, 216 unique records for individual DAPs remained, which could then be used to join program information to the Cost Variance dataset through a one-to-many relationship.

2. Cleaning the Data

As any data scientist knows, cleaning the data can be complicated and time-consuming. Several steps were taken to address unwanted columns, blank or missing values, duplicate records, and incorrectly formatted values.

To clean the data, the first step was to remove the columns from the Cost Variance Table that were not useful for analysis or for understanding the data. The Program URI column was seen as redundant to the Program Number and not useful as a primary key. The Submission Type column consisted of only one value, "SAR," and was therefore not beneficial to the analysis. The Value column consisted of only two values, "Current Changes" and "Previous Changes," and therefore was not considered beneficial to the analysis. All three of these columns were deleted from the Cost Variance Table.

Next, missing values in the tables were addressed. The Program Number column contained null values for the programs PNVC Integrator, B61-12LEP, W76-1 LEP, and W88 ALT 370. To ensure all of the records contained program numbers, the null values were changed to PNVC, B61, W76, and W88, respectively. Additionally, the CONCATENATE function was used to rename all entries as Program ###, with ### representing a program's alphanumeric characters.

The Commodity Type column in the Program Information table had 29 programs without a reported value. Values were imputed based on additional research using publicly available information and previous SARs for these MDAPs. Identified programs without reported commodity types and their imputed values are contained in Appendix A. To observe commodity types by their primary categories, a column titled Commodity Primary Category was created. All commodity types were then grouped into the six categories: Aircraft; Command, Control, Communication, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR); Ground Systems; Missile, Weapons, and

Ammunition; Ships and Submarines; and Other. The table of commodity types and grouped values is contained in Appendix B.

The JCA column in the Program Information table contained 182 blank values. Upon further examination, the "Is Joint" column contained false values corresponding to these blank values. This led to the understanding that the 182 cells were intentionally left blank. To assist with the analysis, the value "Non-Joint Capability Area Program" was imputed to categorize these blank values.

The JCA column was also found to contain values that were no longer used within the current *Charter of the Joint Requirements Oversight Council and Implementation of the Joint Capabilities Integration and Development System* (Chairman of the Joint Chiefs of Staff Instruction [CJCSI] 5123.01I) to define JCAs (Chairman of the Joint Chiefs of Staff [CJCS], 2021). To assist with accurate categorizing and future use of the analysis results, terms that are currently used were imputed and used to replace historical JCA category values. The JCA column contained the values Force Application, Logistics, Battlespace Awareness, Command and Control, Communication and Computers, Protection, Net Centric (Historical), and Force Support (Historical). According to CJCSI 5123.01I, Net Centric and Force Support are not current JCA categories.

When comparing JCA categories in current policy (CJCSI 5123.01I; CJCS, 2021) and previous policies (CJCSI 5123.01H; CJCS, 2018) and (CJCSI 5123.01G; CJCS, 2015), Net Centric aligns best with the JCA category Communication and Computers. Therefore, the JCA category Net Centric was replaced with the more current JCA category Communication and Computers.

The category Force Support was removed as a JCA with the publication of CJCSI 5123.01H. Force Support is defined in CJCSI 3405.01 as support that "provides the ability to establish, develop, maintain, and manage admission-ready Total Force" (CJCS, 2011, p. 27). Only three MDAPs in the Program Information table included Force Support as a JCA: the Utility Helicopter Replacement Program, the Joint Primary Aircraft Training System, and the Defense Integrated Military Human Resources System. The JCA category of the Utility Helicopter Replacement Program was changed to Logistics based on another MDAP with utility helicopters having that value. The Joint

Primary Aircraft Training System was changed to Force Application based on another aircraft training program with that value. Lastly, the Defense Integrated Military Human Resources System to Force Integration was changed to Force Integration based on the 2023 JCA Definition 1.1.4 Human Capital Management, a subcategory of 1.1. Force Integration (Defense Acquisition University, 2023). By making these changes, all records within the Program Information dataset now contained current JCA categories that could be used in the analysis.

The Program Information table initially contained 2,200 records, many of which were recurring entries from annual and quarterly SARs. This meant that there were multiple records for individual DAPs. To use the Program Information table for the analysis, a one-to-many relationship was established by removing these multiple entries for individual DAPs and establishing the Program Number as the primary key value in both tables. After this process, there remained 216 unique records for individual DAPs, which could then be used to join program information to the Cost Variance dataset through a one-to-many relationship.

3. Preparing the Data Using Jmp

To analyze the data, the statistical software JMP (pronounced "jump") was used. Originally launched by the SAS Institute in 1989, JMP software is designed for interactive, visual, and exploratory data analysis. The purpose of the software is to "empower scientists and engineers via statistical discovery software" (JMP, 2024, para. 11) and is marketed to all problem solvers. In this research, JMP allowed for conducting text analysis, logistic regression, and the creation of contingency tables and mosaic plots with the dataset.

To conduct the analysis and answer the research questions from Chapter I, several columns of data were required from the Program Information table. These columns were Program Full Name, Program Type, Acquisition Category (e.g., IB, IC, II), JCA, and Commodity Type. Using the Program Number as the primary key, the "join" function in JMP was used to add the required columns from the Program Information table to the Cost Variance Table.

The columns Cost Variance Then-Year Amount and Cost Variance Base Year Amount are reported in currency values. The Cost Variance Then-Year Amount column contained 11,901 values in exponent form, and the Cost Variance Base Year Amount column contained 11,538 values in exponent form. All exponent values were converted to currency values for the analysis. There were also seven null values contained in the Cost Variance Then-Year Amount columns. Each of these null values was assumed and changed to zero.

As part of the analysis, a focus was placed on cost increases among MDAPs. Therefore, two additional columns within the Cost Variance Table were created using a conditional function that returns a text value based on the values in the Cost Variance Then-Year Amount and Cost Variance Base Year Amount columns. If a value greater than zero was observed, the returned value would be "Cost Growth." If the value was zero, the returned value would be "No Change." If the value was less than zero, the returned value would be "Cost Reduction." This function is based on the supposition that "a positive value is unfavorable because it indicates an increased estimated cost of a program, while a negative value is favorable because it indicates a decreased estimated cost of a program" (Griffin & Schilling, 2011, p. 42). These two columns are named CV Then-Year +/- Impact and CV Base +/- Impact, respectively.

The Explanation column had a default data type of "Character" and a modeling type of "Nominal" when the Cost Variance Table was opened in the JMP software. To assist with the text analysis, the column's modeling type was changed to Unstructured Text.

D. SUMMARY

This chapter provided an overview of the SAR Cost Variance dataset and how it was obtained. The steps taken to transform the dataset for analysis and to answer the questions posed in Chapter I were explained. The chapter concluded by describing the analytic software JMP and detailing the process for preparing the Cost Variance dataset for analysis using the JMP software.

IV. ANALYSIS, FINDINGS, AND RECOMMENDATIONS

This chapter begins by providing an overview of the analysis methods used in this research: Contingency, Logistic, and Text. Next, the chapter presents the results from the three analysis methods used to understand how cost variances differ among different factors in the Cost Variance dataset. The chapter concludes by providing recommendations based on the factors analyzed and how the DoD can benefit from applying text analysis and machine learning to the oversight of MDAPs.

A. ANALYSIS METHODS

The purpose of this research is to understand the effect of different factors on cost variance for MDAPs. This section begins with an explanation of contingency analysis and how it is used. Next, the section presents a discussion of logistic analysis and how this method benefits the research. The section concludes with an explanation of text analysis and its application in this study.

1. Contingency Analysis

A contingency analysis examines the relationship between the X factors Service Component, Funding Category, Commodity Category, Joint Capability Area, and Cost Variance Category and the response variable Cost Variance. The analysis creates a contingency table that displays the frequency distributions in both counts and percentages. The performed analysis also creates a mosaic plot chart that provides a visual depiction of the relationship between the X factors and the response variable.

For both the X factors and the response variable, contingency analysis only uses nominal categorical values. To convert the cost variance amounts into nominal categorical data types, two new columns are created using a conditional function that returns a text value based on the values in the Cost Variance Then-Year Amount and Cost Variance Base Year Amount columns. If a value greater than zero was observed, the returned value was “Cost Growth.” If the value was zero, the returned value was “No Change.” If the value was less than zero, the returned value was “Cost Reduction.” The

columns were named Cost Variance Then-Year +/- Impact and Cost Variance Base Year +/- Impact, respectively.

Contingency analyses were conducted using the JMP analysis platform "Fit Y by X." The factors Service Component, Funding Category, Commodity Category, Joint Capability Area, and Cost Variance Category were used as explanatory variables (X). The column Cost Variance Then-Year +/- Impact was used as the response variable (Y). When the contingency table was created, there were between five and eight X variable levels, depending on the factor analyzed, and three Y variable levels: Cost Growth, No Change, and Cost Reduction (Everitt, 1992).

The purpose of examining the relationship between the response variable and the explanatory variables is to understand whether certain factors, such as an MDAP's Commodity Type, are more likely to experience a cost growth, cost reduction, or no change in cost variance. The analysis assesses the probability of these factors across all records in the dataset as well as specifically among records with a negative impact on cost variance.

2. Logistic Analysis

In addition to contingency analyses, logistic analyses were also conducted to examine how the actual amount of cost variance in "then-year" dollars affected various factors. Similar to the contingency analysis, the JMP analysis platform "Fit Y by X" was used. The factors Service Component, Funding Category, Commodity Category, Joint Capability Area, and Cost Variance Category served as the response variables (Y). The column "Cost Variance Then-Year Dollars" was used as the explanatory variable (X). In the logistic analysis, the Y variable is a nominal categorical data type, while the X variable is a numerical continuous data type.

The typical goal of using a logistic regression model is "to understand a binary or proportional dependent variable based on one or more predictors" (Hilbe, 2009, p. 15). In this research, the logistic model is used to help identify outliers in the data used in the analysis. Outliers are those data points or markers that are more spread out on the chart and represent records with higher cost variances amounts. When the logistic model is

generated, markers representing each record within the population are plotted on the logistic chart. Most of the markers are clustered near the mean of the cost variance for the factor being analyzed. The chart provides a visual representation of the general trend in the data. Identifying these outliers is important because it may indicate instances where something unusual or unexpected happened within the MDAP.

For the logistic regression analysis conducted in this research, the variables selected were based on the primary research question being asked. For the X factor, the Cost Variance Then-Year Amount column was selected because it is a continuous data type. For the Y response values, the columns Service Component, Commodity Prime Category, Funding Category, Joint Capability Area, and Cost Variance Category were selected because they are categorical data types and directly related to the research question being asked.

JMP software includes a tool called "Lasso," which allows the user to trace around a group of markers, highlighting the corresponding records in the data set. By identifying specific records with higher cost variance amounts, further research can be conducted using SARs, GAO weapon system assessment reports, or publicly available information to gain a deeper understanding of the underlying causes.

3. Text Analysis

There are several approaches to text analysis, each suited to different research objectives. For this research, the content analysis approach was chosen due to its ability to systematically examine and interpret words and phrases contained within textual data.

Content analysis, as defined by Klaus Krippendorff (2019), is "a research technique for making replicable and valid inferences from texts to the contexts of their use" (p. 24). In the context of this research, content analysis was applied to examine the terms and phrases contained within the Explanation column of the Cost Variance Table. By analyzing this textual data, the research aims to make valid interpretations about the degree of cost variance associated with specific patterns in the text explanation field of the Cost Variance Table.

The JMP software platform "Text Explorer" was utilized to conduct text analysis in this research. According to JMP (2024), "The Text Explorer platform is used to explore frequently used words and phrases in unstructured text data" (para. 12). This tool was selected for its user-friendly interface and ability to process large volumes of data quickly and efficiently.

"Content analysis involves breaking down text into pertinent units of information in order to permit subsequent coding and categorization" (Ignatow & Mihalcea, 2018, p. 10). Chapter III explained the data preparation processes, which included combining tables, creating new columns, and imputing missing data. These steps were essential to ensure the accuracy and relevance of the results of the text analysis.

To begin using JMP Text Explorer, specific parameters were selected before conducting the analysis. These selections included display language, maximum number of words per phrase, maximum number of phrases, minimum and maximum characters per word, whether stemming was required, how to tokenize the text, and which column to analyze. The parameters selected for the text analysis in the study are shown in Table 1.

Table 1. JMP Text Explorer Parameters

Parameter		Selection
Language		English
Maximum Words per Phrase		12
Maximum Number of Phrases		100,000
Minimum Characters per Word		4
Maximum Characters per Word		50
Stemming		No Stemming
Tokenizing		Regex
Customize Regex		No
Text Column to Analyze		Explanation 2

Upon running the Text Explorer feature, four additional steps had to be completed before a list of key phrases could be used to further understand the data. These steps included recoding, selecting exemption phrases, grouping, and choosing stop words.

The JMP "recode" feature was used to fix known spelling errors and inconsistent phrases. The recode feature found and corrected 329 records containing common spelling errors. The table of recoded terms and their outputs is presented in Appendix C.

After correcting spelling inconsistencies, phrases to exclude from the stop word list (stop words are commonly used words in a given language) were chosen. Subjective decision-making was used to add phrase exceptions that would have the greatest impact on the analysis. The table of phrase exceptions is presented in Appendix D. All single-word terms were then selected as stop words. By removing these stop words, additional focus was given to phrases most relevant to the research questions. To finalize the text analysis, the recode feature was used to group similar phrases. The list of grouped phrases is presented in Appendix E. The result of these steps was a list of 34 important phrases used to better understand the dataset. These phrases are presented with their frequencies in Appendix F.

When these steps were completed, the results were presented through frequency tables and word clouds, which visually summarize the most common phrases identified in the data. In the word clouds, phrases with high frequencies were displayed in larger fonts, making them stand out to the reader.

One of the unique features of the word cloud legend display setting is its ability to color-code phrases based on the continuous value of a variable. For this analysis, the Cost Variance Then-Year Amount column was used to color-code phrases that had cost variance amounts falling outside the standard deviation range of the factor or factors being analyzed. The standard deviation range, assuming there is a normal frequency distribution, consists of "about 68% of all observations (34% less than the mean and 34% greater than the mean)" (Myatt & Johnson, 2014, p. 33). The standard deviations observed in this analysis were determined by subtracting the mean from the standard deviation indicator line value. For example, the word cloud in Figure 4 shows the +1 standard deviation indicator has a value of $153,068,024, the -1 standard deviation indicator has a value of $-132,453,694, and the mean value is $10,307,165. The difference between the mean and both +1 and -1 standard deviation is $142,760,859. In this research, it helps to identify which cost variances are unusually high or low

compared to the average. While phrases appearing in larger fonts in the word cloud are more frequent, those in dark red or blue have a greater impact on cost variances, as they represent cases where the cost variance significantly deviated from the norm.

B. FINDINGS

The findings are organized by aligning the contingency analysis, logistic analysis, and text analysis of the Cost Variance dataset with the respective factor being analyzed. The findings are presented along with recommendations. As indicated earlier, these analyses were conducted using the columns Service Component, Commodity Prime Category, Funding Category, Joint Capability Area, and Cost Variance Category.

1. Cost Variances by Service Component

The Service Component column contained five levels: Air Force, Army, Navy, DoD, and Department of Energy (DOE). The Air Force was the top service component, with a frequency of 32,114 records, accounting for 33.53% of all submitted records. The Air Force reported cost growth in 12,872 submissions (40.08%). The Navy reported similar frequencies, with 31,957 submissions, or 33.36% of all records. The Navy reported 12,539 occurrences (39.24%) of cost growth, 9,930 occurrences (31.07%) of cost reductions, and 9,948 occurrences (29.69%) of no change. The mosaic plot and contingency table of cost variance impact by service component are presented in Figures 1 and 2, respectively.

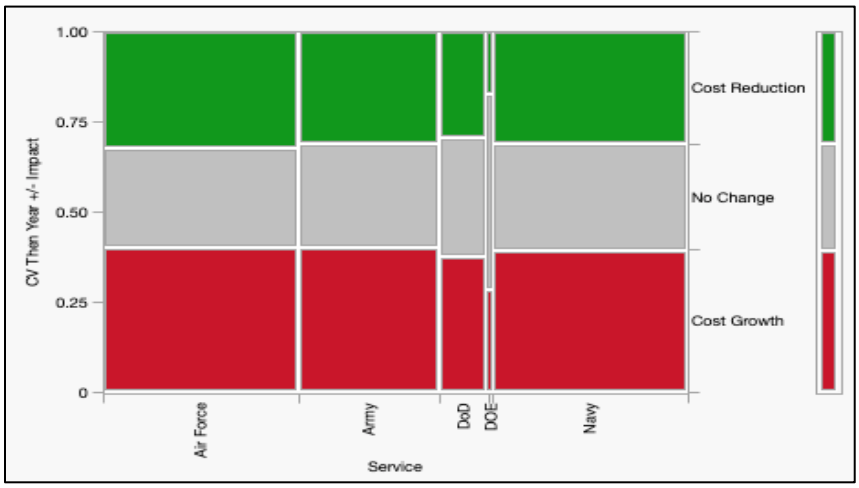
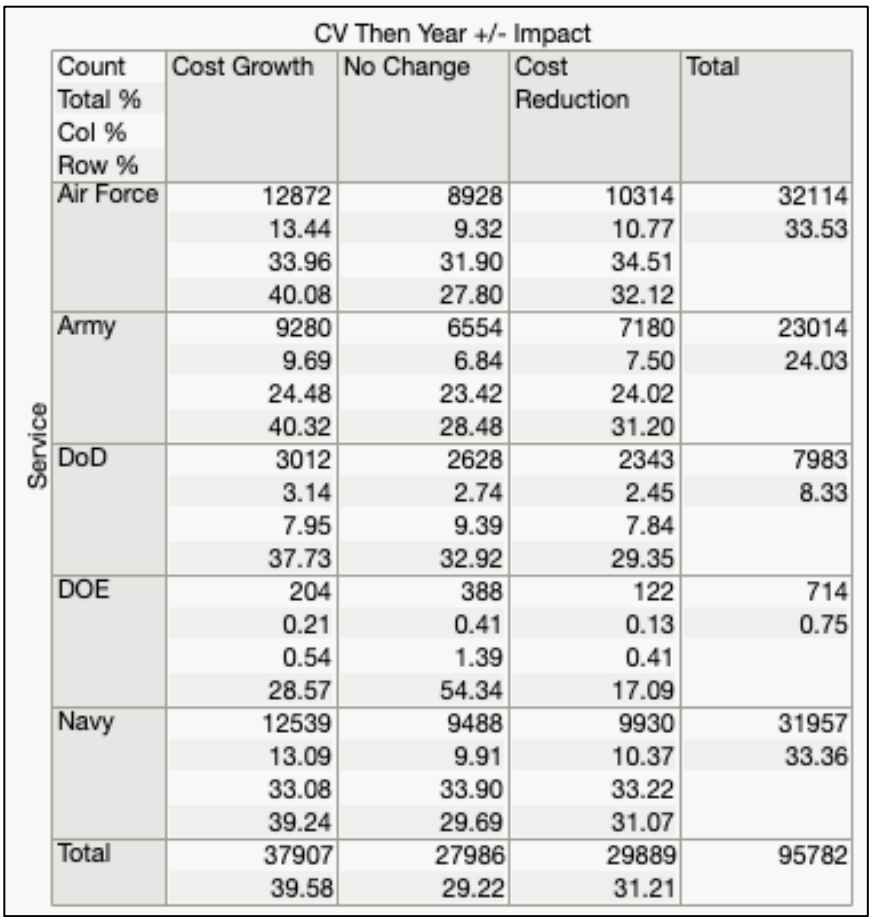


Figure 1. Mosaic Plot of Cost Variance Then-Year +/- Impact by Service Component



CV Then Year +/- Impact

Service	Count Total % Col % Row %	Cost Growth	No Change	Cost Reduction	Total
	Air Force	12872	8928	10314	32114
		13.44	9.32	10.77	33.53
		33.96	31.90	34.51	
		40.08	27.80	32.12	
	Army	9280	6554	7180	23014
		9.69	6.84	7.50	24.03
		24.48	23.42	24.02	
		40.32	28.48	31.20	
	DoD	3012	2628	2343	7983
		3.14	2.74	2.45	8.33
		7.95	9.39	7.84	
		37.73	32.92	29.35	
	DOE	204	388	122	714
		0.21	0.41	0.13	0.75
		0.54	1.39	0.41	
		28.57	54.34	17.09	
	Navy	12539	9488	9930	31957
		13.09	9.91	10.37	33.36
		33.08	33.90	33.22	
		39.24	29.69	31.07	
	Total	37907	27986	29889	95782
		39.58	29.22	31.21	

Figure 2. Contingency Table of Cost Variance Then-Year +/- Impact by Service Component

In the logistic analysis graph in Figure 3, programs owned by the DoD and the Navy were observed as having higher cost variances by dollar amount compared to programs owned by the Air Force or Army. DoD service programs reported an average cost variance of $341 million in then-year dollars. Navy-owned programs had an average cost variance of $90.7 million, Air Force-owned programs had an average cost variance of $55 million, DOE-owned programs had an average cost variance of $49.2 million, and Army-owned programs had an average cost variance of $15.6 million in then-year dollars.

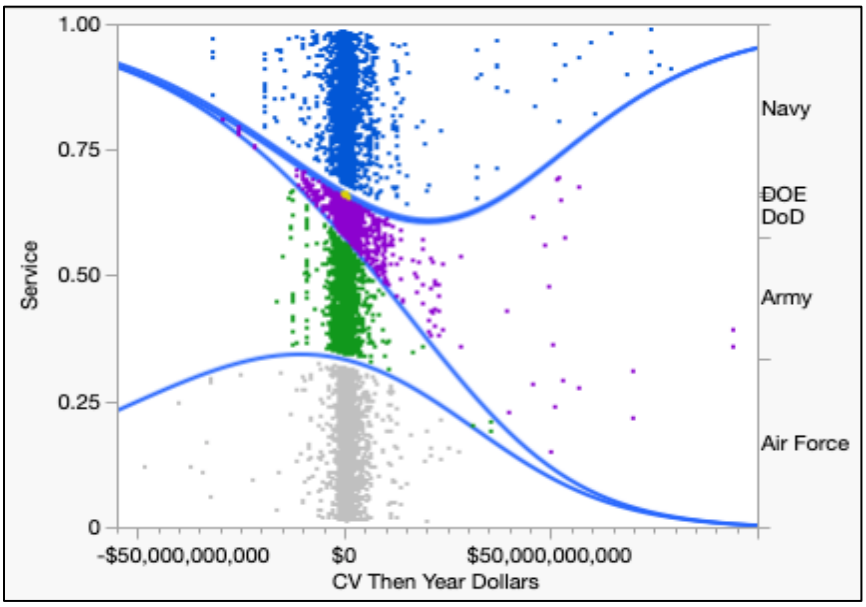


Figure 3. Logistic Analysis of Service Component by Cost Variance Then-Year Amount

Using the JMP lasso tool to isolate and identify records associated with markers that exhibited higher dollar value cost variances revealed that several programs were responsible for the outliers in the data. These MDAPs included the Ballistic Missile Defense System (BMDS; DoD program), the F-35 Joint Strike Fighter (DoD program), the DDG 51 guided missile destroyer (Navy program), and the SSN 774 Virginia-class attack submarine (Navy program). Additional factors from the dataset suggest that the higher cost variances in the F-35 program can be attributed to updated estimating figures. The higher cost variances within the DDG 51 and SSN 774 programs were largely due to the procurement of additional ships and submarines, as these outlier records were categorized under the Cost Variance Category "Quantity."

Outlier records from the BMDS program were associated with SARs processed in 2002, 2006, 2007, 2009–2013, and 2017–2019. These records also contained the following attributes: Service Component: DoD, Commodity Type: Missile, Funding Type: RDT&E, and Cost Variance Category: Engineering. Notably, none of the records included any text data in the Explanation column.

The 2017 GAO report on missile defense includes several factors that could explain the higher cost variances in the BMDS program. One notable point was that

> when MDA (Missile Defense Agency) was established in 2002, it was granted exceptional flexibilities to set requirements and manage the acquisition of the BMDS, developed as a single program, that allow MDA to expedite the fielding of assets and integrated ballistic missile defense capabilities. These flexibilities enable divergence from DoD's traditional acquisition life cycle and defer the application of acquisition policies and laws designed to facilitate oversight and accountability until a mature capability is ready to be handed over to a military service for production and operation. (Chaplain, 2017, p. 6)

As discussed earlier in the research, acquisition programs are more likely to achieve better cost, schedule, and performance results by adhering to the knowledge-based acquisition theory. It appears that the GAO identified a pattern in which the MDA develops, tests, and deploys elements of the BMDS before the technologies have fully matured.

Text analysis showed that the terms occurring most frequently within the Explanation column for the Air Force as a service component were "revised escalation indices" (1,814 occurrences [5.65%]), "revised estimate" (1,624 occurrences [5.06%]), "adjustment for current and prior escalation" (1,242 occurrences [3.87%]), and "adjustment for current and prior inflation" (815 occurrences [2.54%]). These terms occurred within one standard deviation ($142,760,859) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included "quantity variance resulting from an increase" (236 occurrences [0.73%]), "increase in other support" (219 occurrences [0.68%]), and "increase in initial spares" (166 occurrences [0.52%]). These results are portrayed in the word cloud in Figure 4.

Figure 4. Word Cloud Filtered by Service Component–Air Force

Text analysis showed that the terms occurring most frequently within the Explanation column for the Army as a service component were "revised escalation

indices" (1,339 occurrences [5.82%]), "revised estimate" (957 occurrences [4.16%]), "adjustment for current and prior escalation" (748 occurrences [748%]), and "adjustment for current and prior inflation" (736 occurrences [3.20%]). These terms occurred within one standard deviation ($227,575,056) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included "quantity variance from an increase" (217 occurrences [0.94%]), "stretch-out of annual procurement buy profile" (264 occurrences [1.15%]), and "increase in other support" (194 occurrences [0.84%]). These results are portrayed in the word cloud in Figure 5.

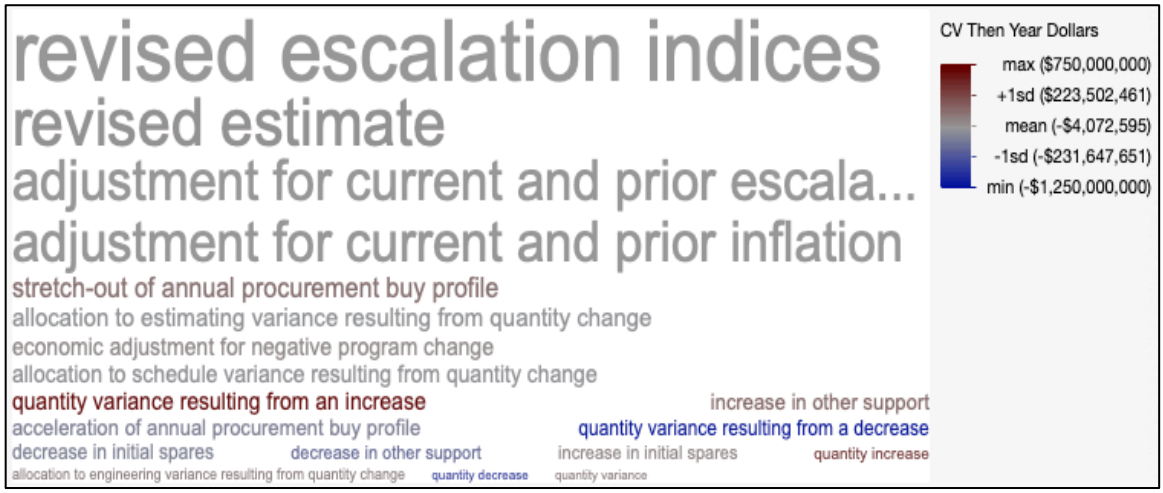


Figure 5. Word Cloud Filtered by Service Component–Army

Text analysis showed that the terms occurring most frequently within the Explanation column for the Navy as a service component were "revised estimate" (1,979 occurrences [6.19%]), "revised escalation indices" (1,844 occurrences [5.77%]), "adjustment for current and prior escalation" (1,362 occurrences [4.26%]), and "adjustment for current and prior inflation" (678 occurrences [2.12%]). These terms occurred within one standard deviation ($281,675,695) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance from an increase" (315 occurrences [0.99%]). These results are portrayed in the word cloud in Figure 6.

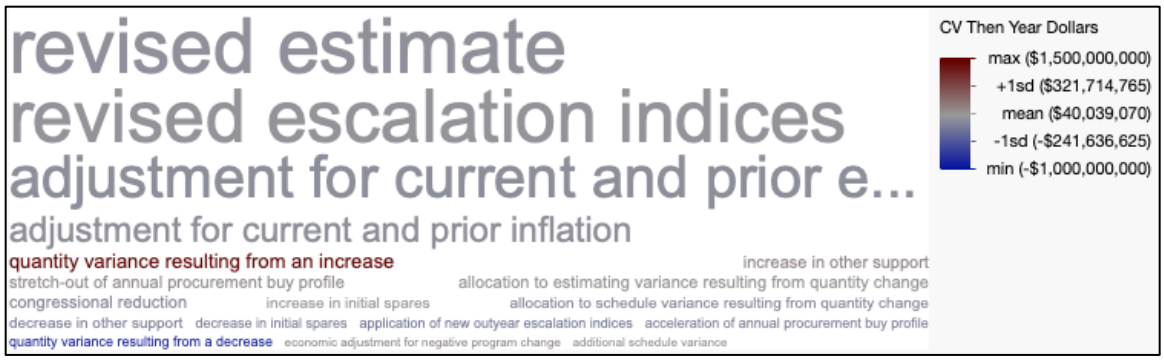


Figure 6. Word Cloud Filtered by Service Component–Navy

Text analysis showed that the terms occurring most frequently within the Explanation column for the DoD-owned programs were "revised escalation indices" (510 occurrences [6.39%]), "revised estimate" (328 occurrences [4.11%]), "adjustment for current and prior escalation" (285 occurrences [3.57%]), and "adjustment for current and prior inflation" (215 occurrences [2.69%]). These terms occurred within one standard deviation ($222,732,048) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "additional schedule variance" (44 occurrences [0.55%]). These results are portrayed in the word cloud in Figure 7.

Figure 7. Word Cloud Filtered by Service Component–DoD

Text analysis showed only three recurring terms within the Explanation column for the DOE-owned programs: "adjustment for current and prior escalation" (19 occurrences [2.66%]), "revised escalation indices" (19 occurrences [2.66%]), and "revised estimate" (4 occurrences [0.56%]). The term "adjustment for current and prior escalation" occurred within one standard deviation ($20,859,618) of the cost variance mean. The term "revised estimate" was associated with higher cost increases. These results are portrayed in the word cloud in Figure 8.

Figure 8. Word Cloud Filtered by Service Component–DOE

The analysis of cost variance by service component concluded that the service component is not a likely indicator of whether an MDAP will experience cost growth. This assertion is based on the similar percentages across service components during the contingency analysis. However, the analysis did indicate that programs owned by the DoD and the Navy have experienced higher cost variances by dollar amount compared to programs owned by the Air Force or Army. Based on the text analysis of cost variance by service component, changes in program costs were most often associated with revised estimates and updated escalation indices, while higher-dollar cost variances were more often attributed to quantity changes.

2. Cost Variances by Commodity Groups

The Commodity Prime Category column contained six levels: Aircraft; C4ISR; Ground Systems; Missile, Weapons, and Ammunition; Ships and Submarines; and Other. Aircraft was the top commodity category, with a frequency of 28,777 records, accounting for 30.04% of all submitted records. Aircraft-type reports contained 12,273 occurrences (42.65%) of cost growth, 9,320 occurrences (32.39%) of cost reductions, and 7,184 occurrences (24.96%) of no change. Similar percentages were reported among the other commodity categories. The mosaic plot and contingency tables of cost variance impact by commodity prime categories are presented in Figures 9 and 10, respectively.

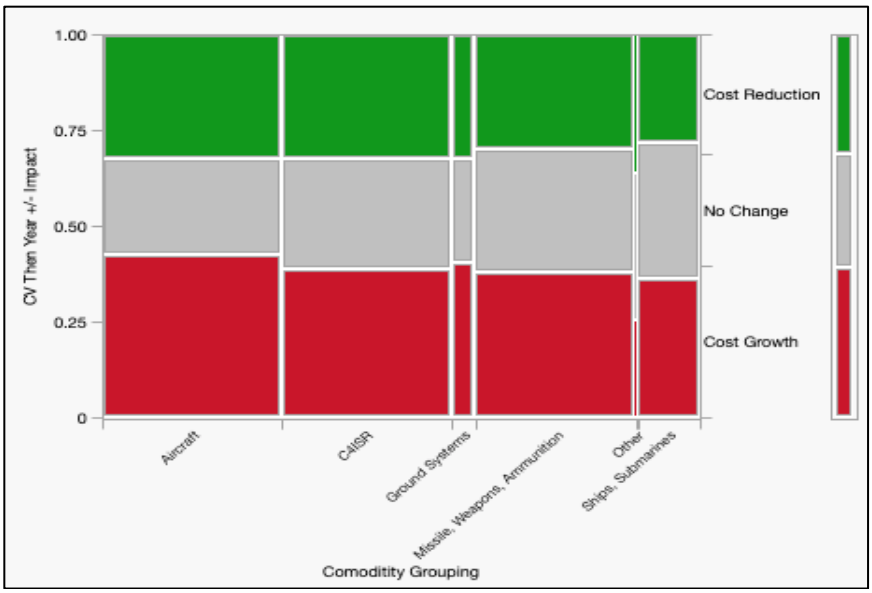


Figure 9. Mosaic Plot of Cost Variance Then-Year +/- Impact by Commodity Prime Category

CV Then Year +/- Impact

Comodity Grouping Count Total % Col % Row %	Cost Growth	No Change	Cost Reduction	Total
Aircraft	12273	7184	9320	28777
	12.81	7.50	9.73	30.04
	32.38	25.67	31.18	
	42.65	24.96	32.39	
C4ISR	10634	7854	8834	27322
	11.10	8.20	9.22	28.53
	28.05	28.06	29.56	
	38.92	28.75	32.33	
Ground Systems	1467	980	1177	3624
	1.53	1.02	1.23	3.78
	3.87	3.50	3.94	
	40.48	27.04	32.48	
Missile, Weapons, Ammunition	9812	8330	7653	25795
	10.24	8.70	7.99	26.93
	25.88	29.76	25.60	
	38.04	32.29	29.67	
Other	91	136	129	356
	0.10	0.14	0.13	0.37
	0.24	0.49	0.43	
	25.56	38.20	36.24	
Ships, Submarines	3630	3502	2776	9908
	3.79	3.66	2.90	10.34
	9.58	12.51	9.29	
	36.64	35.35	28.02	
Total	37907	27986	29889	95782
	39.58	29.22	31.21	

Figure 10. Contingency Table of Cost Variance Then-Year +/- Impact by Commodity Prime Category

From the logistic analysis graph in Figure 11, Ships and Submarines were observed as having higher cost variances by dollar amount compared to other commodity

categories. Ships and Submarines reported an average cost variance of $245.5 million in then-year dollars. Ground Systems had an average cost variance of $121.5 million; Aircraft had an average cost variance of $83.5 million; and Missile, Weapon, and Ammunition programs had an average cost variance of $70.8 million in then-year dollars. C4ISR programs had an average cost variance of $25 million. Programs categorized as "Other" had a cost variance of $-10.1 million in then-year dollars.

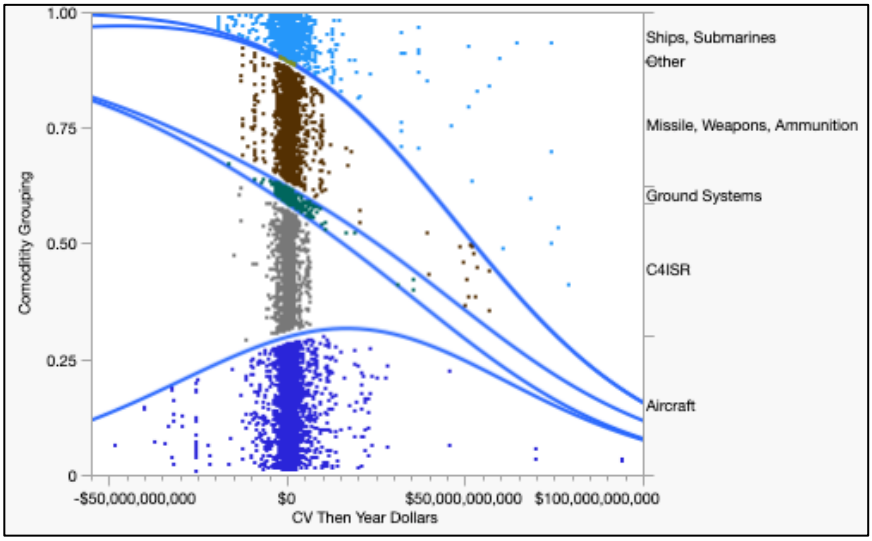


Figure 11. Logistic Analysis for Commodity Prime Category by Cost Variance Then-Year Amount

Using the JMP lasso tool to isolate and identify records associated with markers that exhibited higher dollar value cost variances revealed results that were similar to those from the Logistic Analysis for Service Component. The MDAPs included the BMDS (Missiles, Weapons, and Ammunition), the F-35 Joint Strike Fighter (Aircraft), the DDG 51 guided missile destroyer (Ships and Submarines), and the SSN 774 Virginia-class attack submarine (Ships and Submarines).

Text analysis showed that the terms occurring most frequently within the Explanation column with Aircraft as the commodity category were "revised escalation indices" (1,687 occurrences [5.86%]), "revised estimate" (1,435 occurrences [4.99%]), "adjustment for current and prior escalation" (1,259 occurrences [4.38%]), and "adjustment for current and prior inflation" (784 occurrences [2.72%]). These terms occurred within one standard deviation ($177,054,087) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included

"increase in other support" (246 occurrences [0.85%]), "quantity variance resulting from an increase" (176 occurrences [0.61%]), and "stretch-out of annual procurement buy profile" (197 occurrences [0.68%]). These results are portrayed in the word cloud in Figure 12.

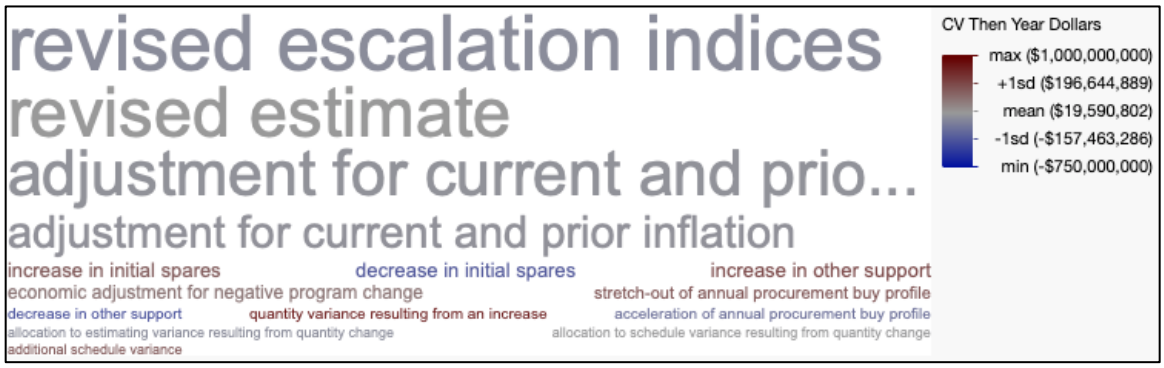


Figure 12. Word Cloud Filtered by Commodity Prime Category–Aircraft

Text analysis showed that the terms occurring most frequently within the Explanation column for the C4ISR as a commodity category were "revised escalation indices" (1,526 occurrences [5.59%]), "revised estimate" (1,421 occurrences [5.20%]), "adjustment for current and prior escalation" (1,068 occurrences [3.91%]), and "adjustment for current and prior inflation" (541 occurrences [1.98%]). These terms occurred within one standard deviation ($119,726,981) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included "quantity variance resulting from an increase" (316 occurrences [1.16%]), "increase in initial spares" (183 occurrences [0.67%]), and "stretch-out of annual procurement buy profile" (270 occurrences [0.99%]). These results are portrayed in the word cloud in Figure 13.

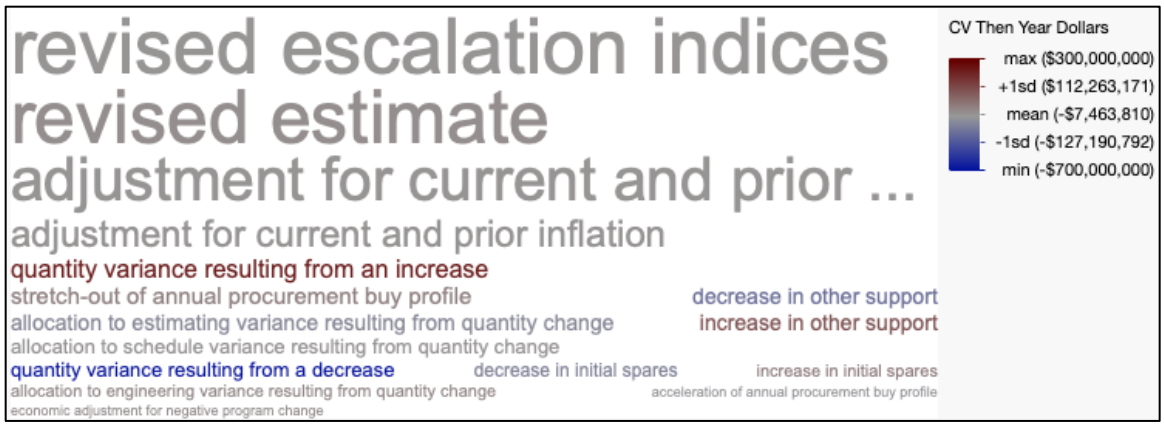


Figure 13. Word Cloud Filtered by Commodity Prime Category–C4ISR

Text analysis showed that the terms occurring most frequently within the Explanation column for Missiles, Weapons, and Ammunition as a commodity category were "revised escalation indices" (1,506 occurrences [5.84%]), "revised estimate" (958 occurrences [3.71%]), and "adjustment for current and prior inflation" (828 occurrences [3.21%]). These terms occurred within one standard deviation ($169,704,787) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance resulting from an increase" (186 occurrences [0.72%]). These results are portrayed in the word cloud in Figure 14.

Figure 14. Word Cloud Filtered by Commodity Prime Category–Missile, Weapons, and Ammunition

Text analysis showed that the terms occurring most frequently within the Explanation column for Ships and Submarines as a commodity category were "revised estimate" (894 occurrences [9.02%]), "revised escalation" (554 occurrences [5.59%]), and "adjustment for current and prior escalation" (359 occurrences [3.62%]). These terms occurred within one standard deviation ($1,011,568,036) of the cost variance mean. These results are portrayed in the word cloud in Figure 15. There were no explanations

provided for cost increases that fell outside of one standard deviation. However, from addition data found in the Cost Variance Category column, higher cost increases were related to the cost variance category "quantity."

Figure 15. Word Cloud Filtered by Commodity Prime Category–Ships and Submarines

Text analysis showed that the terms occurring most frequently within the Explanation column for Ground Systems as a commodity category were "revised escalation indices" (229 occurrences [6.32%]), "revised estimate" (163 occurrences [5.53%]), "adjustment for current and prior escalation" (141 occurrences [3.89%]), and "adjustment for current and prior inflation" (121 occurrences [3.34%]). These terms occurred within one standard deviation ($283,457,836) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included "quantity variance resulting from an increase" (42 occurrences [1.16%]), "increase in other support" (39 occurrences [1.08%]), and "stretch-out of annual procurement buy profile" (24 occurrences [0.66%]). These results are portrayed in the word cloud in Figure 16.

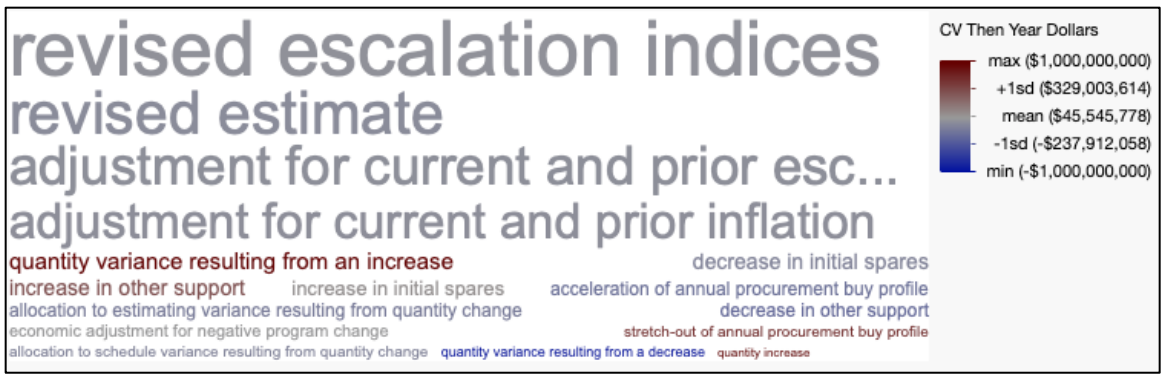


Figure 16. Word Cloud Filtered by Commodity Prime Category–Ground Systems

Text analysis showed that the terms occurring most frequently within the Explanation column for "Other" as a commodity category were "revised escalation

indices" (24 occurrences [6.74%]), "adjustment for current and prior escalation" (22 occurrences or 6.18%), and "revised estimate" (21 occurrences [5.90%]). These terms occurred within one standard deviation ($255,280,697) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases included "additional schedule variance" (6 occurrences [1.69%]) and "stretch-out of annual procurement buy profile" (4 occurrences [1.12%]). These results are portrayed in the word cloud in Figure 17.

Figure 17. Word Cloud Filtered by Commodity Prime Category–Other

The analysis of cost variance by Commodity Prime Category resulted in the Commodity Prime Category not being a likely indicator of whether an MDAP would experience cost growth. This deduction was based on the similar percentages across commodity prime categories during the contingency analysis. However, the analysis did indicate that programs involving ships and submarines as a Commodity Prime Category have experienced higher cost variances by dollar amount compared to other MDAPS. Based on the text analysis of cost variance by Commodity Prime Category, changes in program costs were most often associated with updated escalation indices and revised estimates, while higher-dollar cost variances were more often attributed to quantity changes or increases in other support.

3. Cost Variances by Funding Categories

The Funding Category column contained four categories: MILCON, O&M, RDT&E, and Procurement. Procurement was the top funding type category, with a frequency of 48,988 records, accounting for 51.15% of all submitted records. Procurement funding type reports contained 22,248 occurrences (45.52%) of cost growth, 17,916 occurrences (36.57%) of cost reductions, and 8,824 occurrences (18.01%) of no

change. Procurement funding type reports showed a significantly higher percentage of cost growth and cost reduction occurrences compared to reports with other funding types. The contingency analysis and table of frequencies and probabilities of cost variances by funding type categories are presented in Figures 18 and 19, respectively.

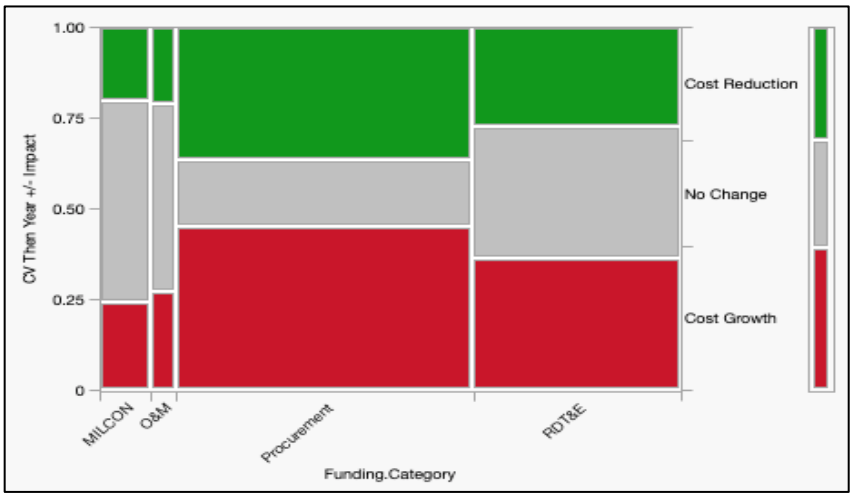


Figure 18. Mosaic Plot of Cost Variance Then-Year +/- Impact by Funding Category

CV Then Year +/- Impact

Count Total % Col % Row %	Cost Growth	No Change	Cost Reduction	Total
MILCON	2067	4720	1722	8509
	2.16	4.93	1.80	8.88
	5.45	16.87	5.76	
	24.29	55.47	20.24	
O&M	1120	2124	874	4118
	1.17	2.22	0.91	4.30
	2.95	7.59	2.92	
	27.20	51.58	21.22	
Procurement	22248	8824	17916	48988
	23.23	9.21	18.70	51.15
	58.69	31.53	59.94	
	45.42	18.01	36.57	
RDT&E	12472	12318	9377	34167
	13.02	12.86	9.79	35.67
	32.90	44.01	31.37	
	36.50	36.05	27.44	
Total	37907	27986	29889	95782
	39.58	29.22	31.21	

Funding.Category

Figure 19. Contingency Table of Cost Variance Then-Year +/- Impact by Funding Category

In the logistic analysis graph in Figure 20, the procurement funding category was observed as having higher cost variances by dollar amount compared to other funding categories. Records with an O&M funding category had an average cost variance of $115 million in then-year dollars. Records with RDT&E funding had an average cost variance

of $79.6 million, Procurement had an average cost variance of $92.9 million, and MILCON had an average cost variance of $3.6 million in then-year dollars.

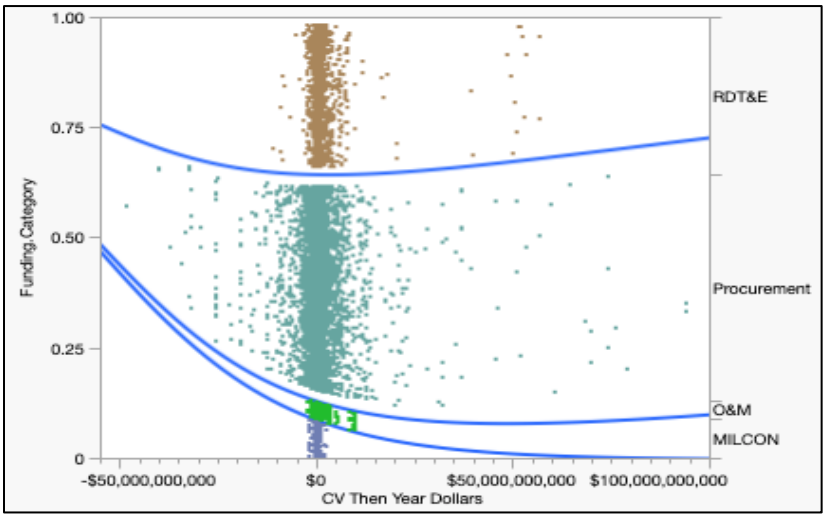


Figure 20. Logistic Analysis for Funding Category by Cost Variance Then-Year Amount

Using the JMP lasso tool to isolate and identify records associated with markers that exhibited higher dollar value cost variances led to results that were similar to the previous logistic analyses. The MDAPs identified included the BMDS (RDT&E), the F-35 Joint Strike Fighter (Procurement), the DDG 51 guided missile destroyer (Procurement), and the SSN 774 Virginia-class attack submarine (Procurement). An additional program identified as having higher cost variances was the Future Combat System (FCS; Procurement).

Outlier records from the FCS program were associated with SARs processed in 2005 and 2006. These records also contained the following attributes: Service Component: Army, Commodity Type: Ground Combat, and Cost Variance Category: Engineering. Notably, none of the records for the FCS included any text data in the Explanation column. The 2007 GAO report on the Army's FCS described the MDAP as "a program characterized by bold goals and innovative concepts: transformational capabilities, system-of-systems approach, new technologies, a first-of-a-kind information network, and a total investment cost of more than $200 billion" (Francis, 2007, p. 2). The report also stated that

> the Army had yet to fully define FCS requirements; FCS technologies that should have been matured in 2003, when the program started, were still immature; key testing to demonstrate FCS performance will not be completed, and maturity of design and product will not be demonstrated until after production starts in 2013; and an independent cost estimate from the Office of the Secretary of Defense is between $203 billion and $234 billion, far higher than the Army's cost estimate. (Francis, 2007, p. 2)

The FCS program was canceled in 2009 and has been characterized as a failed acquisition program.

Text analysis showed that the terms occurring most frequently within the Explanation column when Procurement was a funding category were "revised estimate" (2,983 occurrences [6.09%]), "revised escalation indices" (2,532 occurrences [5.17%]), "adjustment for current and prior escalation" (2,117 occurrences [4.32%]), and "adjustment for current and prior inflation" (1,276 occurrences [2.60%]). These terms occurred within one standard deviation ($259,251,462) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance resulting from an increase" (761 occurrences [1.55%]). These results are portrayed in the word cloud in Figure 21.

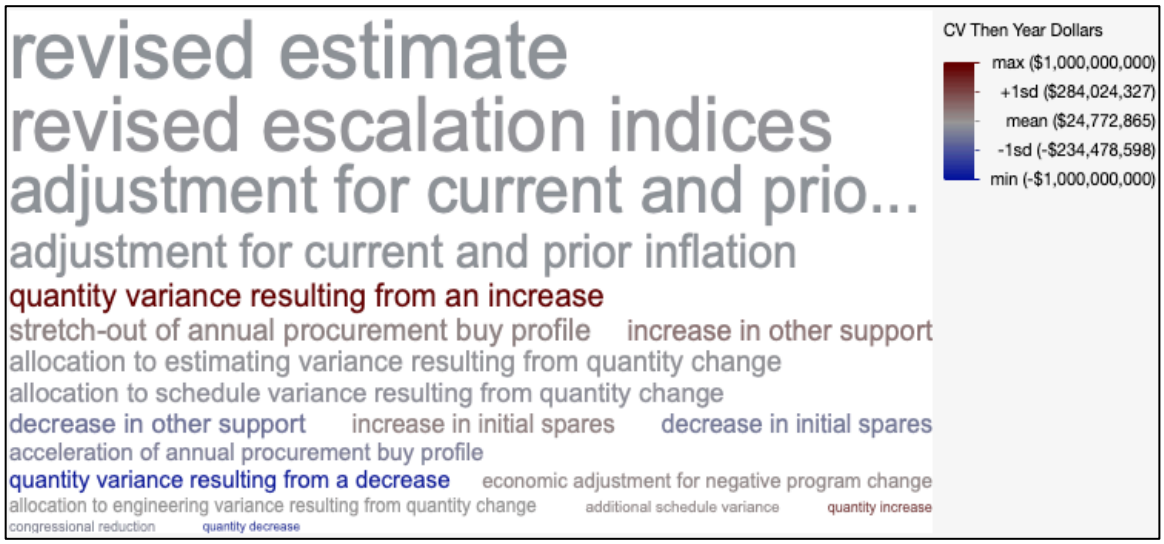


Figure 21. Word Cloud Filtered by Funding Category–Procurement

Text analysis showed that the terms occurring most frequently within the Explanation column when RDT&E was a funding category were "revised escalation indices" (2,305 occurrences [6.75%]), "revised estimate" (1,776 occurrences [5.20%]),

"adjustment for current and prior escalation" (1,211 occurrences [3.54%]), and "adjustment for current and prior inflation" (951 occurrences [2.78%)]). The term "revised estimate" was also associated with negative cost variances greater than one standard deviation ($20,034,135) of the cost variance mean. These results are portrayed in the word cloud in Figure 22.

Figure 22. Word Cloud Filtered by Funding Category–RDT&E

Text analysis showed that the terms occurring most frequently within the Explanation column when MILCON was a funding category were "revised escalation indices" (462 occurrences [5.43%]), "adjustment for current and prior escalation" (263 occurrences [3.09%]), "revised estimate" (194 occurrences [2.28%]), and "adjustment for current and prior inflation" (113 occurrences [1.33%]). The term "revised estimate" was also associated with negative cost variances greater than one standard deviation ($15,781,650) of the cost variance mean. These results are portrayed in the word cloud in Figure 23.

Figure 23. Word Cloud Filtered by Funding Category–MILCON

Text analysis showed that the terms occurring most frequently within the Explanation column when O&M was a funding category were "revised escalation" (227 occurrences [5.51%]), "revised estimate" (139 occurrences [3.38%]), "adjustment for current and prior inflation" (104 occurrences [2.52%]), and "adjustment for current and prior escalation" (65 occurrences [1.58%]). The term "revised estimate" was also

associated with negative cost variances greater than one standard deviation ($50,719,700) of the cost variance mean. These results are portrayed in the word cloud in Figure 24.

Figure 24. Word Cloud Filtered by Funding Category–O&M

The analysis of cost variance by funding category resulted in the funding category being a low-level indicator of whether an MDAP would or would not experience cost growth. This conclusion was based on the varying percentages of records across the funding categories during the contingency analysis, which showed 23.23% of records with the funding category experiencing a cost growth. The analysis also indicated that the procurement phase of a program's acquisition life cycle was more likely to experience higher cost variances by dollar amount compared to other phases using different funding categories. Based on the text analysis of cost variance by funding category, changes in program costs were most often associated with updated escalation indices and revised estimates. Higher cost variances due to quantity changes were observed where procurement funds were used, while higher-dollar cost variances in other funding categories were often attributed to revised estimates.

4. Cost Variances by Joint Capability Areas

The JCA column contained seven levels: Battlespace Awareness, Command and Control, Communications and Computers, Force Application, Force Integration, Logistics, and Protection. Force Application was the top JCA category with a frequency of 37,412 records, accounting for 39.06% of all submitted records. Force Application–type reports contained 14,899 occurrences (39.82%) of cost growth, 11,413 occurrences (30.51%) of cost reductions, and 11,100 (29.67%) occurrences of no change. Similar percentages were reported among the other JCAs, with the exception of Force Integration–type reports. Force Integration–type reports contained six occurrences

(11.11%) of cost growth, eight occurrences (14.81%) of cost reduction, and 40 occurrences (74.04%) with no changes. The mosaic plot and contingency table of cost variance impact by JCA categories are presented in Figures 25 and 26, respectively.

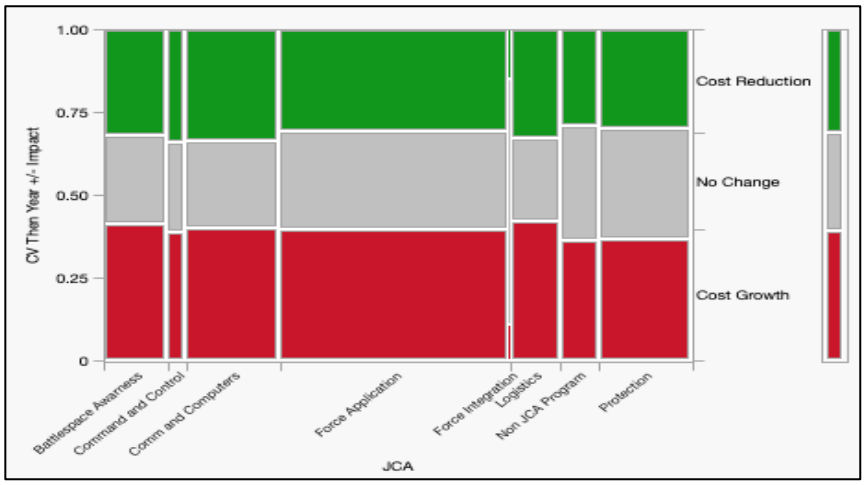


Figure 25. Mosaic Plot of Cost Variance Then-Year +/- Impact by JCAs

CV Then Year +/- Impact

JCA	Count Total % Col % Row %	Cost Growth	No Change	Cost Reduction	Total
	Battlespace Awarness	4311	2778	3314	10403
		4.50	2.90	3.46	10.86
		11.37	9.93	11.09	
		41.44	26.70	31.86	
	Command and Control	1155	817	1007	2979
		1.21	0.85	1.05	3.11
		3.05	2.92	3.37	
		38.77	27.43	33.80	
	Communications and Computers	6182	3979	5158	15319
		6.45	4.15	5.39	15.99
		16.31	14.22	17.26	
		40.36	25.97	33.67	
	Force Application	14899	11100	11413	37412
		15.56	11.59	11.92	39.06
		39.30	39.66	38.18	
		39.82	29.67	30.51	
	Force Integration	6	40	8	54
		0.01	0.04	0.01	0.06
		0.02	0.14	0.03	
		11.11	74.07	14.81	
	Logistics	3401	2035	2631	8067
		3.55	2.12	2.75	8.42
		8.97	7.27	8.80	
		42.16	25.23	32.61	
	Non Joint Capability Area Program	2307	2179	1831	6317
		2.41	2.27	1.91	6.60
		6.09	7.79	6.13	
		36.52	34.49	28.99	
	Protection	5646	5058	4527	15231
		5.89	5.28	4.73	15.90
		14.89	18.07	15.15	
		37.07	33.21	29.72	
	Total	37907	27986	29889	95782
		39.58	29.22	31.21	

Figure 26. Contingency Table of Cost Variance Then-Year +/- Impact by JCAs

From the logistic analysis graph in Figure 27, the JCA category Force Application was observed as having higher cost variances by dollar amount compared to other JCA categories. Force Application was reported as having an average cost variance of $115.2 million in then-year dollars. Logistics had an average cost variance of $108.5 million, Protection had an average cost variance of $97.7 million, and Battlespace Awareness had an average cost variance of $73.2 million in then-year dollars. Command and Control had an average cost variance of $22 million, and Communication and Computers had an average cost variance of $11.6 million. The JCA Force Integration had an average cost variance of -$3 million in then-year dollars.

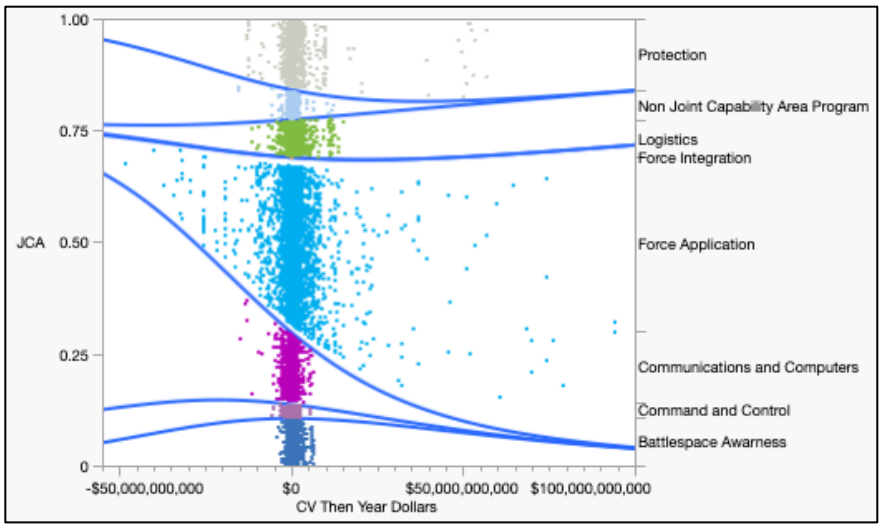


Figure 27. Logistic Analysis for Joint Capability Areas by Cost Variance Then-Year Amount

Using the JMP lasso tool to isolate and identify records associated with markers that exhibited higher dollar value cost variances led to results that were similar to the previous logistic analyses. The MDAPs identified included the BMDS (Protection), the F-35 Joint Strike Fighter (Force Application), the DDG 51 guided missile destroyer (Force Application), the SSN 774 Virginia-class attack submarine (Force Application), and the FCS (Force Application).

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Force Application were "revised estimate" (2,202 occurrences [5.89%]), "revised escalation indices" (2,176 occurrences [5.82%]), "adjustment for current and prior escalation" (1,468 occurrences [3.92%]), and "adjustment for current and prior inflation" (982 occurrences [2.62%]). These terms occurred within one standard deviation ($332,623,158) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance resulting from an increase" (296 occurrences [0.79%]). These results are portrayed in the word cloud in Figure 28.

Figure 28. Word Cloud Filtered by Joint Capability Area–Force Application

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Communications and Computers were "revised escalation indices" (829 occurrences [5.41%]), "revised estimate" (748 occurrences [4.88%]), and "adjustment for current and prior escalation" (646 occurrences [4.22%]). These terms occurred within one standard deviation ($146,634,628) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases were "quantity variance resulting from an increase" (243 occurrences [1.59%]) and "increase in other support" (143 occurrences [0.93%]). These results are portrayed in the word cloud in Figure 29.

Figure 29. Word Cloud Filtered by Joint Capability Area–Communications and Computers

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Protection were "revised escalation indices" (931 occurrences [6.11%]), "adjustment for current and prior escalation" (542 occurrences [3.56%]), and "revised estimate" (484 occurrences [3.18%]). These terms

occurred within one standard deviation ($183,381,871) of the cost variance mean. Terms that occurred less frequently but were associated with higher cost increases were "quantity variance resulting from an increase" (91 occurrences [0.60%]) and "increase in other support" (89 occurrences [0.58%]). These results are portrayed in the word cloud in Figure 30.

Figure 30. Word Cloud Filtered by Joint Capability Area–Protection

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Battlespace Awareness were "revised estimate" (663 occurrences [6.37%]), "revised escalation indices" (584 occurrences [5.61%]), "adjustment for current and prior escalation" (446 occurrences [4.29%]), and "adjustment for current and prior inflation" (228 occurrences [2.19%]). These terms occurred within one standard deviation ($153,545,703) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "increase in other support" (92 occurrences [0.88%]). These results are portrayed in the word cloud in Figure 31.

Figure 31. Word Cloud Filtered by Joint Capability Area–Battlespace Awareness

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Logistics were "revised escalation indices" (488 occurrences [6.05%]), revised estimate (463 occurrences [5.74%]),

"adjustment for current and prior escalation" (414 occurrences [5.13%]), and "adjustment for current and prior inflation" (188 occurrences [2.33%]). These terms occurred within one standard deviation ($241,329,855) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance resulting from an increase" (63 occurrences [0.78%]). These results are portrayed in the word cloud in Figure 32.

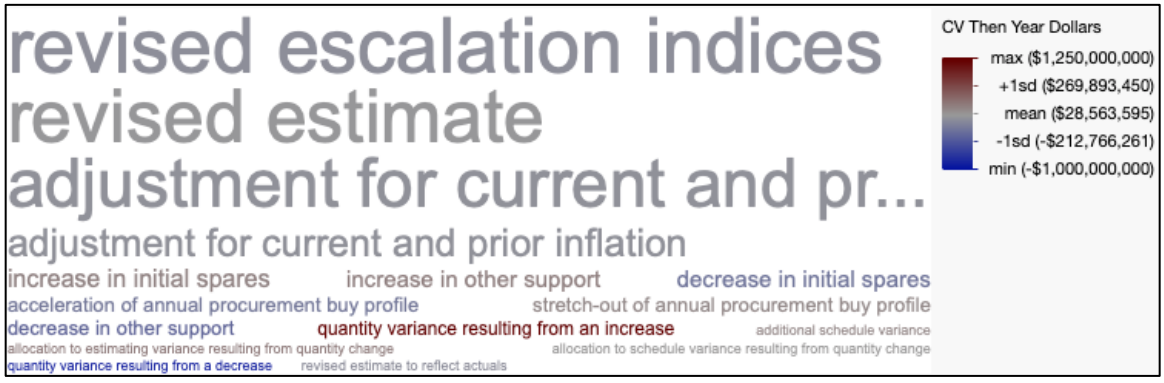


Figure 32. Word Cloud Filtered by Joint Capability Area–Logistics

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Command and Control were "revised estimate" (200 occurrences [6.71%]), "revised escalation indices" (194 occurrences [6.51%]), "adjustment for current and prior escalation" (115 occurrences [3.86%]), and "adjustment for current and prior inflation" (87 occurrences [2.92%]). These terms occurred within one standard deviation ($151,494,166) of the cost variance mean. A term that occurred less frequently but was associated with higher cost increases was "quantity variance resulting from an increase" (34 occurrences [1.14%]). These results are portrayed in the word cloud in Figure 33.

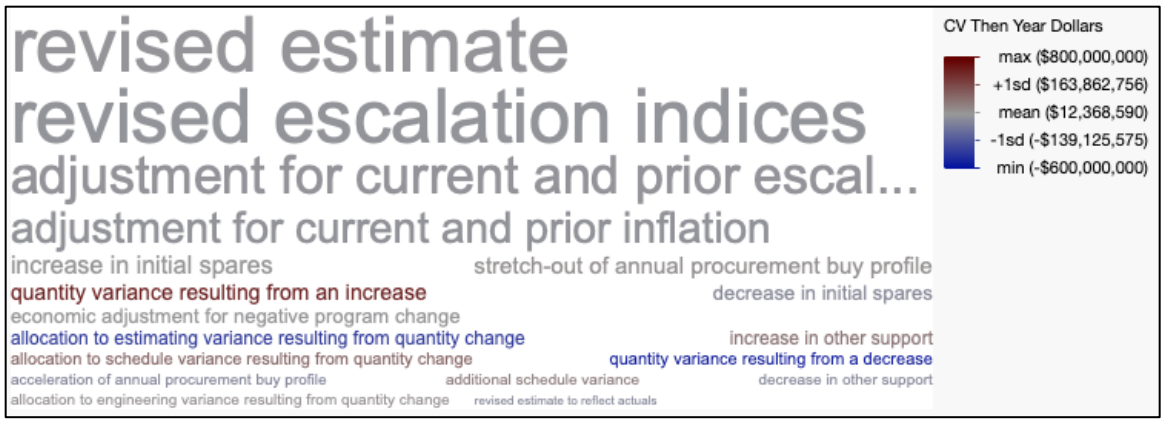


Figure 33. Word Cloud Filtered by Joint Capability Area–Command and Control

Text analysis showed that the terms occurring most frequently within the Explanation column when the JCA category was Force Integration were "adjustment for current and prior escalation" (three occurrences [5.56%]), "revised escalation indices" (three occurrences [5.56%]), and "increase in other support" (one occurrence [1.85%]). The term "adjustment for current and prior escalation" was also associated with negative cost variances greater than one standard deviation ($750,026) of the cost variance mean. These results are portrayed in the word cloud in Figure 34.

Figure 34. Word Cloud Filtered by Joint Capability Area–Force Integration

The analysis of cost variance by JCA category resulted in the JCA category not being a likely indicator of whether an MDAP would experience cost growth. This conclusion is based on the similar percentages across commodity prime categories during the contingency analysis. However, the analysis did indicate that programs with the JCA category Force Application experienced higher cost variances by dollar amount compared to MDAPs with a different JCA category. Based on the text analysis of cost variance by JCA category, changes in program costs were most often associated with updated

escalation indices and revised estimates, while higher-dollar cost variances were more often attributed to quantity changes or increases in other support.

5. Cost Variances by Cost Variance Categories

The Cost Variance Category column contained eight levels: Estimating, Economic, Support, Schedule, Engineering, Quantity, Subtotal, and Other. Estimating was the top cost variance category, with a frequency of 29,681 records, accounting for 30.99% of all submitted records. Estimating-type reports contained 14,181 occurrences (49.92%) of cost growth, 13,629 occurrences (45.92%) with cost reductions, and 1,234 occurrences (4.16%) with no change. Economic-type reports had the next highest frequency, with 14,287 submissions, or 14.92% of all records. Economic-type reports contained 6,107 occurrences (42.75%) of cost growth, 6,848 occurrences (47.93%) of cost reductions, and 1,332 occurrences (9.32%) of no change. Engineering-type reports showed a disproportionate percentage of cost growth occurrences (43.41%) compared to cost reduction occurrences (11.22%). The mosaic plot and contingency table of cost variance impact by funding type categories are presented in Figures 35 and 36, respectively.

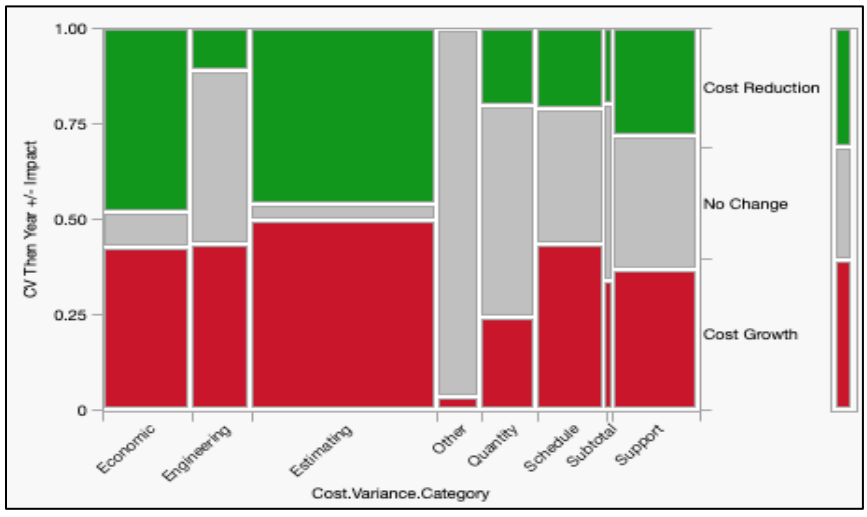


Figure 35. Mosaic Plot of Cost Variance Then-Year +/- Impact by Cost Variance Category

CV Then Year +/- Impact

Cost.Variance.Category	Count Total % Col % Row %	Cost Growth	No Change	Cost Reduction	Total
Economic		6107	1332	6848	14287
		6.38	1.39	7.15	14.92
		16.11	4.76	22.91	
		42.75	9.32	47.93	
Engineering		4187	4377	1082	9646
		4.37	4.57	1.13	10.07
		11.05	15.64	3.62	
		43.41	45.38	11.22	
Estimating		14818	1234	13629	29681
		15.47	1.29	14.23	30.99
		39.09	4.41	45.60	
		49.92	4.16	45.92	
Other		251	6786	10	7047
		0.26	7.08	0.01	7.36
		0.66	24.25	0.03	
		3.56	96.30	0.14	
Quantity		2184	5015	1818	9017
		2.28	5.24	1.90	9.41
		5.76	17.92	6.08	
		24.22	55.62	20.16	
Schedule		4849	3908	2351	11108
		5.06	4.08	2.45	11.60
		12.79	13.96	7.87	
		43.65	35.18	21.16	
Subtotal		332	453	194	979
		0.35	0.47	0.20	1.02
		0.88	1.62	0.65	
		33.91	46.27	19.82	
Support		5179	4881	3957	14017
		5.41	5.10	4.13	14.63
		13.66	17.44	13.24	
		36.95	34.82	28.23	
Total		37907	27986	29889	95782
		39.58	29.22	31.21	

Figure 36. Contingency Table of Cost Variance Then-Year +/- Impact by Cost Variance Category

From the logistic analysis graph in Figure 37, the Cost Variance Category Engineering was observed as having higher cost variances by dollar amount compared to other cost variance categories. Engineering was reported as having an average cost variance of $214.9 million in then-year dollars. Schedule had an average cost variance of $167.7 million, Subtotal had an average cost variance of $145.6 million, and Estimating had an average cost variance of $99.4 million in then-year dollars. Quantity had an average cost variance of $37.6 million, Support had an average cost variance of $33.9 million, and Other had an average cost variance of $6.6 million. The cost variance category Economic had an average cost variance of -$7.7 million in then-year dollars.

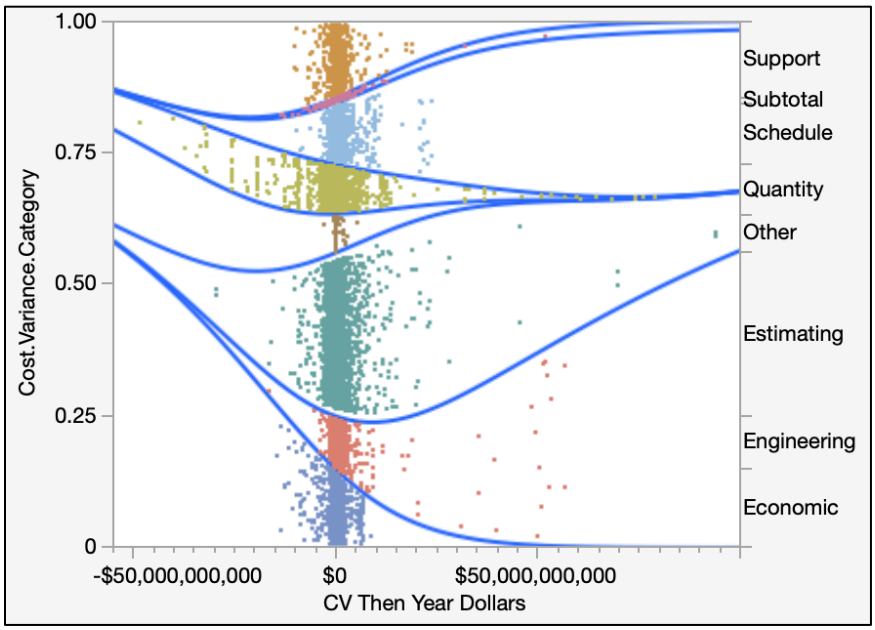


Figure 37. Logistic Analysis of Cost Variance Category by Cost Variance Then-Year Amount

Using the JMP lasso tool to isolate and identify records associated with markers that exhibited higher-dollar value cost variances revealed that several programs were responsible for the outliers among cost variance categories. These MDAPs included the BMDS (Engineering), the F-35 Joint Strike Fighter (Estimating, Schedule, and Support), the DDG 51 guided missile destroyer (Quantity), the SSN 774 Virginia-class attack submarine (Estimating and Quantity), and the FCS (Engineering and Schedule). An additional program identified with higher cost variances was the National Security Space Launch (NSSL) program (Estimating and Quantity).

Outlier records from the NSSL program were associated with SARs processed from 2004–2007 and in 2012. These records also contained the following attributes: Service Component: Air Force, Commodity Type: Aircraft, and Funding Category: Procurement. Notably, none of the records for the NSSL included any text data in the Explanation column.

The NSSL program (previously known as the Evolved Expendable Launch Vehicle program) was initiated in December 1996. Under this program, the Air Force acquires commercial satellite launch services. The GAO reported in 2004 that the MDAP's estimated total program costs were $13 billion, or 85.9%, higher than the base

year estimate (Schinasi, 2005). In 2005, the NSSL program was 81.3% higher than the base year estimate (Schinasi, 2006). In 2006, it was 78.9% higher than the base year estimate. Additionally, the quantity of launch services to be received was reduced by 23.5% (Francis, 2007).

The 2005 GAO report *Defense Acquisitions: Assessments of Selected Major Weapon Programs* stated,

> The decline in commercial satellite launch needs in the late 1990s resulted in program cost increases and a reduction in the anticipated number of Atlas V and Delta IV launches. Cost increases greater than 25 percent over the program's objective triggered a Nunn-McCurdy breach, requiring a review by the Secretary of Defense and a report to Congress. As provided by law, DoD certified in April 2004 that the program is critical to national security and its cost estimates are reasonable. (Schinasi, 2005, p. 56)

This additional information from the GAO report provides some insight into the higher cost variances observed between 2004 and 2007.

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Estimating were "revised estimate" (4,394 occurrences [14.80%]), "adjustment for current and prior escalation" (2,792 occurrences [9.41%]), "adjustment for current and prior inflation" (2,007 occurrences [6.76%]), and "allocation to estimating variance resulting from quantity change" (677 occurrences [2.25%]). These terms occurred within one standard deviation ($24,001,381) of the cost variance mean. These results are portrayed in the word cloud in Figure 38.

Figure 38. Word Cloud Filtered by Cost Variance Category–Estimating

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Economic were "revised

escalation indices" (5,521 occurrences [38.64%]) and "economic adjustment for negative program change" (682 time [4.77%]). The term "economic adjustment for negative program change" was also associated with negative cost variances greater than one standard deviation ($13,805,563) of the cost variance mean. These results are portrayed in the word cloud in Figure 39.

Figure 39. Word Cloud Filtered by Cost Variance Category–Economic

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Support were "adjustment for current and prior escalation" (862 occurrences [6.15%]), "increase in other support" (671 occurrences [4.79%]), "decrease in other support" (597 occurrences [4.26%]), and "increase in initial spares" (567 occurrences [4.05%]). The terms "increase in other support" and "increase in initial spares" were also associated with negative cost variances greater than one standard deviation ($83,847,903) of the cost variance mean. These results are portrayed in the word cloud in Figure 40.

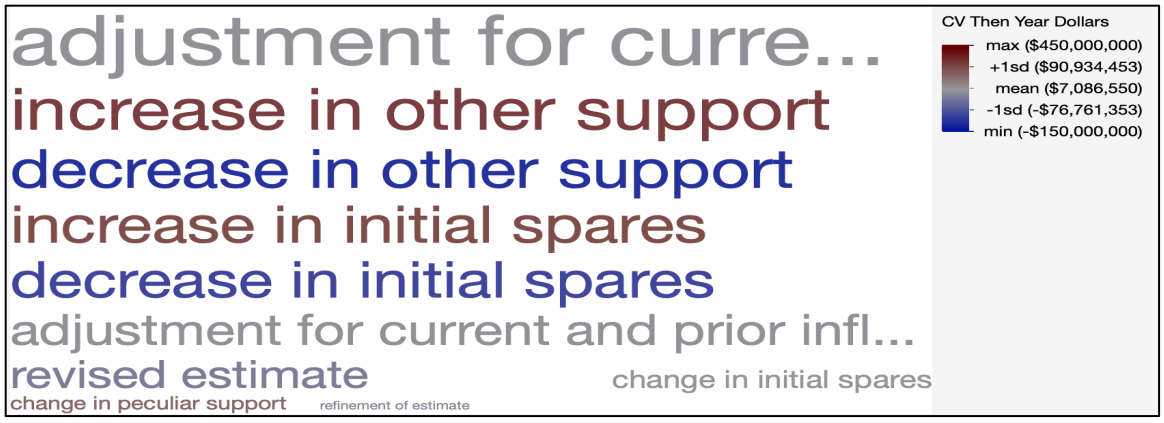


Figure 40. Word Cloud Filtered by Cost Variance Category–Support

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Schedule were "stretch-out of annual procurement buy profile" (713 occurrences [6.42%]), "allocation to schedule

variance resulting from quantity change" (607 occurrences [5.46%]), "acceleration of annual procurement buy profile" (506 occurrences [4.56%]), and "additional schedule variance" (308 occurrences [2.77%]). The terms "stretch-out of annual procurement buy profile" and "additional schedule variance" were also associated with negative cost variances greater than one standard deviation ($63,514,704) of the cost variance mean. These results are portrayed in the word cloud in Figure 41.

Figure 41. Word Cloud Filtered by Cost Variance Category–Schedule

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Engineering were "allocation to engineering variance resulting from quantity change" (374 occurrences [3.88%]) and "revised estimate" (51 occurrences [0.53%]). The term "revised estimate" was also associated with negative cost variances greater than one standard deviation ($35,584,799) of the cost variance mean. These results are portrayed in the word cloud in Figure 42.

Figure 42. Word Cloud Filtered by Cost Variance Category–Engineering

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Quantity were "quantity variance resulting from an increase" (426 occurrences [4.72%]) and "quantity variance resulting from a decrease" (278 occurrences [3.08%]). The term "quantity variance resulting from an increase" was also associated with negative cost variances greater than one standard deviation ($745,479,853) of the cost variance mean. These results are portrayed in the word cloud in Figure 43.

Figure 43. Word Cloud Filtered by Cost Variance Category–Quantity

Text analysis showed that the terms occurring most frequently within the Explanation column when the cost variance category was Subtotal were "quantity variance resulting from an increase" (350 occurrences [35.75%]) and "quantity variance resulting from a decrease" (241 occurrences [24.62%]). The term "quantity variance resulting from an increase" was also associated with negative cost variances greater than one standard deviation ($755,311,723) of the cost variance mean. These results are portrayed in the word cloud in Figure 44.

Figure 44. Word Cloud Filtered by Cost Variance Category–Subtotal

Text analysis of the cost variance category "Other" did not yield any of the 34 selected exception phrases identified as recurring key terms. Upon further examination, the low frequency of unique terms within this level of the cost variance category caused the analysis not to return any key phrases. The cost variance dataset contained 7,047 records with the cost variance category "Other," of which 57 records (less than 1%) had text in the explanation field. Explanations contained in these records can be categorized within the follow groups: labor strikes, schedule delays and costs related to natural events (e.g., hurricanes or earthquakes), and program cancelation. These terms were excluded from the list of key phrases due to their low frequency of occurrence.

The analysis of cost variance by cost variance category resulted in the cost variance category not being a likely indicator of whether an MDAP would experience cost growth. This conclusion is based on the similar percentages across cost variance

categories during the contingency analysis. However, the analysis did indicate that the cost variance category Engineering was likely to experience higher cost variances by dollar amount compared to other categories. The text analysis of cost variance by category produced results that varied depending on the selected cost variance category. For example, the key phrase "stretch-out of annual procurement buy profile" frequently occurred when the cost variance category "Schedule" was selected. In this case, the same quantity of units was being procured; however, the number acquired per year was reduced. As a result, the overall schedule to acquire all units within a particular MDAP was extended.

6. Cost Variances by Individual Programs

The Text Explorer dashboards used in this research include a feature that allows users to drill down to review the full text entries associated with a selected key phrase. Each full text entry is followed by a record identification number that can be used to locate and review all of the data elements from the record in the Cost Variance dataset. This feature is used in this research to gain additional understanding of the key phrases associated with individual MDAPs. The following analysis examines key reasons associated with the F-35 Joint Strike Fighter (F-35) and the DDG 51 guided missile destroyer.

a. F-35 Joint Strike Fighter

Text analysis showed that the term occurring most frequently within the Explanation column when filtered by the F-35 was "revised estimate" (270 occurrences [10.83%]). When the additional filter "Funding Category – Procurement" was applied, the frequency of the key term "revised estimate" decreased to 170 occurrences (13.28%). Procurement funding type was selected based on earlier results, which showed it having a significantly higher percentage of cost growth and cost reduction occurrences compared to reports with other funding types. Full-text explanations containing the term "revised estimate" from this specific query include "initial spares increase due to revised estimate (Navy)" (Cost Variance Dataset, 27348), "increase in initial support due to revised estimate of required risk funding (Navy)" (Cost Variance Dataset, 27529), and "revised

estimate of non-recurring costs (Navy)" (Cost Variance Dataset, 28616). Record 28616 of the Cost Variance dataset included the following additional attributes: Effective Record Date: December 25, 2019, JCA Category: Force Application, Cost Variance Category: Estimating, and a cost reduction of -$99.8 million in then-year dollars. An image of full text explanations from the Show Text tool for the key phrase "revised estimate" is provided in Figure 45.

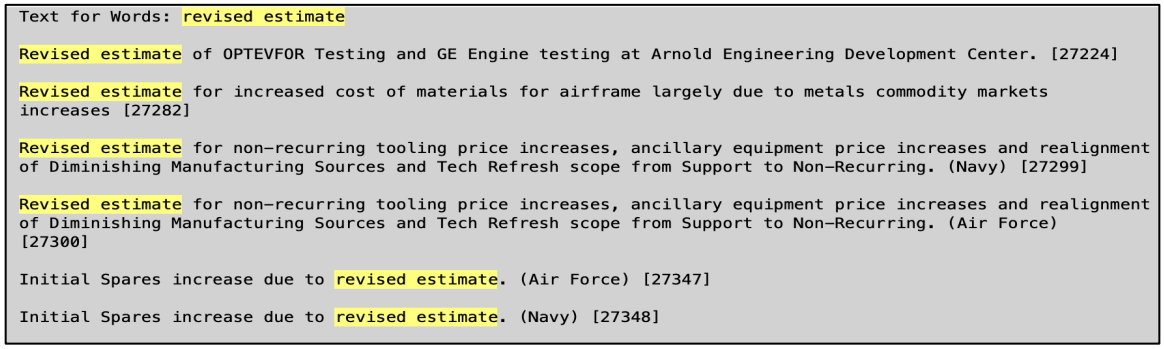


Figure 45. JMP Show Text Tool from Text Analysis of F-35 Program by Key Phrase–Revised Estimate

The 2020 GAO report titled *Defense Acquisitions Annual Assessment: Drive to Deliver Capabilities Faster Increases Importance of Program Knowledge and Consistent Data for Oversight* provides information on the F-35 and its status as an MDAP. The program saw an increase of 78.9% in developmental costs, from an initial estimate of $44.91 billion in 2001 to $80.34 billion in 2019 (Dorado, 2020). Procurement costs also increased by 55.6%, from an initial estimate of $199.25 billion in 2001 to $309.93 billion in 2019 (Dorado, 2020). Acquisition cycle time increased by 35.4%, from 175 to 237 months (Dorado, 2020). Lastly, the total quantities to be procured were reduced by 13.8%, from 2,866 to 2,470. The GAO noted that "As of December 2019, the prime contractor had delivered 491 production aircraft. The program reported that it has reached a high level of manufacturing readiness but that it has not achieved statistical control of critical processes" (Dorado, 2020, p. 204). The reduction in the number of units to be produced may substantiate $-99 million associated with non-recurring costs.

The terms "additional schedule variance" (40 occurrences [3.13%]), "increase in other support" (32 occurrences [2.50%]), and "stretch-out of annual procurement buy profile" (28 occurrences [2.19%]) were associated with negative cost variances greater

than one standard deviation ($462,830,500) of the cost variance mean. Full-text explanations containing the key phrase "increase in other support" from this specific query include "increase in other support due to manpower full-time equivalent (FTE) and associated rates updated (Aircraft Procurement Air Force)" (Cost Variance Dataset, 28434) and "increase in other support due to maturation of the technical baseline, definition of customer requirements, and further definition of Service beddown plans (Navy)" (Cost Variance Dataset, 28632). The cost variance amounts in then-year dollars for the Cost Variance dataset records 28434 and 28632 were $153.7 million and $3 billion, respectively.

A word cloud presenting key phrases from this query is shown in Figure 46. The phrases are color-coded based on cost variance amounts falling outside the standard deviation range of the factors being analyzed.

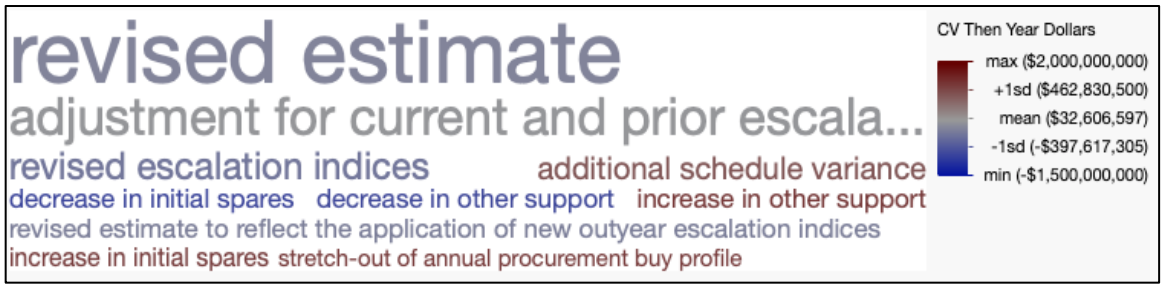


Figure 46. Word Cloud Filtered by MDAP – F-35 Joint Strike Fighter and Funding Category–Procurement

b. DDG 51 guided Missile Destroyer

Text analysis showed that the term occurring most frequently within the Explanation column when filtered by the DDG 51 was "revised escalation indices" (27 occurrences [3.64%]). When the additional filter "Funding Category – Procurement" was applied, the frequency of the key term "revised escalation indices" decreased to 14 occurrences (3.91%) and the frequency of the key term "quantity variance resulting from an increase" increased to 18 occurrences (5.03%). Full-text explanations containing the term "quantity variance resulting from an increase" from this specific query include "Quantity variance resulting from an increase of nine ships from 62 to 71" (Cost Variance Dataset, 32814), "Quantity variance resulting from an increase of two ships from 80 to 82" (Cost Variance Dataset, 32896), and "Quantity variance resulting from an

increase of two ships from 95 to 97" (Cost Variance Dataset, 32965). Record 32965 of the Cost Variance dataset included the following additional attributes: Effective Record Date: December 25, 2018; JCA Category: Force Application; Cost Variance Category: Quantity; and a cost growth of $2.7 billion in then-year dollars. An image of full text explanations from the Show Text tool for the key phrase "revised estimate" is provided in Figure 47.

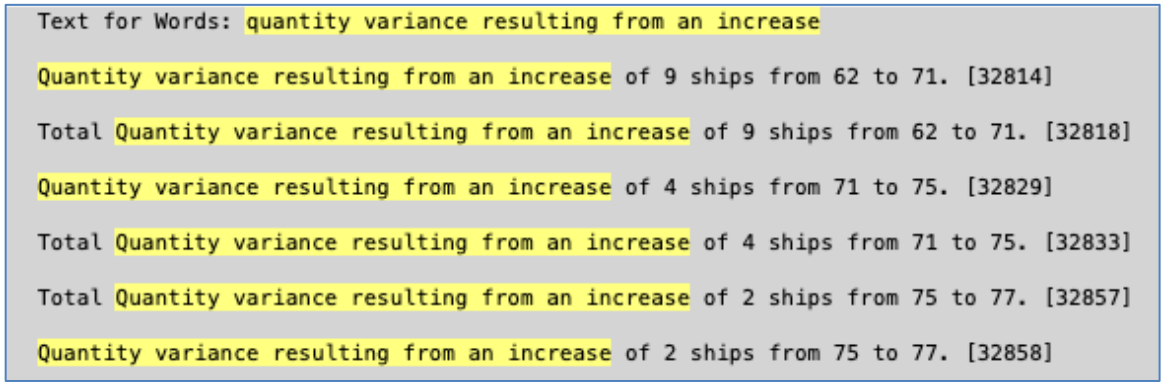


Figure 47. JMP Show Text Tool from Text Analysis of DDG 51 Program by Key Phrase–Quantity Variance Resulting from an Increase

The 2019 GAO report *Weapon Systems Annual Assessment: Limited Use of Knowledge-Based Practices Continues to Undercut DoD's Investments* provides information on the DDG 51 and its status as an MDAP. The estimated program cost reported was $33.7 billion for the procurement of 20 DDG 51 Flight III guided missile destroyers (Oakley, 2019). This is a 44.17% increase from the previous year, in which the estimated program cost was $23.38 billion for the purchase of 14 DDG 51 Flight III guided missile destroyers (Oakley, 2018). The Flight III variant of the DDG 51 is the most current version of this warship since the MPAD's inception in 1985. In 2018, Congress authorized the Navy to enter into one or more multiyear contracts for the procurement of 15 DDG 51 Flight III guided missile destroyers (NDAA, 2018). The 2019 GAO report also stated,

> In September 2018, the Navy awarded multiyear procurement contracts for 10 Flight III ships: six to Huntington Ingalls and four to Bath Iron Works, with options for up to five additional ships split between the ship building yards. The program reported that the Navy exercised one of these options in fiscal year 2019 for an 11th ship. In fiscal year 2019, the Navy added six ships to its planned Flight III quantities to work toward its goal of a 355 ship Navy. (Oakley, 2019, p. 131)

This information from the GAO report supports the findings of the text analysis, which indicated that cost growth was due to an increase in the quantity of ships being procured.

The text analysis conducted on the DDG 51 showed a relationship between quantity increases and other cost variance categories. When there was a cost growth to DDG 51 resulting from a quantity increase, the cost variance categories Schedule, Engineering, and Estimating also showed cost growths. Other terms frequently used in the Explanation column of related records included "allocation to engineering resulting from quantity change" (10 occurrences), "allocation to estimating resulting from quantity change" (10 occurrences), and "allocation to schedule resulting from quantity change" (10 occurrences).

A word cloud presenting key phrases from this query is shown in Figure 48. The phrases are color-coded based on cost variance amounts falling outside the standard deviation range of the factors being analyzed.

Figure 48. Word Cloud Filtered by MDAP – DDG 51 Flight III Destroyer and Funding Category–Procurement

C. RECOMMENDATIONS

The following section provides recommendations based on insights from the research and analysis conducted for this thesis.

1. Enhance Data Entry Standards

During the data cleaning phase of this research, several procedures were necessary to maximize the use of the data during analysis. Imputing data where values were missing or incorrectly formatted was time-consuming, requiring significant effort and additional research. A recommendation from this research is to implement strategies to support data quality standards at the lowest level of the procurement program management chain, ensuring accuracy and reliability early on. One strategy is to develop

clear, written guidelines that establish acceptable formats, abbreviations, and units of measure. This standard procedure should be accessible to all users of the data entry system. Another strategy is to provide procurement team members with training that emphasizes the importance of data accuracy. Data engineers should implement validation and automation where possible. By incorporating mandatory fields on forms, dropdown menus, automated spell checks, and minimum required characters in text fields, the data provided is more likely to contain fewer errors and more details. A data quality control process should also be established. This process may include peer reviews, requiring at least two electronic signatures on data entry reports before it is accepted by the system, or random checks by management to ensure procurement team members comply with standards. Finally, there should be periodic refresher training on common data entry errors and discussions on any updates to data entry standards. By applying strategies like these, data quality will improve at the lowest level, supporting later analysis in the acquisition process, which relies on accurate and complete data.

2. Expand Dataset Accessibility in Advana

Another recommendation is to apply text analysis to up-to-date datasets that contain detailed explanations of program statuses for each cost variance category used in this research. One limitation identified in this research was that only historical SAR data, current as of 2018, were available as a dataset. As discussed in Chapter III, post-2018 acquisition program data were available at the individual program level through assessment reports on the PS website, hosted on the DAVE portal. Assessment reports on the PS website provide color-coded status indicators, a brief synopsis, and a detailed explanation of each assessment.

A unique capability of text analysis is its ability to assess sentiment. In the context of this research, it can summarize perceived concerns related to costs, schedule, and performance. If this type of data were compiled and made available in ADVANA, the techniques used in this research could provide decision-makers and key stakeholders with real-time insights on the causes of cost variance and potentially enable the early detection of issues.

3. Collect Data On a Wider Array of Factors

A third recommendation is to expand data collection on MDAPs to incorporate metrics aligned with the three areas of knowledge-based acquisition principles: (a) mature technology, (b) stable product designs, and (c) mature production processes. As discussed in Chapter II, the GAO and independent researchers have provided recommendations and reports on the use of the knowledge-based acquisition theory in acquiring MDAPs.

In a machine learning environment, a system functions based on the interaction between the learning program and the data. Therefore, the system's performance greatly depends on the quantity and quality of the data (Alpaydin, 2021). The dataset used in this research contained 95,782 records related to 216 MDAPs spanning from 1997–2018. Despite the large volume of records, the factors available for analysis were limited to five categories, which exhibited minimal influence on the degree of cost variance observed within an MDAP.

Collecting data related to the knowledge-based acquisition principles in defense acquisitions would help program managers assess historical program data alongside industry benchmarks and technology readiness levels to identify potential risks to cost, schedule, and performance. These metrics can also be used to track an acquisition program's progress by comparing current status to planned targets, enabling program managers to address risks to MDAPs earlier on.

4. Increase Implementation of Text Analysis and Machine Learning

The fourth and final recommendation is that that the DoD applies text analysis and machine learning to review cost variance data as it continues to develop data-driven oversight of MDAPs. The findings demonstrate that text analysis is a powerful tool for gaining a deeper understanding of the factors influencing cost variances among MDAPs. Text analysis achieves this by scanning unstructured text entries for frequently used terms that may contribute to cost variances. Once terms associated with higher cost variances are identified (e.g., "additional support," "stretch-out of buy profile," or "technology maturation"), a list can be generated and used in an automated process to flag reports

containing these terms. This automated process could be incorporated into a program manager's risk mitigation plan, serving as an early detection system for issues related to cost, schedule, and performance.

D. SUMMARY

This chapter provided an overview of the analysis methods used in this research. It then presented the findings and results from the analyses performed to answer the research questions. The chapter concluded by providing recommendations based on the factors analyzed and how the DoD can benefit from applying text analysis and machine learning to the monitoring and oversight of MDAPs. The next chapter offers a summary, the conclusion, and areas for further research.

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V. SUMMARY, CONCLUSION, AND AREAS FOR FURTHER RESEARCH

This chapter provides a summary of the research that was performed. The chapter begins by providing a summary background, problem statement, and purpose statement, which were the foundation of this research on cost variances in MDAPs. The chapter then provides the conclusion, which restates and summarily answers the research questions. The chapter ends with suggestions for further research.

A. SUMMARY

Major weapon systems acquisition within the DoD has been on the GAO's high-risk list since the list's creation in 1990. Since then, Congress and executive leadership have enacted multiple policies and provided official recommendations to enhance data management and utilization within the DoD and other federal agencies. The foundation of this research was based on extensive policies, independent government reports, and scholarly research on defense acquisition programs, specifically focusing on cost variances, a longstanding challenge for the DoD. The DoD is exploring new approaches to collecting data on MDAPs and producing new data systems to improve the quality of information reported to Congress. Datasets are being created that contain detailed information about program schedules, performance parameters, budget allocations, and risk factors, all essential for the oversight and management of program outcomes. The purpose of this research was to understand how various factors impact cost variances within MDAPs. To identify these factors, a range of data elements from historical SARs on cost variance were considered.

B. CONCLUSION

Based on the contingency, logistic, and text analyses of historical cost variance data, the following conclusions address the research questions.

1. How Do the Causes of Cost Variances Differ Among Factors in Historical Cost Variance Datasets?

The causes of cost variance in the historical Cost Variance dataset differ across the analyzed factors, including service component, commodity prime category, funding category, joint capability area, and cost variance category. The following breakdown summarizes how these factors influence cost variance.

a. Service Component

Analysis indicates that while service component alone is not a strong predictor of cost growth in MDAPs, programs managed by the DoD and the Navy have experienced higher cost variances by dollar amount compared to those managed by the Army or Air Force. The primary contributors to cost variances within service components are revised estimates and updated escalation indices. Higher-dollar cost variances were frequently linked to quantity changes.

b. Commodity Prime Category

Similar to service components, commodity prime categories do not strongly predict cost growth across MDAPs. However, programs in the Ships and Submarines category have shown higher dollar variances compared to others. For this factor, cost variances are often associated with updated escalation indices and revised estimates, while the largest variances tend to be attributed to quantity changes and additional support costs.

c. Funding Category

Funding category was observed as a factor indicating cost growth, with the procurement phase of a program tending to see higher cost variances by dollar amount compared to other phases' funding categories. Cost variances in the procurement phase are typically tied to updated escalation indices and revised estimates. Specifically, quantity changes are linked to higher cost variances when procurement funds are used, while other funding categories see higher cost variances due to revised estimates.

d. Joint Capability Area

The JCA category, like the previous factors, does not predict cost growth across programs. However, MDAPs with a Force Application JCA category have experienced higher cost variances by dollar amount than programs in other categories have. Cost changes in this area are often due to updated escalation indices and revised estimates, while higher cost variances are frequently connected to quantity changes or increased support requirements.

e. Cost Variance Category

Cost Variance Category was another factor observed to indicate cost growth and variance, with the Engineering category being more likely to encounter cost growth and higher cost variances by dollar amount. Additionally, certain phrases, such as "stretch-out of annual procurement buy profile," commonly appear when analyzing the cost variance category Schedule. This phrase indicates a delay in the annual procurement rate, leading to extended schedules for acquiring units within an MDAP.

In summary, while most of these factors did not independently predict cost growth across MDAPs, they do influence the nature and dollar amount of cost variances observed. High-dollar variances were typically associated with quantity changes or revised estimates across categories, and specific cost variance trends were linked to unique attributes within each factor.

2. How Can Text Analytics Be Used to Analyze Historical Cost Variance Data?

Text analysis supports the examination of historical cost variance data by scanning unstructured text from comment and explanation fields, then breaking it down into meaningful units called key terms and phrases. Different approaches to text analysis suit various research objectives; for this study, a content analysis approach was chosen due to its ability to systematically interpret words and phrases within textual data. This method led to valuable insights gained by examining the frequency and degree of cost variance amounts across elements in the analyzed factors.

To visually depict the frequency and degree of cost variance for key phrases, 31 word clouds were produced. High-frequency phrases appeared in larger fonts, making them stand out to the reader, while the degree of cost variance was represented by color: red for phrases associated with cost growth and blue for those associated with cost reduction. These visual features draw attention to more significant phrases and allow users to quickly absorb large amounts of information.

Additionally, the text analysis conducted provided strong support for follow-on research into individual programs using the GAO's annual weapon assessment reports, which reinforced the findings of this research and offered further details on the root issues affecting MDAPs, such as the F-35 Joint Strike Fighter and the DDG-51 Flight III guided missile destroyer.

3. How Do the Current Datasets Lend Themselves to Text Analytics and Machine Learning?

There are benefits and limitations in using the current datasets for text analysis and machine learning. This analysis showed varying degrees of cost variance among the factors and key terms identified. However, due to the limited number of factors analyzed and their minimal influence on predicting cost growth or reduction in MDAPs, this research led to a recommendation to expand data collection to include a broader range of factors that directly impact cost, schedule, and performance. Another limitation identified in this research was the availability of only historical SAR data current as of 2018. Additionally, many text explanation fields in the Cost Variance dataset lacked entries, limiting the effectiveness of the analysis. With a more comprehensive and up-to-date dataset, text analysis could serve as a powerful tool to identify patterns in cost growth explanations and uncover previously unseen trends. Such a dataset would also lend itself well to machine learning applications, enabling the prediction of cost variances based on qualitative data and supporting improved decision-making in acquisition programs.

C. RECOMMENDATIONS

The following recommendations are suggested based on the responses to the research questions and summarizes the full recommendations discussed in Chapter IV. Program owners should implement strategies to support data quality standards at the

earliest stages of the procurement program management chain, ensuring accuracy and reliability from the start. Text analysis should be applied to current datasets that contain detailed explanations of program statuses relevant to the cost variance categories examined in this research. Additionally, data collection for MDAPs should be expanded to include metrics aligned with the three areas of the knowledge-based acquisition theory. Finally, the DoD should leverage text analysis and machine learning techniques to analyze cost variance data as it continues to develop data-driven oversight of MDAPs.

D. AREAS FOR FURTHER RESEARCH

One area for further research is to conduct the same types of analyses using a more comprehensive and up-to-date dataset. As discussed in Chapter III, the PS website contains numerous individually accessible reports for MDAPs. The data analytics website ADVANA allows users to review SAR data at an individual program level. However, neither of these sites currently supports the retrieval of datasets similar to the one used in this research analysis. Other data collection and reporting systems at the service component level that require additional system access requests may contain such datasets.

Another area for further research that may provide valuable insights is a study of the causes behind key phrases associated with higher cost variances. Phrases such as "stretch-out of annual procurement buy profile," "quantity variance resulting from an increase," "increase in other support," and "increase in initial spares" were observed as having higher cost growth among the key phrases. Understanding the driving factors behind these events and why this cost growth was not accounted for in the procurement planning phase may be beneficial.

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APPENDIX A. IMPUTED COMMODITY TYPES.

Program Full Name	Imputed Commodity Type
Sea Launched Cruise Missile Black	Missile
Hawk Utility Helicopter (UH-60L)	Helicopter
Defense Meteorological Satellite Program	Satellite
Army Tactical Missile System-Anti-Personnel Anti-Materiel (ATACMS-APAM)	Missile
Chemical Demilitarization Program (Initial)	Other
Airborne Laser (ABL)	Munitions
B-1 Conventional Mission Upgrade Program-Defensive Systems Upgrade	Aircraft
Single-Channel Ground and Airborne Radio System-VHF	C3I
All Source Analysis System (ASAS) (ATCCS)	C3I
SEAWOLF Class Nuclear Attack Submarine/Combat System	Submarine
B-1 Conventional Mission Upgrade Program-Computer Upgrade	Air Craft - C3I
Navy Theater Wide Ballistic Missile Defense	Missile
Sensor Fused Weapon	Munitions
F-15 Eagle Passive Active Warning Survivability System	Other
Ultra-High Frequency Follow-On Communications Satellite	Satellite
Advanced Field Artillery Tactical Data System (ATCCS)	C3I
Combat Service Support Control System (ATCCS)	C3I
Theater High Altitude Area Defense	Missile
Common Imagery Ground/Surface (Joint Services Imagery Processing Sys)	Aircraft -C3I
Forward Area Air Defense Command, Control, and Intelligence (ATCCS)	Aircraft - C3I
B-1 Conventional Mission Upgrade Program-Joint Direct Attack Munition	Munitions
Coastal Mine Hunter	Ship
Satellite and Terminals	Satellite
National Missile Defense System	Missile
Defense Integrated Military Human Resources System	Other
Presidential and National Voice Conferencing Integrator	C3I
W76 Mod 1 Life Extension Program	Missile
W88 Alteration 370	Missile
B61 Mod 12 Life Extension Program	Missile

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APPENDIX B. COMMODITY PRIMARY CATEGORIES.

Commodity Type	Primary Grouping	Primary Groups Description
Aircraft - Bomber	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Aircraft - C3I	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Aircraft - Fighter	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Aircraft - Other	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Aircraft - Transport	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Aircraft - UAS	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Avionics	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Booster	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
C3I	C4ISR	C4ISR
C3I (RDT&E Only)	C4ISR	C4ISR
Combat Vehicle	Ground Systems	Ground Equipment and Systems (Combat Vehicles, Transportation Vehicles, Equipment)
Ground Combat	Ground Systems	Ground Equipment and Systems (Combat Vehicles, Transportation Vehicles, Equipment)
Helicopter	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Helicopter - System	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Launcher	Missile, Weapons, and Ammunition	Missile, Weapons, and Ammunition
Missile	Missile, Weapons, and Ammunition	Missile, Weapons, and Ammunition
Munitions	Missile, Weapons, and Ammunition	Missile, Weapons, and Ammunition
N/A	Aircraft	Aircraft (Bomber, Fighter, Transport, Helicopter, UAS, Avionics, C3I, Avionics, Other)
Other	Missile, Weapons, and Ammunition	Missile, Weapons, Ammunition
Radar	C4ISR	C4ISR
Satellite	C4ISR	C4ISR
Sensor	C4ISR	C4ISR
Ship	Ships and Submarines	Ships and Submarines
Submarine	Ships and Submarines	Ships and Submarines
Transport Vehicle	Ground Systems	Ground Equipment and Systems (Combat Vehicles, Transportation Vehicles, Equipment)

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APPENDIX C. JMP TEXT EXPLORER RECODED TERMS.

Terms Recoded	Output
estate	estimate
estiamte	estimate
estimate's	estimate
estimatig	estimate
estimations	estimation
estmate	estimate
misc	miscellaneous
miscelaneous	miscellaneous
miscellanous	miscellaneous
qty	quantity
qtys	quantity
quanitites	quantities
quanitity	quantity
quanity	quantity
quantify	quantity
quantites	quantities
quantities	quantity
quantitites	quantities
quantitiy	quantity
strechout	stretch-out
strectch	stretch
stretched	stretch
stretches	stretch
stretchout	stretch-out

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APPENDIX D. JMP TEXT EXPLORER SELECTED PHRASE EXCEPTIONS.

Selected Phrase Exceptions	Count
acceleration of annual procurement buy profile	150
acceleration of procurement buy profile	371
additional quantity variance	146
additional schedule variance	317
adjustment for current and prior escalation	3656
adjustment for current and prior inflation	2444
allocation to engineering resulting from quantity change	240
allocation to engineering variance resulting from quantity change	135
allocation to estimating resulting from quantity change	428
allocation to estimating variance resulting from quantity change	250
allocation to schedule resulting from quantity change	375
allocation to schedule variance resulting from quantity change	233
application of new out year escalation indices	98
application of new outyear escalation indices	161
application of new outyear inflation indices	115
change in initial spares	207
change in peculiar support	133
congressional reduction	305
congressional reductions	171
decrease in initial spares	558
decrease in other support	602
economic adjustment for negative program change	685
funding adjustments	97
increase in initial spares	573
increase in other support	684
increased estimate	130
miscellaneous adjustments	186
quantity decrease	222
quantity increase	287
quantity variance	244
quantity variance associated with decrease	111
quantity variance associated with increase	99
quantity variance resulting from a decrease	408
quantity variance resulting from an increase	677
realignment of funds	199
refinement of estimate	214
revised escalation indices	5526
revised estimate	4921
revised estimate to reflect actuals	180
revised estimate to reflect the application of new outyear escalation indices	123
small business innovation research	104
small business innovative research	185
stretch out of procurement buy profile	424
stretch-out of annual procurement buy profile	307

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APPENDIX E. JMP TEXT EXPLORER GROUPED TERMS.

Phrases grouped	Count	Phrases grouped with	Count
acceleration of procurement buy profile	371	acceleration of annual procurement buy profile	150
allocation to engineering resulting from quantity change	240	allocation to engineering variance resulting from quantity cha	135
allocation to estimating resulting from quantity change	428	allocation to estimating variance resulting from quantity chan	250
allocation to schedule resulting from quantity change	375	allocation to schedule variance resulting from quantity chang	233
application of new out year escalation indices	98	application of new outyear escalation indices	161
congressional reductions	171	congressional reduction	305
quantity variance associated with decrease	111	quantity variance resulting from a decrease	408
quantity variance associated with increase	99	quantity variance resulting from an increase	677
small business innovation research	104	small business innovative research	185
stretch out of procurement buy profile	424	stretch-out of annual procurement buy profile	307

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APPENDIX F. JMP TEXT EXPLORER IMPORTANT PHRASES.

Important Select Phrases	Count
revised escalation indices	5526
revised estimate	4892
adjustment for current and prior escalation	3656
adjustment for current and prior inflation	2444
quantity variance resulting from an increase	776
stretch-out of annual procurement buy profile	731
economic adjustment for negative program change	685
increase in other support	684
allocation to estimating variance resulting from quantity	678
allocation to schedule variance resulting from quantity	608
decrease in other support	602
increase in initial spares	573
decrease in initial spares	558
acceleration of annual procurement buy profile	521
quantity variance resulting from a decrease	519
congressional reduction	476
allocation to engineering variance resulting from quantity	375
additional schedule variance	317
small business innovative research	289
quantity increase	287
quantity variance	244
application of new outyear escalation indices	230
quantity decrease	222
refinement of estimate	214
change in initial spares	207
realignment of funds	199
miscellaneous adjustments	186
revised estimate to reflect actuals	180
revised estimate to reflect the application of new outyear	152
additional quantity variance	146
change in peculiar support	133
increased estimate	130
application of new outyear inflation indices	115
funding adjustments	97

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