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# Analysis of Military Construction Cost Growth in Major Defense Acquisition Programs

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# ANALYSIS OF MILITARY CONSTRUCTION COST GROWTH IN MAJOR DEFENSE ACQUISITION PROGRAMS

THESIS

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**Abstract**

This study is an exploratory analysis combining military construction (MILCON) data from the Selected Acquisition Reports (SAR) of Major Defense Acquisition Programs (MDAP) with the associated Automated Civil Engineer System project actual costs. The analysis uses both descriptive and inferential statistics to identify cost growth of MILCON at the programmatic level as well as to bridge the gap between SAR estimates and actual project costs within those program-level estimates. Overall, programs experience more negative growth (cost savings) in MILCON estimates on SARs, typically less than 0.2% of the total program cost implying minimal impact to program decisions. Estimates got more accurate from first to last SAR in comparison to total MILCON programmed for all projects within the program. However, the last SAR's median MILCON cost estimate was approximately $31 million underestimated to projects currently authorized and appropriated for the MDAPs. This could accumulate and impact budgetary decisions of scarce fiscal resources. Several factors were identified as potential drivers to MILCON cost growth within MDAPs, but require more data points for regression modelling. Preliminary research was restricted to 32 programs, 10 with authorized projects accessible for comparison, but initial results suggest building on this exploratory analysis.

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# ANALYSIS OF MILITARY CONSTRUCTION COST GROWTH IN MAJOR DEFENSE ACQUISITION PROGRAMS

## I. Introduction

Cost estimating is a complex science; it is nearly impossible for total costs at project or program completion to be exactly what the original cost estimate had quoted. Cost estimating military construction (MILCON) projects is no different, and cost estimating total MILCON projects for a major acquisition program up to a decade before a requirement is operationally needed is even more complicated. A myriad of factors within and outside of the Department of Defense's (DoD) control can affect the differences often reported between initial cost estimates and final costs of MILCON projects. However, recent MILCON projects with cost overruns have raised congressional concerns regarding the quality of DoD MILCON cost estimating practices, emphasizing the importance of an accurate cost estimate (Government Accountability Office [GAO], 2018).

For the purpose of this study, a distinction must be made regarding MILCON cost growth and MILCON cost overruns. MILCON cost growth refers to the increase in cost estimates for a project or program over time; it can also represent a positive difference between an estimate at a given time and actual costs. MILCON cost overruns are the increase of actual funds required to complete a project that has already been authorized and appropriated for execution at a lower budgetary level. Previous research and publications only address MILCON cost overruns for projects whereas this thesis aims to address MILCON cost growth at a programmatic level.

**Background**

When the United States Air Force (USAF) acquires new programs, MILCON project requirements accompany the Major Defense Acquisition Programs (MDAP). U.S. Code Title 10 categorizes MDAPs as Acquisition Category I (ACAT 1) programs if they meet any of the following threshold criteria (10 U.S.C. §2430, 2017):

- Total eventual expenditure of research, development, test and evaluation costs greater than $480 million (fiscal year 2014 constant dollars)
- Total eventual expenditure of procurement costs greater than $2.79 billion (fiscal year 2014 constant dollars)
- Specifically designated by milestone decision authority as special interest

Appendix A defines the current ACAT thresholds for all categories (Acquisition Category, 2017).

All MDAPs are required to submit periodic status reports to Congress containing cost, schedule, and technical information; these congressional reports are Selected Acquisition Reports (SAR) prepared by the respective program offices. The Secretary of Defense and the Congress began requiring regular recurring reports in 1968 which introduced the concept of SARs; they became permanent law in 1982 (GAO, 2009). The annual reporting for a particular program may be terminated by the Under Secretary of Defense (Acquisition, Technology, and Logistics) when 90% of expected production deliveries or planned acquisition expense have been made (SAR, 2018). Until such time, reporting must continue periodically.

Title 10 USC § 2432 (2010) mandates that all anticipated system-specific MILCON costs be estimated in every SAR for all MDAPs. Project cost estimates are typically prepared by base-level civil engineer units at bases or headquarters where new

facilities are expected throughout the life of the program acquisition. The program office is responsible for submitting an accumulated programmatic MILCON cost estimate in each SAR submitted to Congress.

Congress has historically scrutinized the DoD for MILCON cost overruns of projects from the time of funding appropriation through project completion. GAO studies specific to MILCON cost estimates date back to 1981 with one as recent as 2018. In these studies, GAO researched project-level cost overruns from MILCON estimates submitted to Congress for appropriation one to five years prior to operational necessity and construction contract award (GAO, 1981 and GAO, 2018). Overall, GAO found a mixture of cost under- and overruns, determining that the DoD should improve its cost estimating processes. The specific findings of these studies are outlined in Chapter II.

Contrary to project-level MILCON studies like the GAO's, no published research exists regarding program-level MILCON cost estimates submitted to Congress through SARs. Civil engineers develop early estimates and program offices deliver these estimates often up to a decade prior to contract bidding for the actual project requirement, intimating the existence of even more uncertainty and complexity than previous research has revealed at the project level.

**Problem Statement**

Decision makers at all levels require accurate cost estimates to make decisions regarding acquisitions, upgrades, and maintenance of weapons systems. Inaccurate MDAP cost estimates in a world of limited resources can present a concern for the defense industry. When reviewing a full span of periodic SARs for a single MDAP,

MILCON cost estimates show a variety of growth, negative growth (cost savings), and complete dismissal. It is understood that every program is different, every estimate is not perfect, and MILCON cost estimating is considerably more complex at a program-level. However, historical data exists and with proper research may provide insight on trends, pitfalls, and potential empirical predictors. The research questions analyzed within this thesis attempt to provide this insight.

**Research Questions**

1. What is the typical growth in program-level MILCON cost estimates for MDAPs led by the USAF?
2. What are the leading trends or drivers of program-level MILCON cost growth?
3. What is the gap between SAR reported program-level estimates and actual project-level costs as of the current date of data (22 October 2018)?

**Methodology**

MILCON cost estimates reported on each periodic SAR for various MDAPs drive the analysis in this thesis. The program-level dataset initially consisted of 1,344 SAR records for 120 programs. The Air Force Life Cycle Management Center (AFLCMC) provided 99% of this dataset and 1% came from the Defense Acquisition Management Information Retrieval (DAMIR) SAR files directly to account for the most recent SARs, after December 2015. The data formulation and verification stage outlined in Chapter III left 32 programs with a total of 444 SAR records for analysis.

The first research question addresses typical cost growth in MILCON estimates using descriptive statistics at the program level from SAR data. The second research question explores potential trends and significant drivers of MILCON cost growth using contingency tables of dummy variables of factors extracted from databases available. Due to the small sample size, contingency tables analyze cost growths from various stages of SAR reporting to various stages of current costs and Fisher's Exact Test identifies driver significance.

The final research question utilizes MILCON program data from SARs as well as MILCON project data from Automated Civil Engineer System – Project Management (ACES-PM). This system provided a dataset for every individual project associated with ten selected MDAPs. Key data included project cost information in the amounts of appropriation, obligation, and expenditure. Accumulated values for current actual project costs were compared to SAR cost estimates to identify cost reporting gaps from project-level to program-level.

**Assumptions and Limitations**

The scope of programs within this study includes USAF-led MDAPs with periodic SARs made available by AFLCMC or located within DAMIR. Additionally, this research only includes uncancelled acquisition programs which reported a MILCON cost for at least one SAR report. SAR data is from October 1966 to December 2017, though all MILCON costs were normalized to constant year 2018.

ACES-PM was fielded in 2000 leaving a limited scope for project comparison with programs. Only nine aircraft and one satellite MDAP had MILCON projects with

the acquisition program name in the construction project title within the scope of 2000 to 2017. To compare project-level costs to program-level costs, MILCON project values were normalized to constant year 2018 as well.

All data was preprocessed for visible errors before analysis. For the SAR data, 185 reports of the 444 (42%) were verified in DAMIR to validate accuracy of the AFLCMC internal SAR database. ACES-PM data was not verified against any budgetary documents as the database was pulled from the system directly. After preprocessing and verification where possible, all data used in analysis is assumed to accurately depict both historical and current cost information as of 22 October 2018.

**Implications**

Having addressed the issue and researched historical data, attention should be drawn to the MILCON cost estimates being reported to congressional decision makers on the periodic SARs. The analysis within this exploratory thesis provides cost estimators and program offices with a typical MILCON cost growth within MDAPs as well as identifies potential drivers of program MILCON cost growths. Analysis has been performed at both the acquisition program-level and the civil engineer project-level to explore the potential gap between what is being reported and what is actually being funded and executed.

**Summary**

This exploratory thesis addresses the typical growth in MILCON costs for major acquisition programs and identifies potential drivers to MILCON cost growth within a program. This chapter provided an overview of the issue and presented the research

questions which the thesis will address, analyze, and make conclusions upon. Chapter II explores and summarizes additional background of the issue through literature reviews of similar studies. Chapter III explains in detail the data and methodology used for the analysis. Chapter IV contains the results and implications from the descriptive statistical and contingency table analyses. Finally, Chapter V concludes the thesis, applying the analysis results to the research questions and suggesting possible future research opportunities regarding MILCON cost estimating for acquisition programs.

## II. Literature Review

This chapter discusses previous research regarding military construction (MILCON) cost estimation processes, historical cost overrun studies in MILCON and general construction projects, and current efforts of managing MILCON cost overruns. The chapter concludes with potential factors which cause construction cost overruns. As stated in the previous chapter, no known published research exists specific to MILCON cost estimating for major acquisition programs or the study of MILCON cost growth at a programmatic level. The reviews covered in this chapter help outline the fundamental processes and factors which lead to MILCON cost overruns within projects. These concepts can then be applied generally toward MILCON cost growth within acquisition programs.

### MILCON Cost Estimation

U.S. Code law provides two essential definitions that prepare the premise of MILCON cost estimates that are reported in Selected Acquisition Reports (SAR). Military construction is defined as "any construction, development, conversion, or extension of any kind carried out with respect to military installation, whether to satisfy temporary or permanent requirements, or any acquisition of land or construction of a defense access road" (10 U.S.C. §2801). SARs are mandated annual reports to Congress for all major defense acquisition programs to include a full life-cycle cost analysis of development, procurement, military construction, and operation and support costs (10 U.S.C. §2432).

According to Air Force Instruction 32-1021 (U.S. Air Force, 2016), MILCON project development and cost estimation begins at the base civil engineer units using a DD Form 1391 to explain and justify the project through all levels of the Air Force, Office of the Secretary of Defense (OSD), Office of Management and Budget (OMB), and Congress. Each of these forms includes the cost estimate for a single project, ensuring the use of parametric estimating tools with historical cost data where applicable. For the purpose of reporting MILCON cost estimates on SARs for all major defense acquisition programs (MDAP), it is assumed that the Air Force Civil Engineer Center (AFCEC) or the Air Force Installation and Mission Support Center (IMSC) prepares the estimate of future MILCON requirements from acquisitions outside of a DD Form 1391. This process was unable to be verified for this study as no written guidance exists and no point of contact was able to validate. It is recommended that the process be outlined for standardization and public awareness. All cost estimates for MDAPs are then coordinated with the respective acquisition program office for annual SAR reporting.

In order to receive project approval and funding appropriation, the projects undergo a review through several offices. The DD Form 1391s are submitted from the base to the Air Force IMSC to prioritize and validate the projects from all bases. The consolidated list is submitted to the Air Force Facility Management Division (AF/A4CF) who validates, prioritizes, and presents a proposed program to the Air Force Corporate Structure (AFCS) for approval (U.S. Air Force, 2016). The AFCS consists of civilian and military members belonging to the Air Staff, Secretariat, Core Function Lead representatives, and the Major Commands (MAJCOM); this group provides a corporate-

style review process when making decisions on Air Force resource allocations (Science Applications International Corporation, 2016).

Following the AFCS review, the Air Force submits an annual MILCON budget to OSD for review; OSD submits the MILCON program to Congress through OMB as part of the President's Budget in listings aggregated by country and state. The Secretary of Defense requests authorization and appropriation from Congress for each MILCON project submitted. After receiving appropriation and project approval, contracts may be awarded and project funds may begin being obligated (U.S. Air Force, 2016).

Where plausible, it is beneficial to complete as much design as possible prior to submitting to Congress for approval. The Government Accountability Office (GAO) stated that attaining 35% design to support the cost estimate in the budget submission to Congress will increase validity (GAO, 1981). This is something that would not be expected for cost estimates being submitted on the SARs while still in early estimation of any actual requirements.

**Cost Overruns in MILCON Projects**

GAO has reported numerous studies on MILCON project processes along with specific in depth case studies to projects of interest as early as 1958. The first GAO study to focus on the cost estimating of MILCON projects was reported in 1981 regarding the variability to actual costs. The latest GAO study on MILCON cost estimating was reported in 2018 concerning the reliability of the estimates. This suggests that MILCON cost estimates or the overruns of costs within projects has been a topic of interest for the past 37 years. These two GAO studies analyzed the cost estimating of ongoing or

completed MILCON projects across the Department of Defense (DoD); all other GAO studies focused on the construction process and efficiencies, unspecific to cost estimating.

GAO's 1981 report compared the budget estimate or what was estimated at the time of requesting funds for the project to the current working estimate. The last GAO MILCON cost estimating study in 2018 compared project appropriated funds to both obligated funds and expended funds. Appropriated funds are what Congress and the military service budgeted specifically for a MILCON project, obligated funds are what has been contracted or "promised" to be paid out, and expended funds are those which have been paid out.

The first GAO (1981) fieldwork study analyzed a broad sample of 83 MILCON projects from fiscal years (FY) 1978-1980; these projects represented a variety of facility types in various stages of cost overruns, cost underruns, and close to budget amounts. They found that most projects were estimated at least 18 months prior to project bidding for contract and that it was not unusual for the contract amount to differ from the estimated amount that was submitted to Congress for budget. This is an important recognition considering the MILCON costs reported in SARs are inevitably estimated more than 18 months prior to contract bidding; a perfect estimate is nearly impossible. Additionally, GAO found that even with the most accurate information at 100% complete design, the actual cost is still influenced by bidding and the contractor's economic conditions and motivation at the time of bidding.

Utilizing the same construction activities at which GAO performed fieldwork on the 83 projects, data was provided for a sample of 160 DoD projects from FY 1979.

Analysis found that 98 of 160 (61%) were being constructed for less than the budgeted amount and 62 (39%) were experiencing cost overruns from the budget estimate when being compared to the project's current working estimate. Approximately 50% of all 160 projects were within 10% of the budget; 87% were within 25%. Regarding reprogramming requests, 134 total requests were submitted to Congress during the fiscal year of 1979, of which MILCON project cost overruns accounted for 41 (31%). Of these 41 projects, only 14 required reprogramming at congressional level because the increase in costs exceeded 25% of the budgeted amount or $1 million, whichever was less. In general, GAO found that cost overruns were from circumstances other than weaknesses in DoD's cost estimating procedures (GAO, 1981).

Concerned with constrained fiscal resources and the military's ability to effectively plan, estimate, and execute MILCON projects, Congress directed the Comptroller General of the United States to review and report on DoD's MILCON cost estimating procedures. This mandate resulted in the 2018 GAO study, which analyzed MILCON appropriations from FY 2005-2016 totaling $66 billion for all DoD MILCON projects for those 11 years. By the end of FY 2016, DoD had obligated $60.9 billion (92%) and expended $55 billion (83%). Unobligated funds still within the five-year construction funding scope can be reprogrammed for MILCON projects needing additional funds or returned to Congress (GAO, 2018).

Research specific to FY 2010-2016 discovered that DoD achieved $4.2 billion in MILCON project savings of which $1.6 billion had been reprogrammed to fund emergency projects, projects that did not receive the full requested appropriation, or projects needing additional funding. A reprogramming example was provided; a repair

shop at Anderson Air Force Base, Guam, received congressional authorization but was not specifically appropriated funds for the project. Instead, the $34.4 million project was funded through reprogrammed funds from three other funded projects in Guam.

Regarding cost overruns, GAO (2018) stated that "some differences between initial estimates and final costs for MILCON projects can be attributed to factors outside of DoD's control, such as unforeseen environmental and site conditions." A cost overrun case study from the report was for a strategic command and control operations building at Offutt Air Force Base, Nebraska. The initial cost estimate in FY 2012 increased from $564 million to $601 million (7% increase) in FY 2014 due to not appreciating the full scope, complexity, and risk of an information technology intensive project.

GAO's overall recommendation was for the DoD to fully incorporate necessary steps in developing reliable cost estimates for military construction, such as the 12 steps outlined in the GAO's Cost Estimating and Assessment Guide. They found that the DoD's current construction guidance, the Unified Facilities Criteria, does not incorporate all of the steps necessary to meet reliable estimate characteristics of comprehensiveness, documentation, accuracy, and credibility. The DoD partially concurred with these recommendations and will issue revised cost guidance in 2019 to benefit the military construction program (GAO, 2018).

Not specific to MILCON projects or their cost overruns, Cancian (2010) takes an interesting stance on cost growth in military acquisition programs suggesting they may be inevitable and necessary. He proposes the term "cost discovery" instead of cost growth when original cost estimates are updated to the cost required to produce the necessary capability. He still deems cost growth important, claiming that accurate estimates may

have guided decision makers to a different decision during the analysis of alternatives. Additionally, cost growth can act as a "tax" on acquisition programs that now have to find internal savings to cover the growth. This is generally done through cutting quantities, slowing development, reducing testing, or cutting support equipment; this taxation on the program increases unit costs, disrupts production efficiencies and supply chains, delays schedules, and could increase risk in performance and readiness. Cost overruns in MILCON projects can exhibit the same cost discovery and taxing affect, requiring savings from other projects, reduction in scope, or disruption of construction causing schedule delays.

**Managing MILCON Cost Overruns**

There are currently two management techniques and processes that are in place for proper MILCON cost estimation and the management of project cost overruns. The Air Force's first safety net is project contingency funds which is typically approximately 5% of the project cost estimate (U.S. Air Force, 2016). These funds can be used for changes within the parameters set by AFCEC. Mandatory changes are those required to continue construction such as unforeseen factors, criteria changes by Headquarters Air Force, unavailability of materials, or differing site conditions. Non-mandatory changes are usually user-requested changes; AFCEC determines if these changes are necessary to meet the mission requirements or to remedy a safety hazard. Mandatory requested changes over $100,000 or exceeding 75% of the available contingency funds and all non-mandatory changes will require detailed descriptions and justifications for the proposed change along with approval by AFCEC (AFCEC, 2013).

The second management process is mandated by law; MILCON may not be increased or decreased by more than 25% of the amount appropriated for the project unless approved by the respective military service's Secretary and Congress has been notified (10 U.S.C. §2853). A report from the Secretary is required to notify congressional defense committees and the Comptroller General of the United States if any MILCON project with an authorized cost greater than $40 million has a cost increase of 25% or more. The report will include a description of reasons for the cost increases, the source of proposed funds to finance the increased costs, and the individuals responsible (House Report, 2017). The DoD has supplemented this law through the Financial Management Regulation (DoD, 2015) requiring reprogramming approval for an increase exceeding 25% or two million dollars, whichever is less.

**Causes of MILCON Cost Overruns**

The construction project literature review identified as many possible factors or causes to project cost overruns (Federe & Pigneri, 1993; Flyvberg, Holm, & Buhl, 2002; Giegerich, 2002; GAO, 1981; Harbuck, 2004; Jahren & Ashe, 1990; Thal, Cook, & White, 2010; Trost & Oberlender, 2003; Zentner, 1996). These articles range from 1981-2010 and cover a plethora of industry projects such as MILCON, transportation infrastructure and highways, nuclear construction, and naval facilities. Table 1 outlines a list of factors which were commonly identified in these articles as variables that can affect construction cost overruns. Appendix B displays the full list of factors identified in the articles, grouping them into seven general categories: bidding environment and

contractor behavior, unforeseen changes, project features, design process, leadership, external factors, and estimation process.

**Table 1: Top Factors Affecting Construction Project Cost Overruns**

| | GAO 1981 | Jahren & Ashe 1990 | Federle & Pigneri 1993 | Zetner 1996 | Flyvberg 2002 | Giegerich, 2002 | Trost 2003 | Harbuck, 2004 | Thal, Cook & White 2010 |
|---|---|---|---|---|---|---|---|---|---|
| Contract Bidder Interest in Project or Number of Bids | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ |
| Changes in Scope/Requirements or Change Orders | ✓ | ✓ | | ✓ | | ✓ | | ✓ | |
| Design Effort or Funds Available for Design | | | ✓ | ✓ | | ✓ | | | ✓ |
| Project/Construction Type | | ✓ | ✓ | | ✓ | | | | ✓ |
| Supervision Effort or Management Involvement | | | ✓ | ✓ | | ✓ | ✓ | | |
| Project Location or Site Requirements | | | ✓ | | ✓ | | ✓ | | |
| Ratio/Difference: Low Bid to Government/Engineer Estimate | | ✓ | ✓ | | | | | | ✓ |

The 1981 GAO study of MILCON projects showed that the degree of bidder interest affected cost more than any other single factor. With several contractors interested, competition lowers bids and with less interest in a project, bids are likely to be higher. If a contractor truly wants a particular contract, they may be willing to alter profits and overhead costs below original government estimation. As for fluctuations in costs for materials and labors, uncontrollable unforeseen economic factors affected by supply and demand can affect project costs. Any project with significant quantities of one or more material or labor skill will be susceptible to changes in the economy at the time of bidding (GAO, 1981).

Jahren and Ashe's (1990) Naval facilities study found that change-order rates directly affect cost overrun rates with the change-order rate increasing as the project size

increases. Their research focused on the factors influencing change orders which in turn affect project cost overruns. Federle and Pigneri's (1993) Iowa Department of Transportation analysis used multiple linear regression to find statistical relationships between the cost estimate, 11 cost variables, and the final cost overrun or underrun. Their significant variables that shared commonality with other studies are shown in Table 1 and Appendix B.

Zetner's (1996) study on nuclear industry construction projects identified 68 causal variables related to final cost with 80% of the top ten causal variables related directly to the identification of the scope and the control of it thereafter. Flybverg's (2002) study of transportation infrastructure projects across 20 countries found that larger projects experienced larger cost overruns based on a percentage scale. Giegerich (2002) focused on identification of early warning signs common to construction projects that may help "flag" those prone to future difficulties.

Trost's (2003) multivariate regression analysis is the only literature found specific to early estimates of construction projects. He highlighted that early estimates are questionable due to limited scope definition leading to scope changes and lack of accurate information available at the time of the estimate. Often the early conceptual stage lacks a comprehensive and definitive process design with outlined site requirements. The research identified factors which would predict the accuracy of the early cost estimate. The most significant drivers of estimate accuracy were the basic process design, the estimating team's experience, accuracy of cost information, and the time allowed to prepare the estimate.

Harbuck (2004) categorized the root causes for project cost overruns to be design problems, construction problems, and third-party problems. Additionally, he explained that the nature of competitive bidding establishes incentives for contractors to be overly optimistic in order to be the lowest bidder and win the contract at the possible expense of not accounting for all risks. Lastly, Thal, Cook, and White (2010) created a regression model to develop a better estimating model for MILCON contingency funds for projects. The model included three quantifiable variables, which would assist in estimating potential cost overruns for the project. These three variables were the design length normalized by dividing by the design cost, initial construction cost estimate divided by the cost at award, and the initial construction cost estimate divided by the original programmed amount.

**Summary**

Though no literature exists discussing MILCON cost growths in MDAPs, the literature reviewed regarding MILCON cost estimation, construction cost factors, and MILCON cost overruns assists in building a framework of understanding the nature of MILCON projects. It is important to consider the many factors that can affect cost estimates and final project costs. All of these factors may be even more influential in deviating from early MILCON cost estimates which are reported on SARs for acquisition programs. Chapter III explores all available factors in relation to MILCON cost growth at the programmatic level.

# III. Methodology

The first portion of this chapter discusses the data collected and modified to build two databases of military construction (MILCON) costs at acquisitions programmatic levels. The latter portion provides an outlined process of the analysis methods utilized and tested on the databases. The two databases are (1) program MILCON data from 32 programs consisting of MILCON cost estimates from the Selected Acquisition Reports (SAR) and (2) project MILCON data from ten programs including accumulated values from actual projects within the programs. Analysis consists of descriptive statistics and Fisher's Exact tests for contingency tables. Each database utilizes both analysis methods to answer the three research questions. Chapter IV discusses the results and implications of the analysis.

## Program MILCON Database

The majority of MILCON data for an acquisition program came from an internal Air Force Life Cycle Management Center (AFLCMC) database of all SARs from 1966-2015. Though the Defense Acquisition Management Information Retrieval (DAMIR) system is the authoritative source for SARs, the system only holds automated SAR records as of December 1997. The AFLCMC database is derived from the original SAR sources dating back to 1966 and therefore provides more program samples for analysis.

This AFLCMC database obtained 120 Air Force-led acquisition programs with 1,330 total SAR records. This was narrowed down to 41 programs containing at least one MILCON cost estimate, leaving 494 associated SAR records. Seven of these acquisition programs were cancelled according to the AFLCMC database, removing 34

additional SAR records from analysis. Thirteen records were added from the DAMIR system for the 34 selected programs to account for recent SAR estimates that were submitted after the AFLCMC database was last updated with SARs from December 2015. Table 2 provides an outline of data inclusions and exclusions for this first database used in both descriptive statistical analysis and contingency table analysis.

**Table 2: Program MILCON Database Inclusions/Exclusions**

| Criteria | Δ Programs | Δ Reports | Total Programs | Total Reports | Years Included |
|---|---|---|---|---|---|
| Initial SAR data provided by AFLCMC | + 120 | + 1,330 | 120 | 1,330 | 1996-2015 |
| MILCON not reported in any SAR for the program | - 79 | - 836 | 41 | 494 | 1966-2015 |
| Acquisition program cancelled | - 7 | - 59 | 34 | 435 | 1966-2015 |
| Latest SARs added from DAMIR | | + 13 | 34 | 448 | 1966-2017 |
| First to last SAR spans less than 12 months | - 2 | - 4 | 32 | 444 | 1966-2017 |

From the 448 records collected and formatted from the AFLCMC database and directly input from DAMIR, two programs were excluded from analysis due to the reporting duration from first to last SAR being less than 12 months. Final analysis was performed on 32 programs from 444 SARs. The final 32 programs for this database are listed in Appendix C with sanitized program names. Figure 1 displays the 32 program commodities in a pie chart and Figure 2 displays the total years of SAR reporting for each program.

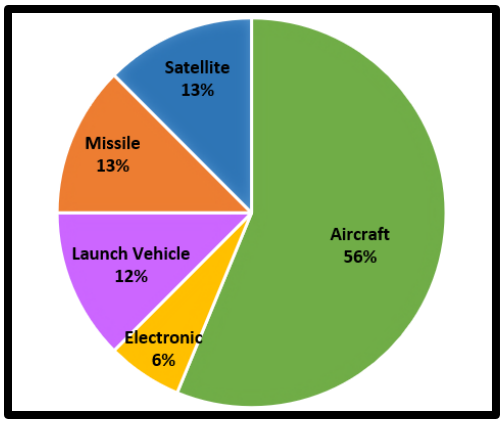


**Figure 1: Program MILCON Database Commodity Types**

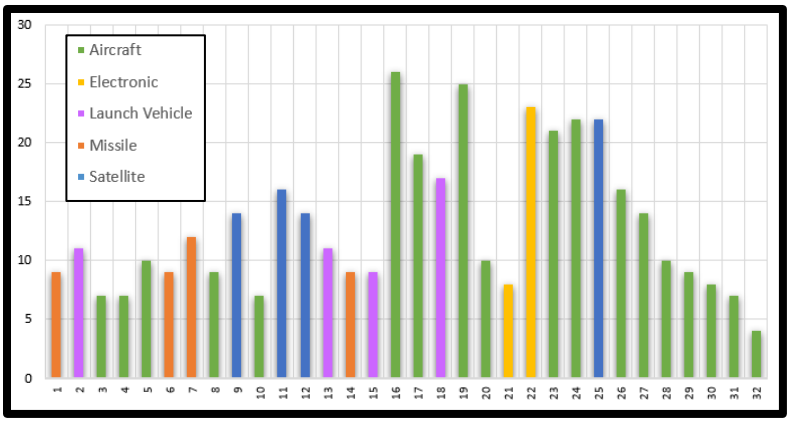


**Figure 2: Program MILCON Database Total Years of SAR Reporting**

***Data Variables***

Three types of variables were derived from the 444 reports before rolling up the data to 32 program data points. (1) A percentage value was calculated as a ratio of MILCON cost estimate to total program cost estimate for each report. (2) MILCON cost estimates and (3) total program cost estimates were normalized from program base years to constant year 2018 using *Military Construction (3300)* factors outlined by the Secretary of the Air Force Economics and Business Management (SAF/FMCE) (2018) and identified in Appendix A. The USAF raw inflation index was used to change the base year to constant year.

The final Program MILCON Database with 444 SAR records was summarized into 32 program records of data. Seventy-one variables were created in order to complete cost growth analysis across the different programs. Several stages of SAR reports were compared to the final SAR's MILCON cost estimate to analyze growth in the form of amounts and percentages. These growths were from the start of reporting, after a quarter of reports have been submitted (25th percentile) , at the median point of submitted reports (50th percentile), after three-quarters of reports have been submitted (75th percentile), at the lowest reported cost estimate, at the highest reported cost estimate, at the average reported cost estimate, and at the median reported cost estimate. This created eight measurements of cost growth across Major Defense Acquisition Programs (MDAP) to be measured in both the dollar value of cost growth and the percentage of cost growth compared to the total program cost.

Three dummy variables were created for six of the eight cost growth percentage target variables; these 18 dummy variables enabled contingency table tests for potential driver factor significance. Minimum and maximum SAR values were not used for contingency table analysis but are included in the descriptive statistical analysis. The dummy variables for these cost growth variables were (1) a positive cost growth where costs increased over time, (2) an absolute value cost growth of more than 1% where costs increased or decreased over time by more than 1% of the total program cost, and (3) an absolute value cost growth of more than 2% where costs increased or decreased over time by more than 2% of the total program cost. Table 3 briefly lists the data variables used; a detailed list of derived variables for the program summary dataset is outlined in Appendix D.

**Table 3: Program MILCON Database Variables**

| Cost Growth Variables for Descriptive Statistics | Dependent Cost Growth Variables for Contingency Tables | Independent Cost Growth Variables for Contingency Tables |
|---|---|---|
| Growth First to Last SAR ( $ and % ) | Growth First to Last SAR (positive %, >\|1%\| and >\|2%\| ) | Commodity Type |
| Growth 1st/2nd/3rd Quartile Report to Last SAR ( $ and % ) | Growth 1st/2nd/3rd Quartile Report to Last SAR (positive %, >\|1%\| and >\|2%\| ) | Prototype |
| Growth Average to Last SAR ( $ and % ) | Growth Average to Last SAR (positive %, >\|1%\| and >\|2%\| ) | Modification |
| Growth Median to Last SAR ( $ and % ) | Growth Median to Last SAR (positive %, >\|1%\| and >\|2%\| ) | Base Year |
| Growth Minimum to Last SAR ( $ and %) | | Average MILCON Cost to Program Cost Ratio |
| Growth Maximum to Last SAR ( $ and %) | | MILCON Cost Estimate on Last SAR |
| | | Total Program Estimate on Last SAR |

**Project MILCON Database**

From the original 32 programs under analysis, only 11 programs included SAR estimates after 2000 when the Automated Civil Engineer System – Project Management (ACES-PM) was fielded. Of these 11 programs, one was a satellite program and the remaining ten were aircraft commodities consisting of various types. Specifically, the ten represent cargo, fighter, helicopter, tanker, trainer, and unmanned aerial vehicle programs. MILCON project data was pulled from ACES-PM with project keywords which included these 11 programs of interest.

Program Element Codes (PEC) are mission description codes which identify the organization entities and resources (manpower, materiel, and funds) needed for the assigned mission (Secretary of the Air Force Deputy Assistant Secretary for Budget, 2017). This would have been the ideal manner in locating projects within acquisition programs, but they could not be used because more than just the reported PEC in the SAR was being used for MILCON projects associated with the weapon system. The

keyword search ensured a more encompassing scope of the projects for each program as of 22 October 2018 when the data was pulled from ACES-PM.

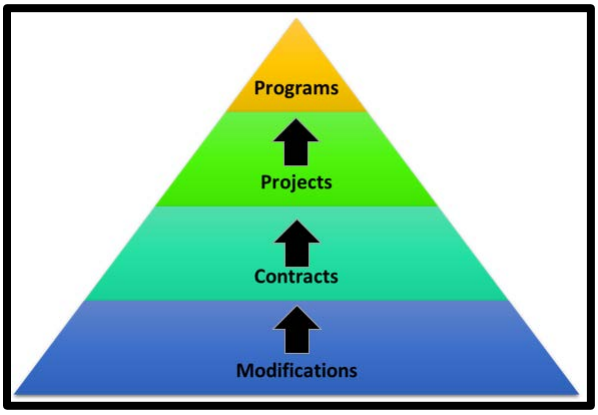


**Figure 3: Project MILCON Database Roll Up Process**

The project data obtained from ACES-PM included contract data, contract modification data, and project data for the 11 programs. The contract modification data was able to roll up into the contract data and the contract data was able to roll up into the project data. All possible variables were extracted at the lowest level to provide as many variables at the project level which would become the foundation to roll up into summarized program data. The final roll up to program-level is what is used in descriptive statistical and contingency table analyses. Figure 3 graphically depicts the roll up process.

The ACES-PM data included 224 project records with 25 variables, 214 contract records with 14 variables, and 2,339 contract modifications with 14 variables for the 11 programs identified. Projects possessed various completion statuses; one program had more than 85% of its projects still in the design or ready to advertise status and was excluded from actual cost analysis. It is assumed that a program's actual costs cannot be determined with most projects still in phases that have no requirement for funding

obligation yet. The final count of programs used at the project-level of analysis was ten, as shown in Appendix C. Each of these ten programs had less than 40% of the projects still in design or ready to advertise status. Figure 4 displays the commodity types in a pie chart and Figure 5 graphs the total number of authorized projects per MDAP

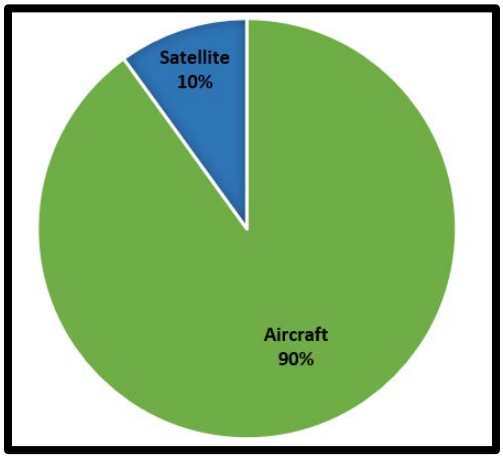


**Figure 4: Project MILCON Database Commodity Types**

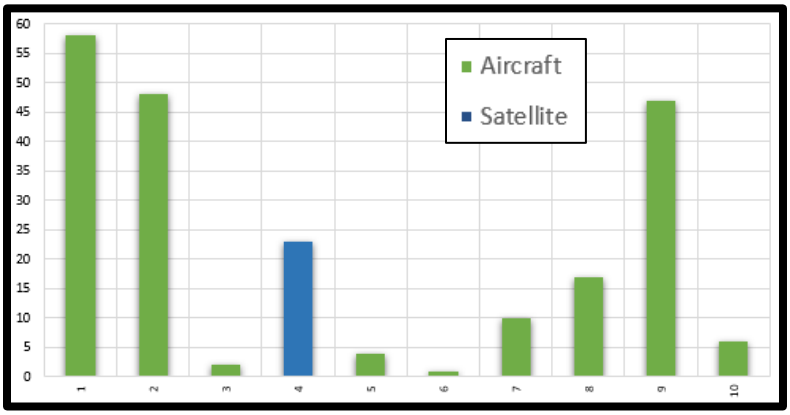


**Figure 5: Project MILCON Database Total Projects Authorized**

Contract and contract modification values were normalized from the respective modification or contract execution fiscal year to constant year 2018. Project totals in the form of programmed amounts, obligation amounts, and expenditure amounts were normalized from the single appropriation fiscal year for the project to constant year 2018.

All project values were normalized using the SAF/FMCE (2018) inflation factors from Appendix A.

***Data Variables***

After the data provided by ACES-PM for contracts, contract modifications, and projects were rolled up into ten program records, a total of 8 contract variables, 6 contract modification variables, and 58 project variables were extracted for analysis. Appendix D outlines the derived variables and the roll up process utilized to gain program values. To explore different variables for the best representation of actual program MILCON costs, programmed amounts, obligation amounts, and expenditure amounts were explored for projects at least (1) financially closed out, (2) with construction completed, and (3) with construction underway.

The program-level roll up from the Project MILCON Database was integrated with the Program MILCON Database for the ten available programs to tie the SAR report variables to the project variables and actual MILCON costs. Cost growth was analyzed at the various stages of SAR reporting similar to the process outlined in the Program MILCON Database variables section and outlined in Table 3. The primary difference in this cost growth analysis is that all SAR reporting stages were compared to programmed amounts, obligation amounts for projects with construction complete, and obligation amounts for projects with construction at least underway instead of the last SAR cost estimate reported. Additionally, the independent variables used for contingency table analysis was beyond the scope of the SAR characteristics.

**Descriptive Statistical Analysis**

Descriptive statistical analysis is used to summarize the cost growth data in both of the databases and provide responses to Research Question One and Research Question Three using seven measurements. The (1) mean and (2) median values of cost growth provide a depiction of "a typical cost growth" in MILCON cost estimates. The (3) standard deviation is a quantitative description of the variation or dispersion in the data. The (4) minimum and (5) maximum values depict the full range of values observed for the variable. Lastly, quartiles quantitatively provide a picture of the distribution of values. The (6) first quartile represents the 25th percentile of cost growth values or percentages and the (7) third quartile represents the 75th percentile.

Utilizing the first database of 32 programs, cost growth of MILCON estimates on SARs was analyzed through descriptive statistics. The descriptive statistics consisted of the mean, standard deviation, maximum, minimum, first quartile, median, and third quartile. These cost growth measurements were analyzed in both dollar value and in percentage through the various stages of SAR reports. Additionally, a scatterplot of cost growth percentages across these 32 programs was generated to display potential data abnormalities.

The second database with ten programs also utilized descriptive statistics to analyze cost growth from SAR estimates to measurements of ACES-PM actual costs for projects within programs. The same descriptive statistics were derived for this database at both the dollar value and percentage of cost growth. The various stages of SAR report estimates were measured against the programmed value and two separate obligation values: (1) obligation amounts for projects with construction at least complete and (2)

obligation amounts for projects with construction at least underway. Similarly, cost growth for these programs was scatter plotted as a visual aid to identify potential outliers; no programs were identified as such.

**Contingency Table Analysis**

Due to both databases having relatively small sample sizes, continuous variables of cost growth in percentages were converted into categorical binary variables, or dummy variables. Three dummy variables were created for each measurement of cost growth to indicate (1) positive cost growth, or estimates increasing over time, (2) at least +/- 1% cost growth, or an increase or decrease of estimates over time by at least 1%, and (3) at least +/- 2% cost growth, or an increase or decrease of estimates over time by at least 2%.

Categorical variables can be tested for dependency through contingency tables. Pearson's Chi-Squared test and the Odds-Ratio test for significance may be more common, but they require a larger sample size for the p-value approximation provided. Fisher's Exact test is ideal for small sample sizes and presents a conditional exact inference. An exact inference does not rely on assumptions that parameters hold true through infinity, but is an exact calculation of a p-value given the data presented (Agresti, 1992).

Both databases were utilized in contingency table analysis to identify potential MILCON cost growth factors for acquisition programs. Due to the small sample size, Fisher's Exact test was used to test for dependency significance. The first database uses a sample size of 32 programs with a cost growth comparing various stages of SAR reporting to the last SAR report MILCON estimate. The second database has a smaller

sample size of ten programs, but is able to consider cost growth from the various stages of SAR reporting to forms of actual costs for projects from ACES-PM. Furthermore, the second database possesses additional variable categories which were analyzed in contingency tables against MILCON cost growth for programs.

**Summary**

Due to the exploratory nature of this study, both databases were prepared and modified to extract as many possible variables and measurements of cost growth. Descriptive statistics and contingency table analysis were the two analysis methods used to explore answers to the research questions. The next chapter, Chapter IV, provides the results of the descriptive statistics from the first database which aims to answer Research Question One regarding typical cost growth in program-level MILCON cost estimates which are reported on SARs. The chapter also provides the results of descriptive statistics from the second database which aims to answer Research Question Three regarding the gap between SAR reported estimates and actual project-level costs. Lastly, Chapter IV provides the contingency table results, outlining potential factors which showed Fisher's Exact test significance.

# IV. Analysis Results

This chapter outlines the results and implications from the analysis methods described in Chapter III, Methodology. First, the chapter presents the descriptive statistical analysis results of various measurements of military construction (MILCON) cost growth from both databases. These statistics are applied to Research Question One and Research Question Three. Next, the chapter outlines the contingency table analysis results measuring multiple variables against various measurements of cost growth, along with the significant Fisher's Exact p-values for the tests. These significant factors are applied to Research Question Two. The chapter concludes with limitations to the data and analysis results.

## Descriptive Statistics for Program MILCON Database

Before statistical analysis was performed, a scatterplot of cost growth was graphed for all 32 programs from the first database. Figure 6 displays cost growth as a percentage to total acquisition program costs (y-axis) from the first Selected Acquisition Report (SAR) cost estimate to the last SAR cost estimate for the 32 programs (x-axis). The majority of programs (78%) show cost growth and cost savings within a 2% difference from the original estimate or a 0% cost growth. Zero percent cost growth from an estimate would represent a perfect estimate and though nearly impossible to persistently achieve, it is the target percentage for this study when considering the mean or median cost growth across programs.

Subsequent the scatterplot, typical cost growth for MILCON estimates was analyzed using descriptive statistics from the 32 programs in the first dataset. Table 4

outlines mean and median cost growth in dollar value and percentage from the first SAR estimate, median SAR estimate, average SAR estimate value, and median SAR estimate value to the last SAR estimate. Variability in the mean and median values represent both positive and negative distribution skews throughout the phases of SAR reporting and when observing the dollar value or percentage. Notably, the percentage of cost growth show less skew and are used to analyze typical cost growth from cost estimates; dollar values possess no normalization across the various types of acquisition programs but are still useful in understanding magnitudes of potential funding impacts. Appendix E provides full cost growth descriptive statistics at all stages of reporting for both databases.

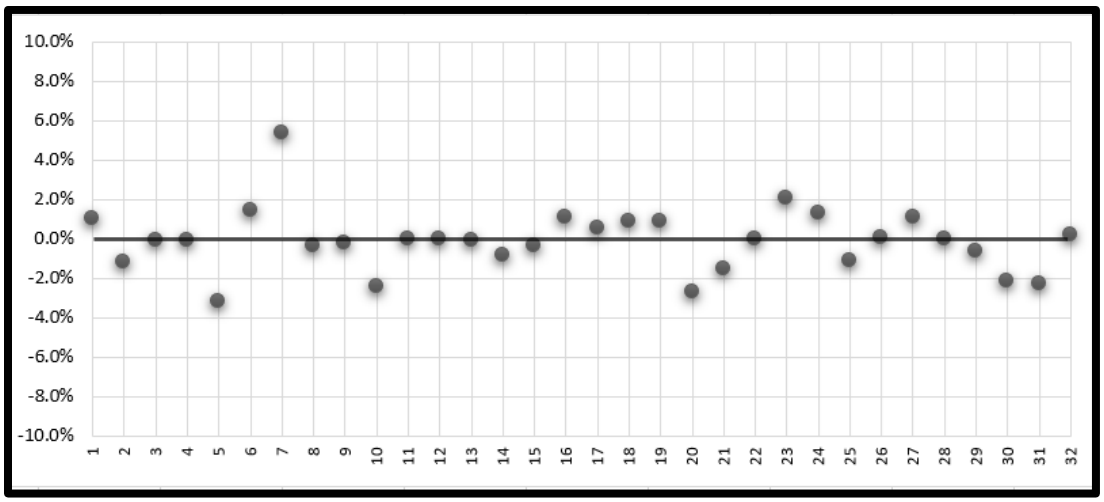


**Figure 6: MILCON Cost Growth as Percentage to Total Program Cost from First to Last SAR Cost Estimates**

Utilizing a sample size of 32 programs and comparing estimates to the final SAR's MILCON cost estimate, a typical cost growth of MILCON estimates reported for Major Defense Acquisition Programs (MDAP) on SARs is relatively small in comparison to the total program cost. Table 4's mean and median percentages indicate that cost

growth percentages range from -0.16% to 0.00% of the total acquisition program cost reported on the last SAR. Due to the mean and median percentages leaning toward negative values, the central tendency for MILCON cost growth amongst MDAPs appears to be cost savings.

**Table 4: Descriptive Statistics of MILCON Cost Growth to Last SAR Estimate (32 Programs)**

| | Mean ($M) | Median ($M) | Mean (%) | Median (%) |
|---|---|---|---|---|
| First Report to Last SAR Estimate | -$28.499 | -$0.129 | -0.11% | -0.03% |
| Median Report to Last SAR Estimate | $8.242 | $0.000 | -0.16% | 0.00% |
| Average Value to Last SAR Estimate | -$6.182 | -$0.431 | -0.14% | -0.04% |
| Median Value to Last SAR Estimate | $7.625 | $0.000 | -0.06% | 0.00% |

**Descriptive Statistics for Project MILCON Database**

Appendix F presents the three scatterplots of cost growth as a percentage to total acquisition program cost reported on the last SAR (y-axis) for the ten programs (x-axis) in the second database. Each of the programs have two data points which represent (1) the cost growth from the first reported SAR (grey) and (2) the cost growth from last reported SAR (black). It was anticipated that the cost growth percentages would move inward to the 0% cost growth target line from the first SAR to the last SAR as MILCON costs begin to actualize within the SAR cost estimates. Figure 7 presents an example of the scatterplots in Appendix F, displaying arrows of estimates getting closer to 0% and circling the two programs with estimates which "got worse", or further from 0% cost growth.

Table 5 outlines the same descriptive statistics as Table 4 with the exception of measuring cost growth against programmed and obligated amounts derived from accumulated actual projects instead of measuring cost growth against the last reported

SAR estimate. The eighth listed program on the x-axis of Figure 7 has a significantly lower programmed and obligated amount than on the reported SAR estimates which is skewing Table 5's means towards cost savings. This could be caused by unprogrammed projects still needed for the future or an improperly high estimate when reporting MILCON estimates in the SARs. Due to the small sample size of ten, this program was not removed for analysis. For the purpose of measuring central tendency values, the median may depict a better measurement for this dataset.

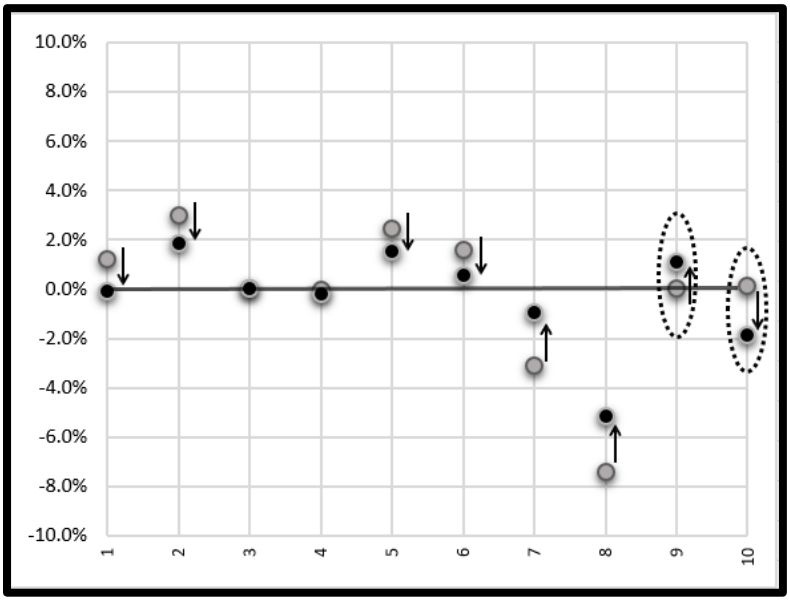


**Figure 7: Example Scatterplot of MILCON Cost Growth from First and Last SAR Estimates to Actual MILCON Costs**

Utilizing programmed amounts as a measurement of actual costs as of 22 October 2018, the median cost growth percentage from SAR reports range from 0.48% to 1.05% of the last reported total acquisition cost on a SAR. In dollar values, the median cost growth from SAR reports to programmed actual costs ranges from $22.92 million to $31.66 million. While the percentage of total acquisition program cost is relatively small,

the dollar values appear significant when considering multiple acquisition programs that may encounter these cost growths from the reported MILCON estimate on SARs.

**Table 5: Descriptive Statistics of MILCON Cost Growth to Actual Costs**

| | Mean ($M) | Median ($M) | Mean (%) | Median (%) |
|---|---|---|---|---|
| First Report to Programmed Amount | -$122.420 | $30.394 | 0.43% | 1.05% |
| Last Report to Programmed Amount | -$71.179 | $31.662 | 0.33% | 0.48% |
| Average Value to Programmed Amount | -$74.819 | $22.915 | 0.28% | 0.51% |
| First Report to Obligated Amount (Construction Complete) | -$231.938 | $3.756 | - 0.37% | 0.10% |
| Last Report to Obligated Amount (Construction Complete) | -$164.903 | $20.346 | - 0.47% | - 0.15% |
| Average Report to Obligated Amount (Construction Complete) | -$184.337 | -$5.084 | - 0.51% | - 0.07% |
| First Report to Obligated Amount (Construction Underway) | -$198.090 | $3.756 | - 0.21% | 0.10% |
| Last Report to Obligated Amount (Construction Underway) | -$146.850 | -$2.774 | - 0.32% | - 0.03% |
| Average Report to Obligated Amount (Construction Underway) | -$150.489 | -$2.017 | - 0.36% | - 0.02% |

Both obligation amount measurements of actual costs display median central tendencies of less cost growth and even depicting cost savings. The median cost growth percentages from SAR reports range from -0.15% to 0.10% of the last reported total acquisition cost on the MDAP SAR. The median dollar amount of cost growth ranges from -$5.08 million to $20.35 million. These values may be smaller than the programmed amount measurement because the obligation amount does not include projects which have not begun construction yet, nor incorporate total costs for projects with construction still underway or not completely financially closed out.

To consider the average estimating gap from SARs to actual MILCON program costs, focus in on the average SAR estimate as the beginning value and the cumulative programmed amount as the end value. The average SAR estimate should measure the

accuracy of reports across the span of required reporting and the programmed amount is more encompassing of projects for costs. Still utilizing the median as the preferred central tendency measurement for this database, the 50th percentile reporting gap is $31.6 million in costs or 0.48% of the program's total cost.

**Contingency Table Analysis**

Utilizing both the Program MILCON Database and Project MILCON Database, dummy variables were utilized in contingency table analysis to identify potential dependent variables which showed significance in Fisher's Exact test with a p-value less than 0.10. This analysis was performed using JMP Pro 13's "Fit Y by X" function which generates contingency tables if both variables are categorical and provides the Fisher's Exact test p-value and tail assignment.

A significant right tail shows that the tested cost growth is more probable if the tested independent dummy variable is indicated with a "1" than if it is a "0". For example, a right tail for the "≥ *15 Years of SAR Reports*" dummy variable tested against positive cost growth tells the reader that positive cost growth is more probable if the program has 15 or more years of SAR reports. A significant left tail shows the opposite is more probable. For example, a left tail for the "*< $10M MILCON on Last SAR*" dummy variable tested against positive cost growth tells the reader that positive cost growth is more probable if the program has more than $10 million estimated in MILCON on the last SAR. For the purpose of this study, all of the contingency table tests use one-tailed hypotheses in order to determine directionality of the variables dependency.

***Program MILCON Database Results***

The Program MILCON Database utilized 18 cost growth target dummy variables with 19 predictor dummy variables, which were created at logical breaks of values and percentages after observing the data in histograms. For example, the average reported MILCON percentage in comparison to total program costs ranged from 0.02% to 15.73%. Approximately half of the programs were less than 1%, approximately a quarter of the programs were less than 0.5%, and approximately 15% of the programs were more than 5%. These three logical breaks of less than 0.5%, more than 1%, and more than 5% were used for dummy variables.

The 18 by 19 dummy variables formed 342 contingency tables to be tested for significance. Fourty-four showed significance at an alpha of 0.10 with 24 variables at an alpha of 0.05 and four variables at an alpha of 0.01. These variables and significance indications are shown in Appendix G; the most frequent variables from the 32 sample programs are highlighted in Table 6. Significance measurements of p-values are marked with asterisks (*). One asterisk indicates a significant Fisher's Exact p-value of 0.10 or less, two asterisks indicate a p-value of 0.05 or less, and three asterisks indicate the highest significance with a p-value of 0.01 or less. Additionally, the right- and left-tailed significance is marked in Table 6 to show whether the independent factor tested more probable (right-tail) or the opposite tested more probable (left-tail).

One predictor variable with a high frequency of significance amongst the various stages of SAR reports was cost growth for programs that had MILCON estimates averaging more than 5% of the total program costs. All five of the significant average MILCON % dummy variables against +/- 1% and +/- 2% cost growth were significant

right tails which means that cost deviation of more than 1% or 2% of the total acquisition cost is more probable for programs averaging MILCON estimates more than 5% of the total program cost. It can be expected that greater deviations of cost growths or savings in comparison to total acquisition costs would occur on larger MILCON estimates with smaller total acquisition costs.

**Table 6: Top Significant Factors for Cost Growth to Last SAR (32 Programs)**

| **Table Legend:**<br>* p-value < 0.10<br>** p-value < 0.05<br>*** p-value < 0.01<br>L left-tail significance<br>R right-tail significance | ≥15 Years of Reports | Aircraft | Missile | <0.5% Avg MILCON % to Total | >5% Avg MILCON % to Total | <$10M MILCON on Last SAR | <$50M MILCON on Last SAR | >$10B Total Program on Last SAR |
|---|---|---|---|---|---|---|---|---|
| First to Last (Positive Growth) | **R *** ** | | | | | **L ** ** | | |
| First to Last (>\|1%\| Growth) | | | | **L ** ** | **R * ** | **L * ** | **L * ** | **R * ** |
| First to Last (>\|2%\| Growth) | | **R * ** | | **L * ** | | | | **R * ** |
| Q1 to Last (Positive Growth) | | | | | | **L ** ** | | |
| Q1 to Last (>\|1%\| Growth) | | | | **L ** ** | **R ** ** | | | |
| Q1 to Last (>\|2%\| Growth) | | | | | | | | |
| Q2 to Last (Positive Growth) | | **R *** ** | | | | | **L *** ** | **R ** ** |
| Q2 to Last (>\|1%\| Growth) | | | **R * ** | | **R ** ** | | | |
| Q2 to Last (>\|2%\| Growth) | | | | | | | | |
| Q3 to Last (Positive Growth) | **R ** ** | **R ** ** | | | | | | **R * ** |
| Q3 to Last (>\|1%\| Growth) | | **L * ** | **R ** ** | | **R ** ** | | | |
| Q3 to Last (>\|2%\| Growth) | | **L * ** | **R ** ** | | **R ** ** | | | |
| MED to Last (Positive Growth) | **R * ** | **R ** ** | | | | | | |
| MED to Last (>\|1%\| Growth) | | | | | | | | |
| MED to Last (>\|2%\| Growth) | | | | | | | | |
| AVG to Last (Positive Growth) | **R * ** | **R ** ** | | | | | **L * ** | |
| AVG to Last (>\|1%\| Growth) | | | | | | | | |
| AVG to Last (>\|2%\| Growth) | | | | | | | | |
| **Total Significant Contingency Tables** | **4** | **7** | **3** | **3** | **5** | **3** | **3** | **4** |

The other predictor variable with the most counts of significant tests amongst stages of SAR reports was cost growth for the aircraft commodity. The four significant aircraft commodity tests against positive cost growth were significant right tails which means that positive cost growth is more probable for aircraft programs than non-aircraft programs. Two of the significant aircraft commodity tests against +/- 1% and +/-2% cost growth were significant left tails which means that a cost deviation (growth or savings) of more than 1% or 2% of the total acquisition cost is more probable for non-aircraft programs than aircraft programs. This could be due to higher total acquisition costs of aircraft programs compared to non-aircraft programs. The average total acquisition cost for aircraft programs was $7.8 billion whereas non-aircraft programs averaged $1.6 billion. In summary, positive cost growth in MILCON estimates is more likely for aircraft programs, but the growth is probably less than 1% of the total program cost.

***Project MILCON Database Results***

The Project MILCON Database utilized 21 cost growth target dummy variables with 24 predictor dummy variables which were created at logical breaks of values and percentages after analyzing the data values in histograms. This formed 504 contingency tables to be tested for significance. Sixty-eight showed significance at an alpha of 0.10 with 31 testing significant at an alpha of 0.05 and nine at an alpha of 0.01. Appendix G displays all tests' significance and left- and right-tail values. Table 7 highlights the most frequent significant factors of the 24 tested. Similar to Table 6, asterisks indicate the significance.

**Table 7: Top Significant Factors for Cost Growth to Programmed Amounts (10 Programs)**

| **Table Legend:**<br>* p-value < 0.10<br>** p-value < 0.05<br>*** p-value < 0.01<br>L left-tail significance<br>R right-tail significance | <4 Bases with Projects | <$50M Programmed for Projects | >$400M Programmed for Projects | <10 Different Companies with Project Contracts | <10,000 Contracted Performance Period Days | >$10B Total Program on Last SAR | <$10M in Contract Modifications | <$3M in Contract Modifications | <200 Contract Modifications | <50 Contract Modifications | ≥75% of Projects w/Contract Modifications |
|---|---|---|---|---|---|---|---|---|---|---|---|
| First to Programmed (Positive Growth) | | | | | | | | | | | |
| First to Programmed (>\|1%\| Growth) | L * | L *** | | | | | | | | L *** | |
| First to Programmed (>\|2%\| Growth) | | L * | R * | L ** | L * | | | | | L * | |
| Q1 to Programmed (Positive Growth) | | | | | | | | | | | |
| Q1 to Programmed (>\|1%\| Growth) | | L * | R * | L ** | L * | | | | | L * | |
| Q1 to Programmed (>\|2%\| Growth) | L ** | | R ** | L *** | L ** | | | | | | |
| Q2 to Programmed (Positive Growth) | | | | | | | | | | | |
| Q2 to Programmed (>\|1%\| Growth) | | L * | R * | L ** | L * | | | | | L * | |
| Q2 to Programmed (>\|2%\| Growth) | L * | | R *** | L ** | L *** | R ** | L * | L ** | L ** | | |
| Q3 to Programmed (Positive Growth) | | | | | | | | | | | R * |
| Q3 to Programmed (>\|1%\| Growth) | | | R * | | L * | | | | | | |
| Q3 to Programmed (>\|2%\| Growth) | | | | | | | | | | | |
| Last to Programmed (Positive Growth) | | | | | | | | | | | R * |
| Last to Programmed (>\|1%\| Growth) | | | R * | | L * | | | | | | |
| Last to Programmed (>\|2%\| Growth) | | | | | | | | | | | |
| MED to Programmed (Positive Growth) | | | | | | | | | | | R * |
| MED to Programmed (>\|1%\| Growth) | | L * | R * | L ** | L * | | | | | L * | |
| MED to Programmed (>\|2%\| Growth) | L * | | R *** | L ** | L *** | R ** | L * | L ** | L ** | | |
| AVG to Programmed (Positive Growth) | | | | | | | | | | | |
| AVG to Programmed (>\|1%\| Growth) | | | | L * | | | | | | | |
| AVG to Programmed (>\|2%\| Growth) | L * | | R *** | L ** | L *** | R ** | L * | L ** | L ** | | |
| **Total Significant Contingency Tables** | **5** | **5** | **10** | **9** | **10** | **3** | **3** | **3** | **3** | **5** | **3** |

The predictor variable which was one of the most frequently significant amongst various stages of SAR reports tested against programmed amounts was cost growths for programs with more than $400 million of MILCON funds programmed for projects. All ten of these significant tests against +/- 1% and +/- 2% cost growth were significant right-tails which means cost deviation of more than 1% or 2% of the total acquisition program cost is more probable for programs that currently have more than $400 million cumulatively programmed for MILCON projects. Perhaps a larger dollar amount programmed for MILCON projects shows increases in planned projects' costs or shows that new projects were added to the mission requirement for the acquisition program, deviating SAR estimates by more than 1% or 2% of the total program cost.

The other most significant predictor variable was cost growth for programs with less than 10,000 cumulative performance period days contracted for projects. This variable is a summation value from all contracts for all projects within a program, consisting of a cumulative number of days on contract for performance periods. All ten of these significant tests against +/- 1% and +/- 2% cost growth were significant left-tails which means cost deviation of more than 1% or 2% of the total acquisition cost is more probable for programs with 10,000 or more cumulative performance period days on contracts for all projects within the program. This finding suggests that programs requiring more performance period days cumulatively across all projects for the program are more likely to experience changes in costs from the original SAR estimates.

**Limitations**

A Research and Development (RAND) Corporation study by Hough (1992) identified numerous limitations when using SARs for measurements of cost growth. A few of these concerns are potential exclusion of significant cost elements, changing guidelines for SAR preparations and the inconsistent interpretations of the guidelines across different programs, cost sharing in joint programs, exclusion of certain classes of major programs, an inconsistent baseline cost estimate, inaccurate inflation forecasts, and lack of precise cost accounting when quantities change for the program. Though these limitations exist, SARs are still deemed suitable for identifying broad trends and patterns across various programs as long as the limitations are understood.

The largest limitation to the analysis described in this chapter is the sample size available for program-level MILCON costs. Additionally, cost growth is best measured against actual costs and actual costs are best displayed as expenditures. With the data available, not all obligations were expended for the ten programs with actual project data. Appendix C outlines the budget process statuses for these programs.

Using obligated values in lieu of expended values still has limitations as 27 of 216 projects (12.5% of projects) for the ten programs were in design phase, ready to advertise, or open for contract bid. Minimal costs would be obligated for those projects, perhaps only design costs if applicable. In addition to these pre-construction phases, 19 of 216 projects (8.8% of projects) for the ten programs were still in construction phase. It is not likely and will not be assumed that all costs have been obligated for these projects.

Programmed values present an overarching program-level estimate for all projects in all phases, but does not depict actual costs. Programmed values are more thorough and

recent estimates for requests from Congress for appropriation and authorization to construct projects. While technically not an actual cost, it is assumed to be a better cost estimate from the civil engineers which can be compared to SAR estimates from program offices.

Figure 8 graphically depicts an example program from the Project MILCON Database to show the differences in programmed, obligated, and expended values. The variable white line represents the MILCON estimates (y-axis) reported on each year's SAR (x-axis). The dotted horizontal lines depict the three possible values of actual cost measurements for this study. For this example, the expended and obligated values differed by approximately $3 million and are therefore nearly overlapping in the graph.

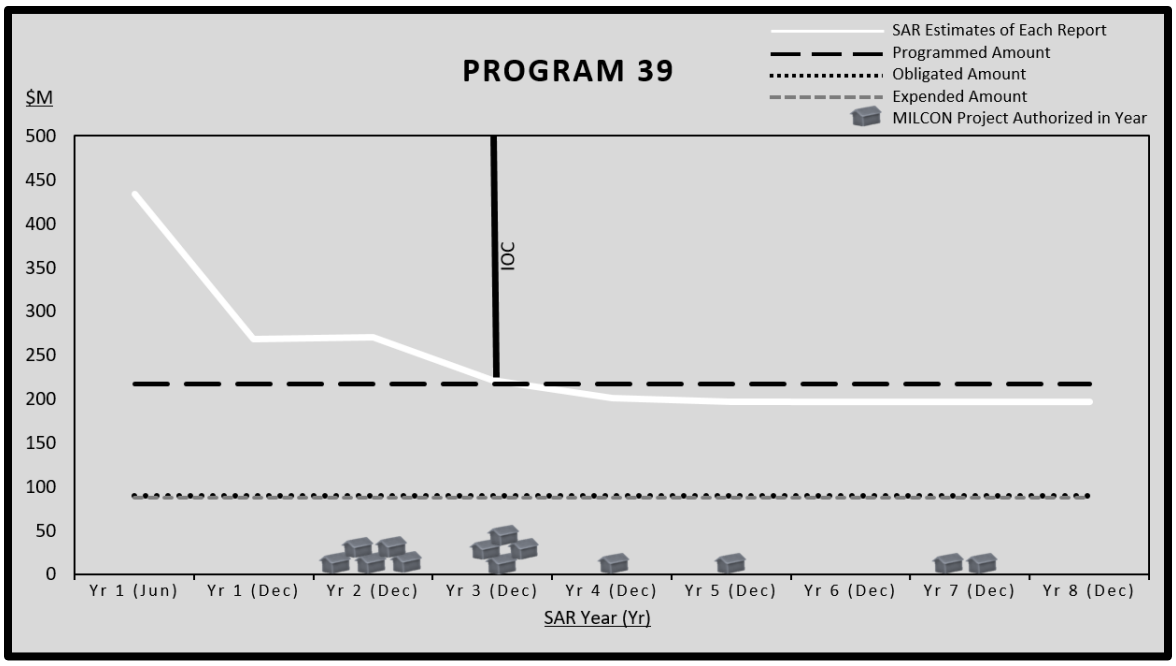


**Figure 8: Example Program of MILCON Cost Estimates from SARs with Actual Costs and Project Authorizations**

Additionally, the graph in Figure 8 displays a mini-building for each MILCON project authorized during that year of SAR reporting. The initial operational capability

(IOC) vertical line represents the date during production when minimal operational capabilities are met (IOC, 2018). Graphically displaying the story of this program provides support to using the programmed amount for measurements to actual costs by showing the potential disparity between expended or obligated amounts to the programmed amounts given the data available for the recent ten programs with actual projects. Furthermore, the graph connects the acquisitions estimate reporting with operational capability and civil engineer project authorizations from Congress.

# V. Conclusion

This final chapter of the thesis utilizes the results from Chapter IV and applies them directly to the three research questions outlined in Chapter I. Where applicable, results are compared to findings from previous studies referenced in Chapter II. The descriptive statistical results are unable to be compared to other studies' quantitative statistics due to the lack of publication for analogous military construction (MILCON) studies in Major Defense Acquisition Programs (MDAP). However, the factors identified from contingency table analysis can be compared to previous construction studies, unspecific to MILCON projects in MDAPs. Finally, the chapter concludes with recommendations for future research when more automated project data is made available for acquisition programs.

## Research Questions Revisited

### *Research Question One*

*What is the typical growth in program-level MILCON cost estimates for MDAPs led by the United States Air Force?* Typical cost growth for program-level MILCON costs estimates were analyzed from various reporting stages of Selected Acquisition Report (SAR) to the last SAR's reported MILCON estimate. The Program MILCON Database with 32 programs had more sample programs for analysis, but was only able to analyze growth to the final SAR cost estimate. Analysis showed that growth deviations decreased over time of reportings with the average SAR estimate being $6.2 million over the MILCON cost estimate on the last report. Using the median, the average SAR

estimate was only $431 thousand over the MILCON estimate from the last report. This equates to a cost savings of 0.04% of the total program cost on the last SAR report.

Considering cost growth from the first MILCON SAR estimate to the last MILCON SAR estimate, the typical or average cost growth was -$28.5 million and the median cost growth was -$129 thousand suggesting cost savings as the typical trend for MILCON in MDAPs led by the Air Force. Utilizing a percentage to total program costs, the average cost growth from first to last SAR is -0.11% of the total program cost and the median cost growth across a program's span of SARs is -0.03% of the total program cost. This study analyzed many other measurements of cost growth within SAR estimates and presented all of the descriptive statistics in Appendix E.

***Research Question Two***

*What are the leading trends or drivers of program-level MILCON cost growth?* Due to the exploratory nature of this research and relatively small sample size of programs, variables were tested in 846 total contingency tables. MILCON cost growth was analyzed at various stages of SAR reportings against the final SAR report and against actual programmed amount for all located projects for the program. Significance of predictor variables was sought for positive cost growth, cost growth deviations greater than +/- 1% and cost growth deviations greater than +/- 2%.

Utilizing Appendix G's contingency table significance counts, the following five variables may be considered leading drivers to program-level MILCON cost growth. First, aircraft commodities tend to drive positive cost growth for MILCON projects but not more than 1% of the total program cost. Second, a higher average percentage of MILCON cost estimates reported on SARs for a program compared to the total program

cost estimate can drive cost growth or savings by more than 1% or 2% of the total program cost. Third, more funds cumulatively programmed for projects within a program may drive cost growth or savings by more than 1% or 2% of the total program cost. Fourth, higher cumulative performance period days on contracts across all projects within a program may indicate cost growth or savings by more than 1% or 2% of the total program cost. Lastly, more companies contracted for projects within a program may drive cost growth or savings by more than 1% or 2% of the total program cost.

Several other factors tested significant and should be considered possible drivers to MILCON cost growth in MDAPs. The number of bases authorized for projects within a program, the number of contract modifications, and the monetary value of contract modifications may affect the size of cost growth in comparison to total program costs. Additionally, the number of years between the first and last MILCON SAR estimate and the percentage of projects with contract modifications may drive positive cost growth.

Given the data available for MILCON projects from the Automated Civil Engineer System – Project Management (ACES-PM) for MDAPs, most of the factors outlined by previous studies were not available for analysis. Examples of these unobtained factors are the number of bids for the projects, the difference in the lowest bid to the government's estimate, changes in project schedule, the design process or effort, the economics and politics surrounding the project, and the involvement of leadership in the design, estimating, or construction process.

Four of the previously studied factors share commonalities with the findings of this thesis. (1) Federle & Pigneri (1993) found that the duration of the construction project can affect cost overruns for the project. We found that the cumulative total of

contracted performance period days was significant with regards to cost growth at the programmatic level of MILCON. (2) Four studies from Table 1 in Chapter II's literature review showed that the type of project or construction affected the cost overrun of the project. This study found that MILCON projects for aircraft acquisition programs were more probable to see cost growth than the non-aircraft MDAPs when testing at the programmatic level. (3) Table 1 also showed five studies which found changes in requirements or the presence of change orders to be an indication of cost overruns in construction projects. This study found both the monetary value and the number of contract modifications tested significant for MILCON in acquisition programs. Lastly, (4) three studies from the literature review reported the location of projects to affect cost overruns. Looking at projects cumulatively for programs makes this factor unique; the number of different locations required for the program tested significant as well as whether or not locations were located outside of the continental United States (OCONUS). Table 9 revisits the shared factors from the literature review's Table 1 and Appendix B.

**Table 8: Revisited Factors Affecting Construction Project Cost Overruns**

| | GAO 1981 | Jahren & Ashe 1990 | Federle & Pigneri 1993 | Zetner 1996 | Flyvberg 2002 | Giegerich, 2002 | Trost 2003 | Harbuck 2004 | Thal, Cook & White 2010 | Angell, et al. 2019 |
|---|---|---|---|---|---|---|---|---|---|---|
| Changes in Scope/Requirements or Change Orders | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | ✓ |
| Project/Construction Type | | ✓ | ✓ | | ✓ | | | | ✓ | ✓ |
| Project Location or Site Requirements | | | ✓ | | ✓ | | ✓ | | | ✓ |
| Construction Duration/Length | | | ✓ | | | | | | | ✓ |

***Research Question Three***

The Project MILCON Database with ten programs had considerably less sample programs than the first database, but allowed analysis of actual cost growth from projects that have been completed or at minimum have been authorized for programming as of 22 October 2018. With various MILCON requirements for different programs and commodities, dollar values varied greatly across programs. For the purpose of analyzing the gap between cost estimates on the SARs and actual costs from projects, percentages of cost growth were used. Zero percent cost growth suggests perfect estimation with no gap between SAR reportings and actual costs.

Analyzing the median cost growth percentage from all stages of SAR reporting to the current programmed amount, results range from 0.39% to 1.05% of the total program cost. This suggests that the SAR estimates were slightly underestimated to what has been programmed for projects within the acquisition program. The median cost growth percentages to the current obligation amounts range from -0.37% to 0.10% of the total program cost. This proposes that the SAR estimates are generally closer to what has been already obligated on projects and could remain more accurate if no other obligations were made toward the programmed amounts. This course of action is highly unlikely.

**Future Research**

Utilizing the potential variable drivers identified in this thesis and additional program record samples as future data becomes available, a prediction model can be explored to provide decision makers and analysts with additional tools for MILCON cost estimating in early phases of concept. The prediction model could be in the form of a

decision tree to predict either the actual amount of program MILCON costs or the accuracy of the SAR estimates based on predictor variables available. The amount of MILCON costs could be determined by a dollar value or as a percentage of the total program costs. The accuracy of the SAR MILCON cost estimate could be determined by predicting the cost growth of the estimate. Logistic regression could also explore these predictions.

Previous Government Accountability Office (GAO) reports of MILCON project costs analyzed cost overruns through case study analysis. A similar style analysis could be applied at a programmatic level by analyzing specific performance and cost growths for projects within a few program case studies. Specific SARs and DD Form 1391s could be analyzed for those programs to identify more specific causes to cost growth amongst MDAP MILCON projects and for the program cumulatively.

**Final Thoughts**

This thesis was exploratory in nature as a topic with no published empirical studies. With numerous published studies regarding MILCON project overruns and general construction overrun factors, MILCON cost growth for Air Force MDAPs has yet to be analyzed in a published forum. Though only able to utilize a small sample size of acquisition programs, this study found typical MILCON cost growth to be negative indicating more cost savings than cost growth across SAR MILCON estimates. The savings is typically less than 0.2% of the total program cost implying minimal impact to MDAP decisions regarding the weapon system as a whole.

The early MILCON estimates from SARs compared to current programmed or obligated values for projects show a gap in estimating on the SAR reports. Though estimates got more accurate from the first SAR to the last SAR for most programs, Table 5 from Chapter IV shows the last SAR's median MILCON cost estimate was approximately $31 million underestimated to projects currently authorized and appropriated for the programs. Though the median cost growth percentage from last SAR to programmed amount is only 0.48% of the total acquisition program's cost, the dollar value can add up and impact budgetary decisions of scarce resources.

Lastly, several factors tested significant as potential drivers to MILCON cost growth for acquisition programs. Unfortunately with the programs available for analysis, a prediction model cannot be built with these factors in order to take cost estimating action when preparing SAR estimates. Further research and program data points are needed to build this model. At this time, it is advantageous for program offices and decision makers to recognize the potential driver factors within their acquisition program and generally prepare for changes in MILCON costs as the program matures.

## Appendix A

### Table A1: DoD Acquisition Category Tresholds

| Acquisition Category | Threshold Designations<br>*(in Fiscal Year 2014 constant dollars)* |
|---|---|
| ACAT I<br>(MDAP) | - Total RDT&E costs > $480 million or<br>- Total Procurement costs > $2.79 billion or<br>- Designated by milestone decision authority as special interest |
| ACAT IA<br>(MAIS) | *Specific to Automated Information Systems*<br>- Total program costs > $40 million in any single Fiscal Year or<br>- Total program costs > $165 million through system deployment or<br>- Total program costs > $520 million through system lifecycle or<br>- Designated by milestone decision authority as special interest |
| ACAT II | - Total RDT&E costs > $185 million and < $480 million or<br>- Total Procurement costs > $835 million and < $2.79 billion |
| ACAT III | - Total RDT&E costs < $185 million and<br>- Total Procurement costs < $835 million |
| ACAT IV | *Specific to Navy and Marine Corps only* |

### Table A2: Inflation Factors Used for Normalization

| From BY | CY 18 Factor | From BY | CY 18 Factor | From BY | CY 18 Factor |
|---|---|---|---|---|---|
| 1965 | 0.150338 | 1986 | 0.521567 | 2007 | 0.844009 |
| 1966 | 0.154397 | 1987 | 0.535649 | 2008 | 0.864265 |
| 1967 | 0.159338 | 1988 | 0.551719 | 2009 | 0.877229 |
| 1968 | 0.165074 | 1989 | 0.574891 | 2010 | 0.884247 |
| 1969 | 0.172832 | 1990 | 0.597887 | 2011 | 0.901932 |
| 1970 | 0.182338 | 1991 | 0.623596 | 2012 | 0.918167 |
| 1971 | 0.191637 | 1992 | 0.641057 | 2013 | 0.931939 |
| 1972 | 0.200453 | 1993 | 0.658365 | 2014 | 0.945918 |
| 1973 | 0.209273 | 1994 | 0.671532 | 2015 | 0.956323 |
| 1974 | 0.225596 | 1995 | 0.684292 | 2016 | 0.967799 |
| 1975 | 0.249960 | 1996 | 0.697977 | 2017 | 0.984252 |
| 1976 | 0.267208 | 1997 | 0.712635 | *2018* | *1.000000* |
| 1977 | 0.285378 | 1998 | 0.717623 | 2019 | 1.017000 |
| 1978 | 0.304783 | 1999 | 0.723364 | 2020 | 1.036323 |
| 1979 | 0.334043 | 2000 | 0.733491 | 2021 | 1.057049 |
| 1980 | 0.368783 | 2001 | 0.746694 | 2022 | 1.078190 |
| 1981 | 0.412668 | 2002 | 0.752668 | 2023 | 1.099754 |
| 1982 | 0.450634 | 2003 | 0.760194 | 2024 | 1.121749 |
| 1983 | 0.472715 | 2004 | 0.775398 | 2025 | 1.144184 |
| 1984 | 0.490678 | 2005 | 0.797110 | 2026 | 1.167068 |
| 1985 | 0.507361 | 2006 | 0.821820 | 2027 | 1.190409 |

## Appendix B

### Table B1: Factors Affecting Construction Project Cost Overruns

| | GAO 1981 | Jahren & Ashe 1990 | Federle & Pigneri 1993 | Zetner 1996 | Flyvberg 2002 | Giegerich, 2002 | Trost 2003 | Harbuck, 2004 | Thal, Cook & White 2010 |
|---|---|---|---|---|---|---|---|---|---|
| **Unforeseen Changes** | | | | | | | | | |
| Changes in Scope/Requirements or Change Orders | ✓ | ✓ | | ✓ | | ✓ | | ✓ | |
| Changes in Schedule or Delays | | | | | | ✓ | | ✓ | |
| Changes in Anticipated Bid Opening Date | ✓ | | | | | | | | |
| Changes in Site Location | ✓ | | | | | | | | |
| **Bidding Environment and Contractor Behavior** | | | | | | | | | |
| Contract Bidder Interest in Project or Number of Bids | ✓ | ✓ | ✓ | | | | ✓ | ✓ | ✓ |
| Ratio/Difference: Low Bid to Government/Engineer Estimate | | ✓ | ✓ | | | | | | ✓ |
| Contractor History or Unsatisfactory Performance | | | ✓ | | | ✓ | | | |
| Disputes or Claims | | ✓ | | | | ✓ | | | |
| Bid Range: Highest to Lowest Bid | | | ✓ | | | | | | |
| **Design Process** | | | | | | | | | |
| Changes, Errors, or Ambiguity in Design | ✓ | | | | | | | ✓ | |
| Design Effort or Funds Available for Design | | | ✓ | ✓ | | ✓ | | | ✓ |
| Design Complexity | | | | | | ✓ | | | |
| Design Length | | | | | | | | | ✓ |
| **External Factors** | | | | | | | | | |
| Fluctuations in Labor/Material Costs or Economics | ✓ | | | | | | ✓ | | |
| Local Government/Permitting Agencies or Politics | | | | | ✓ | | | ✓ | |
| **Project Features** | | | | | | | | | |
| Construction Type | | ✓ | ✓ | | ✓ | | | | ✓ |
| Location or Site Requirements | | | ✓ | | ✓ | | ✓ | | |
| Size | | ✓ | | | | | | | |
| Construction Duration/Length | | | ✓ | | | | | | |
| **Estimation Process** | | | | | | | | | |
| Cost Information Available | | | | | | | ✓ | | |
| Estimator Team Experience | | | | | | | ✓ | | |
| Estimate Effort or Time Allowed to Prepare Estimate | | | | | | | ✓ | | |
| **Leadership** | | | | | | | | | |
| Improper Scope Definition | | | | ✓ | | | | | |
| Lack of Estimate Accountability | | | | ✓ | | | | | |
| Strategic Misrepresentation | | | | | ✓ | | | | |
| Supervision Effort/Management Involvement | | | ✓ | ✓ | | ✓ | ✓ | | |

## Appendix C

### Table C1: 32 Programs Included in Program MILCON Database

| | Weapon System Type | Total Years Reported | Final SAR? |
|---|---|---|---|
| Program 1 | Missile | 9 | Yes |
| Program 2 | Launch Vehicle | 11 | Yes |
| Program 3 | Aircraft | 7 | Yes |
| Program 4 | Aircraft | 7 | Yes |
| Program 5 | Aircraft | 10 | Yes |
| Program 6 | Missile | 9 | Yes |
| Program 7 | Missile | 12 | Yes |
| Program 9 | Aircraft | 9 | Yes |
| Program 10 | Satellite | 14 | Yes |
| Program 12 | Aircraft | 7 | Yes |
| Program 13 | Satellite | 16 | Yes |
| Program 14 | Satellite | 14 | Yes |
| Program 15 | Launch Vehicle | 11 | Yes |
| Program 16 | Missile | 9 | Yes |
| Program 19 | Launch Vehicle | 9 | Yes |
| Program 20 | Aircraft | 26 | Yes |
| Program 21 | Aircraft | 19 | Yes |
| Program 22 | Launch Vehicle | 17 | Yes |
| Program 23 | Aircraft | 25 | Yes |
| Program 25 | Aircraft | 10 | Yes |
| Program 28 | Electronic | 8 | Yes |
| Program 29 | Electronic | 23 | Yes |
| Program 30 | Aircraft | 21 | Yes |
| Program 31 | Aircraft | 22 | N/A |
| Program 32 | Satellite | 22 | N/A |
| Program 33 | Aircraft | 16 | Yes |
| Program 34 | Aircraft | 14 | Yes |
| Program 36 | Aircraft | 10 | Yes |
| Program 38 | Aircraft | 9 | N/A |
| Program 39 | Aircraft | 8 | N/A |
| Program 40 | Aircraft | 7 | N/A |
| Program 41 | Aircraft | 4 | N/A |

**Table C2: 10 Programs Included in Project MILCON Database**

| | Commodity | Total Years Reported | Total Projects | First Project Date (After First SAR) | Total Bases | % Projects Complete | % Projects Underway + Complete | % Expenditures of Programmed | % Obligations of Programmed |
|---|---|---|---|---|---|---|---|---|---|
| **Program 20** | Aircraft | 26 | 58 | 16 Years | 8 | 100.00% | 100.00% | 89.96% | 95.64% |
| **Program 23** | Aircraft | 25 | 48 | 15 Years | 8 | 97.92% | 100.00% | 90.26% | 97.90% |
| **Program 30** | Aircraft | 21 | 2 | 11 Years | 2 | 100.00% | 100.00% | 110.10% | 110.10% |
| **Program 31** | Aircraft | 22 | 23 | 7 Years | 6 | 65.22% | 86.96% | 55.65% | 57.99% |
| **Program 32** | Satellite | 22 | 4 | 5 Years | 2 | 75.00% | 75.00% | 31.69% | 30.38% |
| **Program 33** | Aircraft | 16 | 1 | 9 Years | 1 | 100.00% | 100.00% | 112.40% | 112.40% |
| **Program 34** | Aircraft | 14 | 10 | 2 Years | 3 | 100.00% | 100.00% | 89.70% | 89.79% |
| **Program 39** | Aircraft | 8 | 17 | 1 Year | 4 | 58.82% | 76.47% | 39.97% | 41.24% |
| **Program 40** | Aircraft | 7 | 47 | 3 Years | 5 | 44.68% | 63.83% | 44.22% | 52.39% |
| **Program 41** | Aircraft | 4 | 6 | - 11 Years | 3 | 50.00% | 66.67% | 34.51% | 45.63% |

# Appendix D

## Table D1: Variables from Summarized Program MILCON Data for Cost Growth Analysis (Both Databases)

| Database 1 32 Prgms | Database 2 10 Prgms | Variable [DV] = Dummy Variable | Descriptive Statistics Use | Contingency Table Use | Type | Description |
|---|---|---|---|---|---|---|
| *Cost Estimate Variables* | | | | | | |
| X | X | First SAR MILCON Estimate | | | Continuous | MILCON cost estimate value from first reported SAR in FY18 unit of millions |
| X | X | 1st Quartile SAR MILCON Estimate | | | Continuous | Using =QUARTILE.EXC(array,1) in Excel, SAR month was rounded up to actual SAR report; MILCON cost estimate for report representing 25th percentile of reports for program |
| X | X | 2nd Quartile SAR MILCON Estimate | | | Continuous | Using =QUARTILE.EXC(array,2) in Excel, SAR month was rounded up to actual SAR report; MILCON cost estimate for report representing 50th percentile of reports for program |
| X | X | 3rd Quartile SAR MILCON Estimate | | | Continuous | Using =QUARTILE.EXC(array,3) in Excel, SAR month was rounded up to actual SAR report; MILCON cost estimate for report representing 75th percentile of reports for program |
| X | X | Average SAR MILCON Estimate | | | Continuous | Using =AVERAGE(array) in Excel, average MILCON cost estimate was identified for program |
| X | X | Median SAR MILCON Estimate | | | Continuous | Using =MEDIAN(array) in Excel, median MILCON cost estimate was identified for program |
| X | X | Minimum SAR MILCON Estimate | | | Continuous | Using =MIN(array) in Excel, minimum MILCON cost estimate was identified for program |
| X | X | Maximum SAR MILCON Estimate | | | Continuous | Using =MAX(array) in Excel, maximum MILCON cost estimate was identified for program |
| X | X | Last SAR MILCON Estimate | | | Continuous | MILCON cost estimate value from last reported SAR in FY18 unit of millions |
| X | X | [DV] x2 Last SAR MILCON | | Independent | Binary | DV for MILCON cost estimate of < $10M and < $50M |
| X | X | Last SAR Total Program Estimate | | | Continuous | Total program cost estimate value from last reported SAR in FY18 unit of millions |
| X | X | [DV] x2 Last SAR Total Program | | Independent | Binary | DV for program cost estimate of > $1B and > $10B |
| | X | Total Programmed Funds for Projects | | | Continuous | Summation value of programmed funds for all projects within a program in Fiscal Year 2018 unit of millions |
| | X | [DV] x2 Total Programmed Funds | | Independent | Binary | DV for value of total programmed funds for all listed projects < $50M and >$400M |
| *Cost Growth Variables (Measured to Last SAR MILCON Estimate)* | | | | | | |
| X | | Growth First to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by first MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Average Growth per Year | | | Continuous | Total growth from first to last MILCON estimates divided by total years between reports |
| X | | Growth First to Last SAR Percent | % | | Percentage | Total growth from first to last MILCON estimates divided by last reported total program estimate |
| X | | [DV] x3 Growth First to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| X | | Growth 1st Quartile to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by 1st quartile MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth 1st Quartile to Last SAR Percentage | % | | Percentage | Total growth from 1st quartile report to last MILCON estimate divided by last reported total program estimate |
| X | | [DV] x3 Growth 1st Quartile to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| X | | Growth 2nd Quartile to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by 2nd quartile MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth 2nd Quartile to Last SAR Percentage | % | | Percentage | Total growth from 2nd quartile report to last MILCON estimate divided by last reported total program estimate |
| X | | [DV] x3 Growth 2nd Quartile to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| X | | Growth 3rd Quartile to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by 3rd quartile MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth 3rd Quartile to Last SAR Percentage | % | | Percentage | Total growth from 3rd quartile report to last MILCON estimate divided by last reported total program estimate |
| X | | [DV] x3 Growth 3rd Quartile to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |

| Database 1 32 Prgms | Database 2 10 Prgms | Variable [DV] = Dummy Variable | Descriptive Statistics Use | Contingency Table Use | Type | Description |
|---|---|---|---|---|---|---|
| X | | Growth Average to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by average MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth Average to Last SAR Percentage | % | | Percentage | Total growth from average estimate of reports to last MILCON estimate divided by last reported total program estimate |
| X | | [DV] x3 Growth Avergae to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| X | | Growth Median to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by median MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth Median to Last SAR Percentage | % | | Percentage | Total growth from median estimate of reports to last MILCON estimate divided by last reported total program estimate |
| X | | [DV] x3 Growth Median to Last | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| X | | Growth Minimum to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by minimum MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth Minimum to Last SAR Percent | % | | Percentage | Total growth from minimum estimate of reports to last MILCON estimate divided by last reported total program estimate |
| X | | Growth Maximum to Last SAR Amount | $ | | Continuous | Last MILCON estimate subtracted by maximum MILCON estimate in unit of millions; negative growth is cost savings |
| X | | Growth Maximum to Last SAR Percentage | % | | Percentage | Total growth from maximum estimate of reports to last MILCON estimate divided by last reported total program estimate |
| *Cost Growth Variables (Measured to Project Programmed Funds)* | | | | | | |
| | X | Growth First SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by first SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth 1st SAR to Programmed Funds Percentage | % | | Percentage | Total growth from first SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth First to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth 1st Quartile SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by 1st quartile SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth 1st Quartile SAR to Programmed Funds Percentage | % | | Percentage | Total growth from 1st quartile SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth 1st Quartile to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth 2nd Quartile SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by 2nd quartile SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth 2nd Quartile SAR to Programmed Funds Percentage | % | | Percentage | Total growth from 2nd quartile SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth 2nd Quartile to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth 3rd Quartile SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by 3rd quartile SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth 3rd Quartile SAR to Programmed Funds Percentage | % | | Percentage | Total growth from 3rd quartile SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth 3rd Quartile to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth Last SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by last SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth Last SAR to Programmed Funds Percentage | % | | Percentage | Total growth from last SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth Last to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth Average SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by average SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth Average SAR to Programmed Funds Percentage | % | | Percentage | Total growth from average SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth Average to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |

| Database 1 32 Prgms | Database 2 10 Prgms | Variable [DV] = Dummy Variable | Descriptive Statistics Use | Contingency Table Use | Type | Description |
|---|---|---|---|---|---|---|
| | X | Growth Median SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by median SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth Median SAR to Programmed Funds Percentage | % | | Percentage | Total growth from median SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | [DV] x3 Growth Median to Programmed | | Dependent | Binary | DV for positive cost growth, >\|1%\| cost growth, and >\|2%\| cost growth |
| | X | Growth Minimum SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by minimum SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth Minimum SAR to Programmed Funds Percentage | % | | Percentage | Total growth from minimum SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | Growth Maximum SAR to Programmed Funds Amount | $ | | Continuous | Programmed MILCON estimate subtracted by maximum SAR MILCON estimate in unit of millions; negative growth is cost savings |
| | X | Growth Maximum SAR to Programmed Funds Percentage | % | | Percentage | Total growth from maximum SAR to programmed MILCON estimate divided by last reported total program estimate |
| | X | (x 9) Same Growth Measurements to Obligated Funds (Construction Complete) Amount | $ | | | Obligated MILCON estimate (for projects with construction complete or financially closed out) subtracted by various SAR MILCON estimate in unit of millions |
| | X | (x 9) Same Growth Measurements to Obligated Funds (Construction Complete) Percentage | % | | | Total growth from various SAR estimates to obligated MILCON estimate (for projects with construction complete or financially closed out) divided by last reported total program estimate |
| | X | (x 9) Same Growth Measurements to Obligated Funds (Construction Underway) Amount | $ | | | Obligated MILCON estimate (for projects with construction underway or complete or financially closed out) subtracted by various SAR MILCON estimate in unit of millions |
| | X | (x 9) Same Growth Measurements to Obligated Funds (Construction Underway) Percentage | % | | | Total growth from various SAR estimates to obligated MILCON estimate (for projects with construction underway or complete or financially closed out) divided by last reported total program estimate |
| *Program Variables* | | | | | | |
| X | X | Commodity | | | Categorical | Type of MDAP weapon system |
| X | | [DV] x5 Commodity | | Independent | Binary | DV for aircraft, electronic, launch vehicle, missile, and satellite commodity |
| X | X | [DV] Prototype | | Independent | Binary | Did MDAP have a prototype developed? |
| X | X | [DV] Modification | | Independent | Binary | Was MDAP a modification program? |
| X | X | Base Year | | | Interval | First base year used for values reported on SAR |
| X | | [DV] x2 Base Year | | Independent | Binary | DV for base year 1960-1979 and base year 1980-1999 |
| | X | [DV] x1 Base Year | | Independent | Binary | DV for base year ≥ 2000 |
| X | X | Total Years of SARs Reporting | | | Interval | Last SAR reported year subtracted by first SAR reported year |
| X | X | [DV] x3 Years of Reports | | Independent | Binary | DV for < 5 years, < 10 years, and ≥ 15 years |
| X | X | First SAR MILCON Cost to Program Cost Ratio | | | Percentage | First SAR's MILCON estimate divided by total program costs from first SAR |
| X | X | Last SAR MILCON Cost to Program Cost Ratio | | | Percentage | Last SAR's MILCON estimate divided by total program costs from last SAR |
| X | X | Average MILCON Cost to Program Cost Ratio | | | Percentage | Average percent of MILCON costs divided by total program costs from all reported SARs |
| X | | [DV] x3 Average MILCON Cost to Program Cost | | Independent | Binary | DV for < 0.5%, > 1%, and > 5% MILCON to total program costs |
| X | X | [DV] All Reports Not Verified in DAMIR | | | Binary | Were any program SARs from years prior to 1997 and therefore not verified in DAMIR? |
| | X | Total Projects | | | Continuous | Summation value of projects located in ACES-PM with keyword search of the program |
| | X | [DV] Total Projects | | Independent | Binary | DV for programs with < 10 projects |
| | X | Oldest Project Fiscal Year | | | Interval | The fiscal year of the oldest project found for the program in ACES-PM |
| | X | Newest Project Fiscal Year | | | Interval | The fiscal year of the newest project found for the program in ACES-PM |
| | X | Number of Bases | | | Continuous | The amount of different bases which had projects listed in ACES-PM for the program |
| | X | [DV] Number of Bases | | Independent | Binary | DV for programs with projects at < 4 different bases |
| | X | Number of OCONUS Bases | | | Continuous | The amount of different overseas bases which had projects listed in ACES-PM for the program |
| | X | [DV] OCONUS Bases | | Independent | Binary | Were any projects for the program listed for an overseas base? |
| | X | Number of OCONUS Projects | | | Continuous | Summation value of overseas projects located in ACES-PM with keyword search of the program |

| Database 1 32 Prgms | Database 2 10 Prgms | Variable [DV] = Dummy Variable | Descriptive Statistics Use | Contingency Table Use | Type | Description |
|---|---|---|---|---|---|---|
| | X | Number of Projects in Stages (x5) | | | Continuous | Summation value of projects in various stages of completion: financial and project closeout complete (HIS), construction complete (CMP), construction underway (CNS), design in progress (DSG), bid open/contractor selection in progress/ready to advertise (BID/RTA) |
| | X | Percent of Projects in DSG or BID/RTA Stage | | | Percentage | The number of projects still in design or bidding/ready to advertise stage divided by total projects for the program |
| | X | Number of Total Contracts | | | Continuous | Summation value of total contracts awarded for all listed projects within a program |
| | X | Number of Different Contractor Companies for Projects | | | Continuous | Number of different/separate contractor companies who were awarded a contract for all listed projects within a program |
| | X | [DV] Different Contractor Companies | | Independent | Binary | DV for < 10 different contractor companies awarded contracts for projects within program |
| | X | Oldest Contract Award | | | Interval | Date of oldest contract award for project within program |
| | X | Newest Contract Award | | | Interval | Date of newest contract award for project within program |
| | X | Total Performance Period Days Contracted | | | Continuous | Summation value of performance period days on contract for all projects within program; modifications not included |
| | X | [DV] x2 Performance Period Days on Contract | | Independent | Binary | DV for summation of performance period days on contract for all projects within program at < 5,000 days and <10,000 days |
| | X | Total Contract Award Amount | | | Continuous | Summation value of all contract awards for projects within program in Fiscal Year 2018 unit of millions |
| | X | Number of Projects with Contract Modification | | | Continuous | Number of projects within program that have at least one contract modification reported |
| | X | Number of Contracts with Modifications | | | Continuous | Number of contracts within program that have at least one modification reported |
| | X | Number of Contract Modifications | | | Continuous | Number of contract modifications reported for projects within program |
| | X | [DV] x2 Contract Modifications | | Independent | Binary | DV for < 50 and < 200 contract modifications within a single program for all projects listed |
| | X | First Contract Modification | | | Interval | Date of first reported contract modification for project within program |
| | X | Last Contract Modification | | | Interval | Date of latest reported contract modification for project within program |
| | X | Total Contract Modifications Amount | | | Continuous | Summation value of all contract modifications reported for all projects within program |
| | X | [DV] Contract Modifications Amount | | Independent | Binary | DV for < $10M and < $3M total in contract modifications for projects within program |
| | X | Total Contract and Modification Amount | | | Continuous | Summation value of contract awards plus contract modifications for all projects within program |
| | X | Percent of Projects with Contract Modifications | | | Percentage | Number of projects with contract modifications divided by total number of projects for program |
| | X | [DV] Percent of Projects with Contract Modifications | | Independent | Binary | DV for < 75% of projects within program reporting at least one contract modification |
| | X | Percent of Contracts with Modifications | | | Percentage | Number of contracts with modifications divided by total number of contracts for program |
| | X | [DV] Percent of Contracts with Modifications | | Independent | Binary | DV for < 75% of contracts within program reporting at least one modification |

# Appendix E

| KEY |
|---|
| ≤ 0.5% (Best) |
| ≤ 1.0% (Better) |
| ≤ 2.0% (Good) |

**Table E1: Descriptive Statistics of Cost Growth to Last SAR in Percentage (32 Programs)**

| | % of Cost Growth to Total Program Cost | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First to Last SAR | Q1 to Last SAR | Q2 to Last SAR | Q3 to Last SAR | AVG to Last SAR | MED to Last SAR | MIN to Last SAR | MAX to Last SAR |
| Mean | -0.11% | -0.07% | -0.16% | -0.24% | -0.14% | -0.06% | 0.62% | -0.99% |
| Std Dev | 1.62% | 1.64% | 0.97% | 0.73% | 0.52% | 0.64% | 1.28% | 1.20% |
| Max | 5.39% | 6.69% | 1.35% | 0.31% | 0.84% | 1.20% | 6.69% | 0.00% |
| 3rd Quartile | 0.90% | 0.14% | 0.04% | 0.00% | 0.02% | 0.01% | 0.90% | -0.07% |
| Median | -0.03% | -0.02% | 0.00% | 0.00% | -0.04% | 0.00% | 0.09% | -0.46% |
| 1st Quartile | -1.04% | -0.48% | -0.04% | -0.01% | -0.21% | -0.03% | 0.00% | -1.99% |
| Min | -3.21% | -3.09% | -4.44% | -2.85% | -1.87% | -2.30% | 0.00% | -4.44% |

**Table E2: Descriptive Statistics of Cost Growth to Last SAR in Dollar Value (32 Programs)**

| | $ Amounts of Cost Growth | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First to Last SAR | Q1 to Last SAR | Q2 to Last SAR | Q3 to Last SAR | AVG to Last SAR | MED to Last SAR | MIN to Last SAR | MAX to Last SAR |
| Mean | -$28.50 | -$24.34 | $8.24 | -$2.51 | -$6.18 | $7.63 | $30.86 | -$56.54 |
| Std Dev | $177.16 | $132.72 | $34.77 | $20.56 | $52.58 | $32.19 | $62.31 | $161.85 |
| Max | $207.06 | $131.77 | $139.05 | $70.74 | $108.59 | $122.96 | $238.61 | $0.00 |
| 3rd Quartile | $14.88 | $3.59 | $1.63 | $0.00 | $0.44 | $0.12 | $30.35 | -$0.64 |
| Median | -$0.13 | -$0.11 | $0.00 | $0.00 | -$0.43 | $0.00 | $1.14 | -$10.36 |
| 1st Quartile | -$14.19 | -$10.53 | -$1.54 | -$0.05 | -$3.49 | -$0.64 | $0.01 | -$27.64 |
| Min | -$859.77 | -$633.47 | -$35.58 | -$76.75 | -$217.17 | -$35.58 | $0.00 | -$859.77 |

**Table E3: Descriptive Statistics of Cost Growth to Programmed Funds in Percentage (10 Programs)**

| | % of Cost Growth to Total Program Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Programmed | Q1 to Programmed | Q2 to Programmed | Q3 to Programmed | Last to Programmed | AVG to Programmed | MED to Programmed | MIN to Programmed | MAX to Programmed |
| Mean | 0.43% | 0.27% | 0.41% | 0.05% | 0.33% | 0.28% | 0.39% | 1.07% | -0.46% |
| Std Dev | 2.81% | 2.39% | 1.85% | 1.99% | 2.10% | 2.05% | 1.86% | 2.04% | 2.51% |
| Max | 3.12% | 2.92% | 2.86% | 2.10% | 3.67% | 2.63% | 2.86% | 3.67% | 1.95% |
| 3rd Quartile | 2.50% | 2.07% | 1.65% | 1.58% | 1.69% | 1.87% | 1.63% | 2.66% | 1.49% |
| Median | 1.05% | 0.41% | 0.39% | 0.47% | 0.48% | 0.51% | 0.42% | 1.10% | 0.30% |
| 1st Quartile | -0.46% | -0.52% | -0.15% | -0.65% | -0.47% | -0.56% | -0.16% | 0.12% | -2.12% |
| Min | -6.23% | -5.63% | -3.92% | -4.17% | -3.96% | -4.54% | -3.96% | -3.34% | -6.23% |

**Table E4: Descriptive Statistics of Cost Growth to Programmed Funds in Dollar Value (10 Programs)**

| | $ Amounts of Cost Growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Programmed | Q1 to Programmed | Q2 to Programmed | Q3 to Programmed | Last to Programmed | AVG to Programmed | MED to Programmed | MIN to Programmed | MAX to Programmed |
| Mean | -$122.42 | -$105.97 | -$40.62 | -$76.18 | -$71.18 | -$74.82 | -$44.96 | $14.65 | -$190.18 |
| Std Dev | $820.41 | $738.28 | $540.36 | $551.41 | $521.11 | $605.02 | $543.98 | $492.45 | $781.50 |
| Max | $564.85 | $478.72 | $496.85 | $428.53 | $357.79 | $466.39 | $479.45 | $564.85 | $357.79 |
| 3rd Quartile | $236.53 | $229.00 | $173.41 | $126.21 | $120.99 | $173.90 | $174.66 | $238.62 | $112.95 |
| Median | $30.39 | $21.52 | $20.35 | $22.38 | $31.66 | $22.92 | $20.92 | $40.35 | $15.50 |
| 1st Quartile | -$52.21 | -$28.52 | -$4.92 | -$19.14 | -$13.92 | -$34.69 | -$4.48 | $4.56 | -$113.56 |
| Min | -$2,364.35 | -$2,138.06 | -$1,485.87 | -$1,581.33 | -$1,504.59 | -$1,721.76 | -$1,504.59 | -$1,265.98 | -$2,364.35 |

**Table E5: Descriptive Statistics of Cost Growth to Obligated Funds in Percentage (10 Programs - Construction Complete)**

| | % of Cost Growth to Total Program Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Obligated: Construction Complete | Q1 to Obligated: Construction Complete | Q2 to Obligated: Construction Complete | Q3 to Obligated: Construction Complete | Last to Obligated: Construction Complete | AVG to Obligated: Construction Complete | MED to Obligated: Construction Complete | MIN to Obligated: Construction Complete | MAX to Obligated: Construction Complete |
| Mean | -0.37% | -0.53% | -0.39% | -0.75% | -0.47% | -0.51% | -0.41% | 0.27% | -1.26% |
| Std Dev | 3.18% | 2.77% | 2.24% | 2.27% | 2.19% | 2.40% | 2.25% | 2.26% | 2.85% |
| Max | 2.97% | 2.77% | 2.71% | 1.95% | 1.88% | 2.49% | 2.71% | 3.03% | 1.80% |
| 3rd Quartile | 1.76% | 1.06% | 0.72% | 0.81% | 1.17% | 0.87% | 0.74% | 1.84% | 0.54% |
| Median | 0.10% | -0.03% | -0.15% | -0.37% | -0.15% | -0.07% | -0.13% | 0.47% | -0.44% |
| 1st Quartile | -0.93% | -1.26% | -1.11% | -1.53% | -1.34% | -1.22% | -1.13% | -0.39% | -2.81% |
| Min | -8.03% | -7.43% | -5.71% | -5.96% | -5.76% | -6.33% | -5.76% | -5.13% | -8.03% |

**Table E6: Descriptive Statistics of Cost Growth to Obligated Funds in Dollar Value (10 Programs - Construction Complete)**

| | $ Amounts of Cost Growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Obligated: Construction Complete | Q1 to Obligated: Construction Complete | Q2 to Obligated: Construction Complete | Q3 to Obligated: Construction Complete | Last to Obligated: Construction Complete | AVG to Obligated: Construction Complete | MED to Obligated: Construction Complete | MIN to Obligated: Construction Complete | MAX to Obligated: Construction Complete |
| Mean | -$231.94 | -$215.49 | -$150.03 | -$185.69 | -$164.90 | -$184.34 | -$154.48 | -$94.87 | -$299.70 |
| Std Dev | $1,018.72 | $935.73 | $733.96 | $747.30 | $722.72 | $801.50 | $738.16 | $682.54 | $982.52 |
| Max | $505.48 | $419.34 | $437.47 | $369.15 | $298.42 | $407.01 | $420.07 | $505.48 | $298.42 |
| 3rd Quartile | $176.20 | $149.22 | $113.55 | $94.36 | $111.72 | $115.45 | $115.25 | $182.42 | $77.98 |
| Median | $3.76 | -$2.77 | -$11.00 | -$20.08 | $20.35 | -$5.08 | -$9.53 | $11.66 | -$20.15 |
| 1st Quartile | -$99.40 | -$65.61 | -$46.48 | -$91.46 | -$60.48 | -$71.78 | -$51.10 | -$39.27 | -$150.65 |
| Min | -$3,046.91 | -$2,820.62 | -$2,168.43 | -$2,263.89 | -$2,187.15 | -$2,404.32 | -$2,187.15 | -$1,948.54 | -$3,046.91 |

**Table E7: Descriptive Statistics of Cost Growth to Obligated Funds in Percentage (10 Programs - Construction Underway)**

| | % of Cost Growth to Total Program Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Obligated: Construction Underway | Q1 to Obligated: Construction Underway | Q2 to Obligated: Construction Underway | Q3 to Obligated: Construction Underway | Last to Obligated: Construction Underway | AVG to Obligated: Construction Underway | MED to Obligated: Construction Underway | MIN to Obligated: Construction Underway | MAX to Obligated: Construction Underway |
| Mean | -0.21% | -0.38% | -0.24% | -0.59% | -0.32% | -0.36% | -0.26% | 0.42% | -1.10% |
| Std Dev | 3.04% | 2.64% | 2.11% | 2.15% | 2.04% | 2.27% | 2.12% | 2.12% | 2.71% |
| Max | 2.97% | 2.77% | 2.71% | 1.95% | 1.88% | 2.49% | 2.71% | 3.03% | 1.80% |
| 3rd Quartile | 1.82% | 1.41% | 0.77% | 0.86% | 1.22% | 0.93% | 0.79% | 1.89% | 0.59% |
| Median | 0.10% | 0.02% | -0.04% | -0.13% | -0.03% | -0.02% | -0.02% | 0.64% | -0.19% |
| 1st Quartile | -0.81% | -1.21% | -1.03% | -1.47% | -1.20% | -1.17% | -1.09% | -0.26% | -2.76% |
| Min | -7.42% | -6.82% | -5.11% | -5.36% | -5.15% | -5.73% | -5.15% | -4.53% | -7.42% |

**Table E8: Descriptive Statistics of Cost Growth to Obligated Funds in Dollar Value (10 Programs - Construction Underway)**

| | $ Amounts of Cost Growth | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | First to Obligated: Construction Underway | Q1 to Obligated: Construction Underway | Q2 to Obligated: Construction Underway | Q3 to Obligated: Construction Underway | Last to Obligated: Construction Underway | AVG to Obligated: Construction Underway | MED to Obligated: Construction Underway | MIN to Obligated: Construction Underway | MAX to Obligated: Construction Underway |
| Mean | -$198.090 | -$181.638 | -$116.286 | -$151.845 | -$146.850 | -$150.489 | -$120.629 | -$61.020 | -$265.854 |
| Std Dev | $952.908 | $869.536 | $669.118 | $681.463 | $651.911 | $735.803 | $673.114 | $619.094 | $915.282 |
| Max | $552.974 | $466.835 | $484.967 | $416.649 | $345.914 | $454.508 | $467.570 | $552.974 | $345.914 |
| 3rd Quartile | $180.139 | $172.608 | $117.019 | $94.364 | $92.276 | $117.513 | $118.268 | $182.423 | $77.983 |
| Median | $3.756 | $0.874 | -$3.164 | -$9.349 | -$2.774 | -$2.017 | -$1.550 | $11.662 | -$14.269 |
| 1st Quartile | -$88.496 | -$60.169 | -$41.044 | -$86.016 | -$69.031 | -$66.339 | -$45.660 | -$28.366 | -$145.207 |
| Min | -$2,816.165 | -$2,589.870 | -$1,937.683 | -$2,033.145 | -$1,956.399 | -$2,173.568 | -$1,956.400 | -$1,717.792 | -$2,816.165 |
| Upper 95% Mean | $483.579 | $440.391 | $362.372 | $335.644 | $319.500 | $375.872 | $360.887 | $381.854 | $388.899 |
| Lower 95% Mean | -$879.760 | -$803.666 | -$594.944 | -$639.334 | -$613.199 | -$676.851 | -$602.146 | -$503.893 | -$920.607 |

## Appendix F

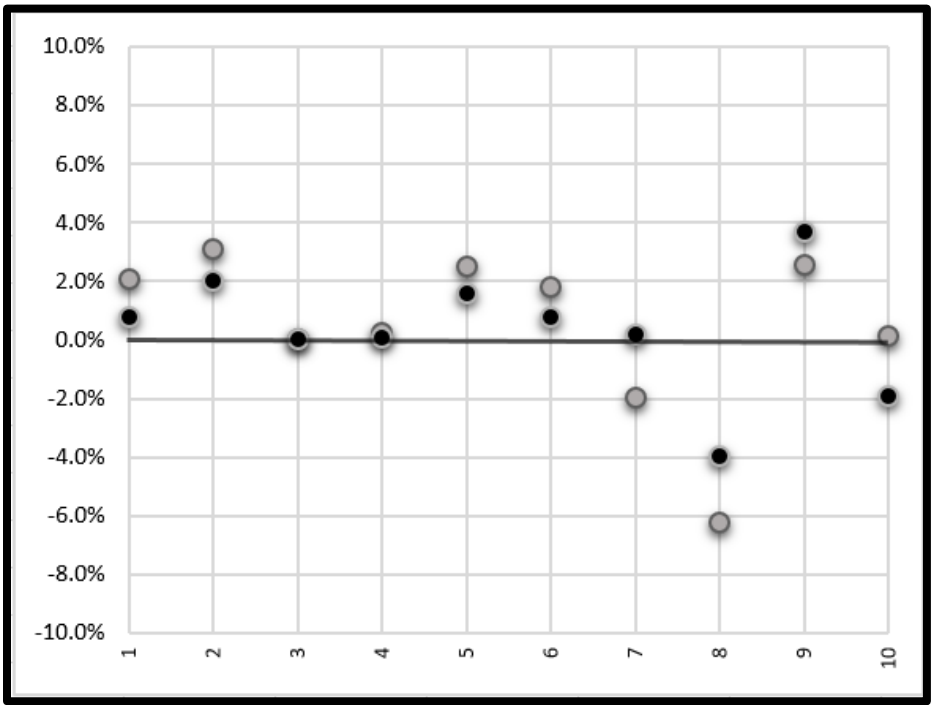


**Figure F1: Cost Growth Percentage from First (Grey) and Last (Black) SAR to Programmed Amounts**

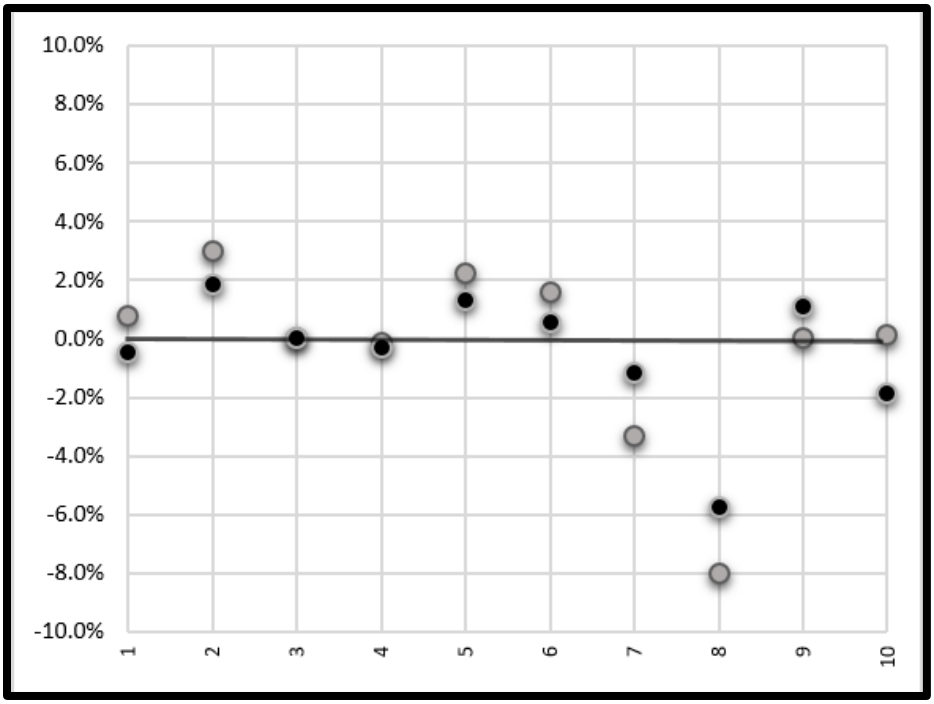


**Figure F2: Cost Growth Percentage from First (Grey) and Last (Black) SAR to Obligated Amounts – Construction Complete**

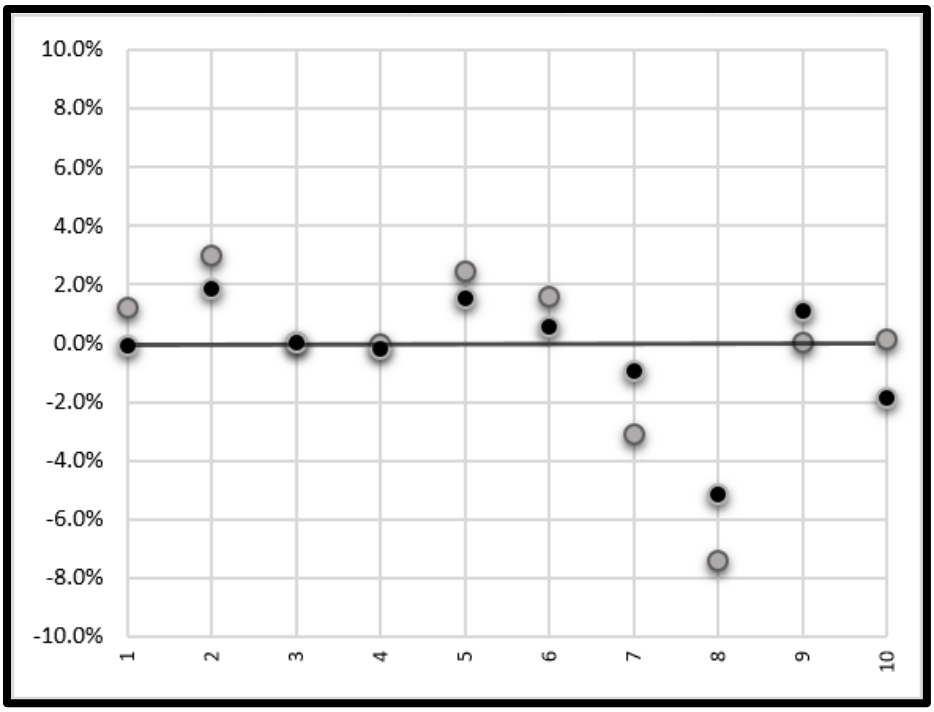


**Figure F3: Cost Growth Percentage from First (Grey) and Last (Black) SAR to Obligated Amounts – Construction Underway**

# Appendix G

## Table G1: Program MILCON Database Contingency Table Significance Results (32 Programs)

**Table Legend:**
* p-value < 0.10
** p-value < 0.05
*** p-value < 0.01
L left-tail significance
R right-tail significance

| | <5 Years of Reports | <10 Years of Reports | ≥15 Years of Reports | Prototype | Modification | Aircraft | Electronic | Launch Vehicle | Missile | Satellite | <0.5% Avg MILCON % to Total | >1% Avg MILCON % to Total | >5% Avg MILCON % to Total | <$10M MILCON on Last SAR | <$50M MILCON on Last SAR | >$1B Total Program on Last SAR | >$10B Total Program on Last SAR | 60's-70's Base Year | 80's-90's Base Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First to Last (Positive Growth) | | L *** | R *** | R ** | | | | | | | | | | L ** | | | | | |
| First to Last (>\|1%\| Growth) | | | | | | | | | | | L ** | R ** | R * | L * | L * | | R * | | |
| First to Last (>\|2%\| Growth) | | | | | | R * | | | | | L * | R ** | | | | | R * | | |
| Q1 to Last (Positive Growth) | | | | R * | | | | | | | | | | L ** | | | | | |
| Q1 to Last (>\|1%\| Growth) | | | | | | | | | | | L ** | | R ** | | | | | | |
| Q1 to Last (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | |
| Q2 to Last (Positive Growth) | | | | | | R *** | | | | | | | | | L *** | R * | R ** | L ** | R * |
| Q2 to Last (>\|1%\| Growth) | | | | | | | | | R * | | | | R ** | | | | | | |
| Q2 to Last (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | |
| Q3 to Last (Positive Growth) | | | R ** | | | R ** | | | | | | | | | | R * | R * | L ** | R * |
| Q3 to Last (>\|1%\| Growth) | | | | | | L * | | | R ** | | | | R ** | | | | | | |
| Q3 to Last (>\|2%\| Growth) | | | | | | L * | | | R ** | | | | R ** | | | | | | |
| MED to Last (Positive Growth) | | | R * | | | R ** | | | | | | | | | | | | | |
| MED to Last (>\|1%\| Growth) | | L * | | | | | | | | | | | | | | | | | |
| MED to Last (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | |
| AVG to Last (Positive Growth) | | | R * | | | R ** | | | | | | | | | L * | | | | |
| AVG to Last (>\|1%\| Growth) | | | | | | | | | | | | | | | | | | | |
| AVG to Last (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | |
| **Total Significant Contingency Tables** | **0** | **2** | **4** | **2** | **0** | **7** | **0** | **0** | **3** | **0** | **3** | **2** | **5** | **3** | **3** | **2** | **4** | **2** | **2** |

**Table G2: Project MILCON Database Contingency Table Significance Results (10 Programs)**

**Table Legend:**
* p-value < 0.10
** p-value < 0.05
*** p-value < 0.01
L left-tail significance
R right-tail significance

| | <5 Years of Reports | <10 Years of Reports | ≥15 Years of Reports | Protype | Modification | Aircraft | <10 Total Projects | <4 Bases with Projects | OCONUS Base(s) with Projects | <$50M Programmed for Projects | >$400M Programmed for Projects | <10 Different Companies with Project Contracts | <5,000 Contracted Performance Period Days | <10,000 Contracted Performance Period Days | <$10M MILCON on Last SAR | <$50M MILCON on Last SAR | >$10B Total Program on Last SAR | ≥2000 Base Year | <$10M in Contract Modifications | <$3M in Contract Modifications | <200 Contract Modifications | <50 Contract Modifications | ≥75% of Projects w/Contract Modifications | ≥75% of Contracts w/Modifications |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First to Programmed (Positive Growth) | | R * | | | | | | | | | | | | | | | | | | | | | | |
| First to Programmed (>\|1%\| Growth) | | | | | | | L ** | L * | R * | L *** | | | L ** | | | | | | | | | L *** | | |
| First to Programmed (>\|2%\| Growth) | | | | | | | | | | L * | R * | L ** | | L * | | | | | | | | L * | | |
| Q1 to Programmed (Positive Growth) | | | | | | | | | | | | | | | | | | | | | | | | |
| Q1 to Programmed (>\|1%\| Growth) | | | | | | | | | | L * | R * | L ** | | L * | | | | | | | | L * | | |
| Q1 to Programmed (>\|2%\| Growth) | | | | | | | L * | L ** | | | R ** | L *** | L * | L ** | | | | | | | | | | |
| Q2 to Programmed (Positive Growth) | | | | | | | | | R * | | | | | | | | | | | | | | | R * |
| Q2 to Programmed (>\|1%\| Growth) | | | | | | | | | | L * | R * | L ** | | L * | | | | | | | | L * | | |
| Q2 to Programmed (>\|2%\| Growth) | | | | | | | | L * | | | R *** | L ** | | L *** | | | R ** | | L * | L ** | L ** | | | |
| Q3 to Programmed (Positive Growth) | | | | | | | | | | | | | | | | | | | | | | | R * | |
| Q3 to Programmed (>\|1%\| Growth) | | | | | | | | | | | R * | | | L * | | | | | | | | | | |
| Q3 to Programmed (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | | | | | | |
| Last to Programmed (Positive Growth) | | | | | | | | | | | | | | | | | | | | | | | R * | |
| Last to Programmed (>\|1%\| Growth) | | | | | | | | | | | R * | | | L * | | | | | | | | | | |
| Last to Programmed (>\|2%\| Growth) | | | | | | | | | | | | | | | | | | | | | | | | |
| MED to Programmed (Positive Growth) | | | | | | | | | | | | | | | | | | | | | | | R * | |
| MED to Programmed (>\|1%\| Growth) | | | | | | | | | | L * | R * | L ** | | L * | | | | | | | | L * | | |
| MED to Programmed (>\|2%\| Growth) | | | | | | | | L * | | | R *** | L ** | | L *** | | | R ** | | L * | L ** | L ** | | | |
| AVG to Programmed (Positive Growth) | | | | | | | | | | | | | | | | | | | | | | | | |
| AVG to Programmed (>\|1%\| Growth) | | | | | | | | | | | | L * | | | | | | L ** | | | | | | |
| AVG to Programmed (>\|2%\| Growth) | | | | | | | | L * | | | R *** | L ** | | L *** | | | R ** | | L * | L ** | L ** | | | |
| **Total Significant Contingency Tables** | **0** | **1** | **0** | **0** | **0** | **0** | **2** | **5** | **2** | **5** | **10** | **9** | **2** | **10** | **0** | **0** | **3** | **1** | **3** | **3** | **3** | **5** | **3** | **1** |

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We conduct an exploratory analysis to study combining military construction (MILCON) data from the Selected Acquisition Reports (SAR) of Major Defense Acquisition Programs (MDAP) with the associated Automated Civil Engineer System project actual costs. The analysis uses both descriptive and inferential statistics to identify cost growth of MILCON at the programmatic level as well as to bridge the gap between SAR estimates and actual project costs within those program-level estimates. Overall, programs experience more negative growth (cost savings) in MILCON estimates on SARs, typically less than 0.2% of the total program cost implying minimal impact to program decisions. Estimates got more accurate from first to last SAR in comparison to total MILCON programmed for all projects within the program. However, the last SAR's median MILCON cost estimate was approximately $31 million underestimated to projects currently authorized and appropriated for the MDAPs. This could accumulate and impact budgetary decisions of scarce fiscal resources. Several factors were identified as potential drivers to MILCON cost growth within MDAPs, but require more data points for regression modelling. Preliminary research was restricted to 32 programs, 10 with authorized projects accessible for comparison, but initial results suggest building on this exploratory analysis.

**15. SUBJECT TERMS**
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