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A Decadal Analysis of Shifts in Engineering Manufacturing Development Factors for DoD Assets

Michael J. Smith

A DECADAL ANALYSIS OF SHIFTS IN ENGINEERING MANUFACTURING DEVELOPMENT FACTORS FOR DoD ASSETS

THESIS

Michael J. Smith, 1st Lt, USAF

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AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

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Michael J. Smith, BA

1st Lieutenant, USAF

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Michael J. Smith, BA

1st Lieutenant, USAF

Committee Membership:

Dr. Brandon Lucas

Chair

Dr. Jonathan D. Ritschel

Member

Dr. Edward D. White

Member

Shawn Valentine

Member

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Abstract

This research involves the analysis of standard parametric factors by decade within the development stage of acquisitions. Analysts use factors to develop budgets, create a baseline for measuring project progress, or as a crosscheck to the other estimating techniques. This research analyzed data from 408 1921s across seven decades and eight work breakdown structure (WBS) elements. It further analyzed these decades by commodity type, contract and contractor type, and service branch. The statistical tests used in this research determined which decades within our categories were dissimilar and drew conclusions about the impact of those differences. These tests determined that factors have either increased, decreased, or had spikes in many WBS elements, indicating that not all decades represent the overall WBS element or subcategory. The outcome of this research is that cost estimators must take into consideration the decade from which to calculate factors. Analysts will have a reference of which WBS elements, subcategories, and decades to use to develop factors.

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A DECADAL ANALYSIS OF SHIFTS IN ENGINEERING MANUFACTURING DEVELOPMENT FACTORS FOR DoD ASSETS

I. Introduction

Background

Cost analysts use cost estimating to inform Department of Defense (DoD) decision-makers on possible financial risks and benefits of a particular program or system. There are many methods a cost analyst has at their disposal to create the most accurate and robust cost estimates. Four common methods are analogy, parametric, engineering build-up, and expert opinion, often called Subject Matter Expert (SME) opinion. Which individual or combination of methods the analyst uses can be influenced by what data is available, necessary confidence for the acquisition stage being estimated, and time needed for data collection and analysis (Department of the Air Force, 2007). DoD Directive 5000.01 directs acquisitions programs to have a disciplined approach to lifecycle management. The Work Breakdown Structure (WBS) is the foundation of the lifecycle cost estimate. Common Elements are at Level II of the WBS and include System Engineering, Program Management, and Training, among others (Department of Defense, 2018). These elements will be of particular interest in this analysis.

There are two standard factors used in cost estimating that use historical system data: the analogy factor and the parametric factor. The analogy factor bases the estimate on a single existing and similar program. This type of factor is typically a percent or ratio between the costs of a program's elements. This factor is most useful when the new system is substantially similar to the historical system, and the analyst can quantify the differences. Conversely, parametric cost factors are the statistical relationships of many historical program costs. Standard factors include the relationship between the cost of prime mission product (PMP) to the Level II Common Elements in the WBS (Department of the Air Force, 2007). This thesis will focus on these parametric cost factors.

Modern changes in the way the DoD acquires assets and the complexity of those assets have led to shifts in the relationships between components and elements within those assets. Traditional parametric factors research has analyzed factors for the category of assets with insufficient consideration of the innovations and evolution of the acquisitions process. Cost analysts and organizations like AFLMC create and update a set of standard factors to improve the relevance and accuracy of future cost estimates. Understanding the time-driven aspect of these factors may help analysts create more defendable and accurate estimates.

Problem Statement

AFLCMC currently produces factor tables for development costs. These factors are common throughout the DoD for cost analysis and cross-check efforts. Ms. Joan Blair originally developed factor tables as a part of a major aircraft cost factor study in 1988, and Mr. Don Wren expanded that work in 1998 (Wren, 1998). However, those factors were based primarily on avionics and not regularly updated. In response, Markman et al. (2021) studied and developed factors for common Engineering, Manufacturing, and Development (EMD) across several DoD platforms. Edwards et al. (2020) expanded their work to include production factor analysis. This research aims to further extend prior work by developing decadal EMD factors and analyzing them for time trends. This research is available to analysts as a guide for the creation of improved parametric factors as well as to track any changes in the composition of development program costs. This could give greater insight into future factors used during the development phase of programs.

Research Objectives/Questions

We pose the following questions to best understand the time component within existing EMD factors and develop factors for our analysis and future operational consideration. Answering these questions will help illuminate shortfalls in the current formation and use of parametric factors, and lend insight into future research and study.

1. In each decade, what are the level II WBS factors for various DoD commodities, contract types, contractor types, and service branches?
2. What are the statistical differences between decades in level II WBS factors for various DoD commodities, contract types, contractor types, and service branches?

Methodology

The Cost Data Summary Report (CDSR), also known as DD Form 1921, is an aggregate data repository of incurred costs to date as well as the estimated cost at completion by WSB element (Department of the Air Force, 2007). Analysts can access contractor produced reports through the Cost Assessment Data Enterprise (CADE) database. AFLCMC/FZC collected the costs per WBS element and organized them into a central repository. Since they organized the data by commodity type, contractor type, service, and year of milestones, including Milestone B, we can collate the necessary information to create our factors. We will first analyze this data using descriptive statistics and develop our factors. Analysis of the mean, median, and standard deviation offer insight into trends, while interquartile ranges allow discernment of our factors against existing published EMD factors.

Due to the skew of our samples, we will not assume normality. We use non-parametric testing to understand the relationship between factors and decades. We use Kruskal-Wallis and Wilcoxon tests to compare within groups and between decade factors. These results will illustrate the applicability of these factors in future estimating and analysis, and give insights into possible changes or trends between decades.

Scope and Limitations

The AFLCMC/FZC database is based on 1921 reports stored in CADE, which is a cost data repository for DoD. CADE receives continual updates and our 1921 data contains Milestone B dates from 1961 to 2019. As the reporting of contractor costs is a requirement of Contractor Cost Data Reporting (CCDR) for all Acquisition Category (ACAT) I and IA programs (Department of Defense, 2007), it represents a comprehensive and cohesive source of up to date and accurate cost data necessary for the creation of accurate factors. Contractors format 1921s following the WBS structure outline in the newest revision of MIL-STD-881. The WBS elements of interest in this study are Systems Engineering/Program Management (SEPM), System Test and Evaluation (ST&E), Training, Data, Peculiar Support Equipment (PSE) and Common Support Equipment (CSE), Site Activation, G&A, and Spares.

We categorize 1921 data from completed and near-completed programs by type and decade to calculate accurate and reliable factors over time and across categories. In cases when the completed or near completed 1921s are not available, we include interim 1921s on a case-by-case basis. AFLCMC/FZC provided insight into which interim 1921s represented programs awaiting completed status. We included these programs to ensure the final factors of this analysis are as robust and representative as possible. We excluded programs that do not report to CADE or are otherwise not readily available and considered others that do not fit this analysis on a case-by-case.

Thesis Overview

Factors are an early tool for estimating a DoD program, often used well before the program office fully understands all the system requirements. The development and distribution of diverse and accurate factors to estimators helps establish a robust estimate baseline for this critical stage in acquisitions. However, analyzing the changes and trends over time in these factors can clarify what historical data best applies to a new program. This research will build upon existing factors to create decadal factors for common development phase WBS elements and lend insight into how development costs have evolved.

The next chapter in this thesis will contain a literature review of previous research, applicable policies, and understandings of how parametric factors fit into cost estimating. Chapter Three will delve into the specific methodology used in gathering the data and the necessary statistical tests needed to analyze the data. An analysis of these tests will follow in Chapter Four. Chapter Four will lay out and explain the insights we gleaned about the factors and any discernable trends. We will address any trends we discovered within each commodity type, contractor level, or service branch and their applications and significance. The final chapter will conclude the thesis by stating the answers to our original research questions. We will also discuss the applicable use case for these factors in DoD acquisitions.

II. Literature Review

Chapter Overview

Prediction is very difficult, especially when it's about the future.

Niels Bohr, 1922

The impetus for defendable acquisitions programs derives from the DoD Directive 5000.01 "Defense Acquisitions System." This directive outlines the need for a disciplined approach to acquisitions to deliver "products and services that satisfy user needs … at a fair and reasonable price" (Department of Defense, 2020). The Air Force Cost Analysis Handbook (AFCAH) expands on the directive by providing guidelines on preparing cost estimates, including methods and techniques that are standard in the Air Force. AFCAH includes a process for developing a new program, estimating future costs, and common tools used to reinforce and develop those estimates.

The parametric factor is one such tool cost analysts use to develop cost estimates and cross-checks. However, to understand its role in the process, it is best to understand some basic concepts in the field of acquisitions. This chapter will discuss the primary cost estimating methodologies and where factors fit in this process, the Work Breakdown Structure (WBS), and identify possible influences on the acquisitions process that may affect our research. It will also outline previous research on this topic and its relation to this thesis. Then it will outline some significant changes in the DoD acquisitions environment as possible influences on the composition of historical estimates. Finally, it will provide a framework for the usefulness of parametric factors and how changes in the composition of factors can improve this process.

Cost Estimating Methodologies

As cost estimators, we are effectively beholden to the American people to create efficient and effective estimates of future DoD assets and programs. Congress relies on the Government Accountability Office (GAO) to encourage these objectives by establishing the guidelines and best practices for cost estimates. The GAO publishes the Cost Estimating and Assessment Guide as a reference for which the DoD acquisitions community can obtain procedures to create trusted and verifiable estimates (Government Accountability Office, 2020). However, it is up to the cost estimator to tailor an estimate utilizing the best data available and in a timely manner. Just as every program is part new and part heritage, estimates must be unique to the program and built from the knowledge of the previous programs.

The outcome of a cost estimate is the point estimate. The point estimate is the culmination of data that results in a reasonable estimate of a program or asset’s costs. The point estimate is the best prediction of future costs. An analyst establishes a point estimate by collecting data within each element of the program. Methodologies are the process of collecting and applying this data to a new program. A cost estimator may choose a combination of the following methodologies to construct an accurate point estimate: Expert Opinion, Engineering Build-Up, Analogy, and Parametric. The following sections will explain each of these in detail. Which methodologies are appropriate depends on data availability, which stage in the acquisitions process the program is in, and how much data the estimator can collect in the time available (Department of the Air Force, 2007). These methodologies can be a cross-check to a previously developed estimate.

Expert Opinion

A subject matter expert (SME) can often be the driving data source for an estimate. The SME is typically an expert in the program or product that can draw inferences from their experience to establish a baseline for the estimate. These SMEs are essential to understanding the operational environment and program specifications within a new asset. However, relying on a cost estimate for an element of the program given by a SME can be problematic as subjective biases influence the estimate. The estimator can alleviate this bias by analyzing the SME's reasoning to determine the source of their opinion. Still, expert opinion is useful when the estimator cannot yet develop other alternatives and does not require a high level of precision (Government Accountability Office, 2020).

Expert opinion is best suited for early estimates when an estimator has not sufficiently developed the program costs or cross-checked existing cost elements. In the latter case, an expert opinion can give credence to a reasonable estimate or help determine deficiencies in a less well-developed estimate. The possible processes for collecting data from SMEs include the Delphi method or the round-table discussion. The Delphi method consists of polling several SMEs individually and then examining and comparing each expert's input. Each SME receives a summary of this process to gauge coordination. The round-table method places the SMEs in a collaborative environment where they can debate and scrutinize an estimate until they achieve a consensus (Department of the Air Force, 2007).

Engineering Build-Up

Sometimes called bottom-up or grass-roots estimating, an engineering build-up methodology consists of a summation of the lowest level cost elements for which the estimator can collect data and derive the cost of the whole system based on its constituent parts. Often considered the most robust and accurate of the methods of cost estimating, this method is time-consuming and requires a high level of data collection. This method also includes reliance on the SMEs, often the engineering team, to fully understand the scope and system specifications in detail for the program. The estimator develops an estimate for each lower-level element and sums them to the highest level to determine the overall cost (Government Accountability Office, 2020).

The engineering build-up methodology is best suited for programs containing some development or production historical costs. They use detailed statements of work and schedules to determine future costs. They can also use labor hours and learning curves (Department of the Air Force, 2007). A learning curve is the reduction in man-hours as a task becomes more efficient. The engineering build-up may also utilize other methods within its lower elements, or the analyst may combine it with other methods to develop the estimate. The engineering build-up is useful as it expresses many elements, can give insight into which elements drive costs, and compare the estimate to other programs. However, its time commitment and inflexibility to change make it less desirable in programs with higher uncertainty (Government Accountability Office, 2020). It may also be difficult to include every element needed for the program to meet its requirements.

Analogy

The analogy methodology of cost estimating is when a historical cost for a comparable element or product is the baseline for an element or product within a developing system. These costs typically match only partially, and the analyst must correct them in the new estimate. The differences can be in terms of size, performance, composition, or complexity. The analyst can account for these differences using analogy factors. These factors scale the actual or historical costs based on quantifiable measures between the old and the new program. Discussions with SMEs within the program and an analysis of programmatic details can highlight and verify these differences (Department of the Air Force, 2007). As analogies tend to rely on expert opinion and accurate quantitative comparisons, they are typically suited for early in a program, but after identifying the programmatic and technical details of the program. However, if the analogy is based on sound and reasonable arguments, it can be a cost-efficient and defensible basis for an estimate (Government Accountability Office, 2020).

The analogy method of cost estimation can be effective as the DoD rarely develops completely novel systems. There is often a program or element of a program that shares some technical capability with the new program. (Department of the Air Force, 2007). Determining which program or element and any factor or adjustment is necessary to account for differences, and using an analogy in an estimate requires the estimator to use credible logic and rationale. Referred to as the “reasonable person” test (Government Accountability Office, 2020), if any reasonable person would accept the estimator’s logic, then the analogy is sound. However, since an analogy is based on a singular historical reference, it is not always the best-suited methodology. It may also lack objectivity around hard to quantify parameters, such as complexity or efficiency (Government Accountability Office, 2020).

Parametric

Like the analogy methodology, the parametric method relies on historical costs from comparable systems. However, the parametric method utilizes the statistical relationship between many systems to determine the historical relationship between elements of the systems. This is also known as the "top-down" approach. The analyst develops a parametric estimate by collecting data on several similar programs and analyzing the cost drivers to determine if a statistically significant relationship exists between them. This assumes that the same relationship that drove costs in the past will continue to drive costs in the future (Government Accountability Office, 2020). Called a cost estimating relationship (CER), this relationship can be as simple as an arithmetic formula or as complicated as a multivariate regression equation. The CER can then apply to a new program where the independent variables are known. Some possible variables are lines of code, labor hours, weight, and costs of other high-level elements of the estimate (Department of the Air Force, 2007).

Parametric estimates are a useful methodology early in the program or to develop what-if estimates. A what-if estimate analyzes the effect on cost from changes to several cost drivers. An example of a what-if estimate is a trade-off study, where analysts evaluate the changes to the estimate brought about by design changes of individual elements or system components (Department of the Air Force, 2007). Since the parametric methodology is based on the statistically verified CERs, it remains valid when the system characteristics change. However, the system characteristic must remain within the CER dataset. The parametric method falls short when a new system does not significantly match the program or parameters of the historical programs, when not enough data exists to create a CER, or when complexity hinders understanding of the baseline relationships. Sometimes referred to as a black-box, it is not always clear how the elements of a CER affect each other (Government Accountability Office, 2020).

One practical and simple parametric CER is the parametric factor. A factor is a number that, when multiplied by a cost element, the result is another cost element. For this research, we will examine the relationship between the level II WBS elements and the Prime Mission Equipment (PME) of the program. The analyst uses the ratio of the PME to the level II WBS element in new programs to determine an estimate for that element. This factor can also be expressed as a percentage (NASA, 2015). For example, if System Engineering and Program Management (SEPM) costs are $50k and the PME costs are $150k, we would say the factor of SEPM to PME is $50k/$150k or 33%. If a new program had a PME cost of $185k, multiplying PME by the factor of 33%, we can estimate the SEPM costs to be about $62k. As our factors are based on the parametric model, the factor would be a composite of several similar programs. The costs that go into a factor must have a linear relationship and a logical basis for comparison (International Society of Parametric Analysts, 2008).

Other Estimating Methods

The four methodologies mentioned above are the primary techniques in DoD cost estimating. However, they are not the only techniques in use. Other methodologies are often necessary in specific circumstances or in conjunction with the primary methodologies. One such methodology is the extrapolation from actual costs. If a program has existing work documented, the costs of these elements can estimate future costs. Akin to extrapolation is the learning curve, where the assumption is that the more end items a contractor produces, the more efficient the workflow will become. Therefore less hours will be necessary for future items (Government Accountability Office, 2020). Another method is the industrial engineering standard, where each task for a project has a known completion time, and the sum of all completion times determines an estimate for labor hours required for the product (Department of the Air Force, 2007). More methodologies may cover niche cases or better fit the available data. It is up to the analyst to choose the best method for the stage of the program life cycle their program is in. Figure 1 shows an example from the AFCAH of when an estimator may need each of the four primary methodologies.

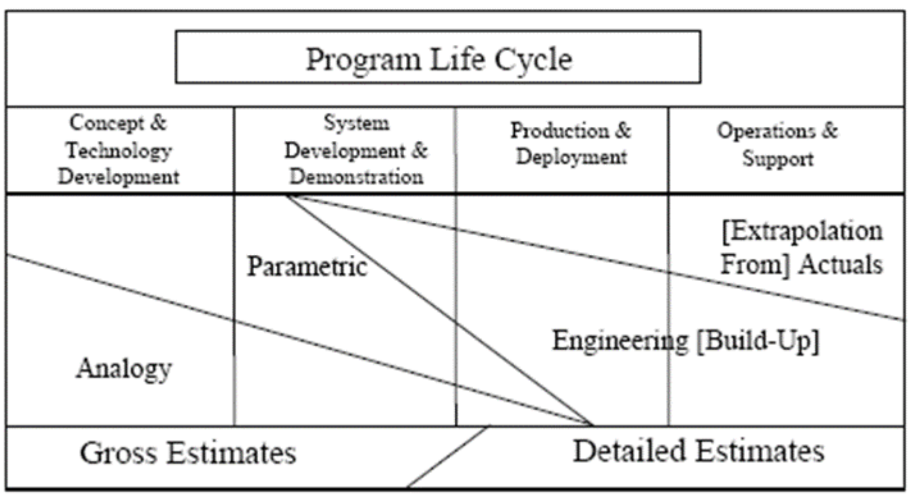


Figure 1: Methodology used in Program Life Cycle (Department of the Air Force, 2007)

Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) is the framework for detailing the system requirements of a program. Organized in a hierarchical structure where each level specifies an aspect of the level above it, its purpose is to describe a system in enough detail to understand and manage the system. Creating standard WBS formats throughout DoD acquisitions ensures consistency between programs. This assists in analysis tools such as the Earned Value Management System (EVMS) to effectively interpret the system's cost and schedule performance and defines the relationships between a system, its subsystems, parts, and efforts (Department of Defense, 2005). For this analysis, the WBS provides the breakdown of the costs of our reference programs, allowing for the production and direct comparison of consistent factors between programs.

The design of the common WBS expresses which elements of a system are essential to understanding the cost and schedule of the program. The first level (Level 1) is the entire system or project. Every other element will eventually connect to the Level 1 WBS element, and so too will all costs. The next level (Level 2) consists of the major elements of the system. The Level 2 elements used in this analysis include the Prime Mission Product (PMP), Systems Engineering/Program Management (SE/PM), System Test and Evaluation (ST&E), Training, Data, Peculiar Support Equipment (PSE), Common Support Equipment (CSE), Site Activation, General and Administrative (G&A), and Spares. We have combined PSE and CSE into Support Equipment for our analysis as their definitions may overlap from program to program. These elements are typical of most major acquisitions programs and will be of particular interest in our research. Below Level 2 is WBS Level 3. This level consists of all the necessary elements to understand the previous level.

Further levels of the WBS exist in the same fashion. It is only necessary to include lower-level WBS elements if they contribute to the methodology of the precedent elements or the program acquisition level dictates a certain level of detail. The WBS structure is also subject to change as the system develops and the cost estimate evolves. Figure 2 depicts the general structure of a DoD WBS. If the whole system is the level 1 WBS element, the PME, SEPM, ST&E etc. are level 2, and Level III Elements are listed in level 3.

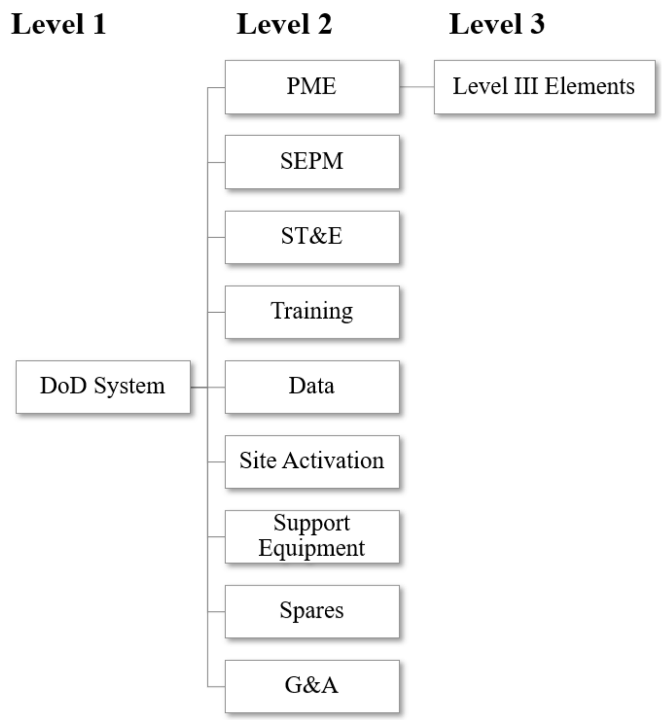


Figure 2: Example of WBS structure

The Prime Mission Equipment (PME) is one of the Level 2 elements and consists of the direct deliverable of the system, such as the aircraft or software itself. Systems Engineering/Program Management (SE/PM) is the engineering, technical control, and business management of the system. System Test and Evaluation (ST&E) consists of the design and production of models, prototypes, and hardware necessary to validate the system during the development stage. Training includes all deliverable training services, devices, equipment, and parts used to instruct personnel on the use and maintenance of the system. The Data element includes the production, acquisition, transformation, and storage of data used within the program. Support Equipment includes Common Support Equipment and Peculiar Support Equipment. Common Support Equipment (CSE) is the design, development, and production of equipment necessary to support and maintain the system when not directly engaged in its mission. Peculiar Support Equipment (PSE) is the design, development, and production of equipment necessary to support and maintain the system when it is not directly engaged in its mission but is not CSE efforts. Site Activation includes real estate, construction, utilities, and equipment needed to house, service, and launch the PMP. Spares consist of spare components, assemblies, and subassemblies for the initial replacement of the PMP (Department of Defense, 2018). Finally, the General and Administrative (G&A) WBS element is the costs of labor and overhead needed by the contractor not included in the other elements (Department of the Air Force, 2007).

Utilizing a standardized WBS makes estimation more consistent across programs and departments. The program manager can also give direction to contractors and industry regarding the requirements and structure of the program by defining a WBS dictionary, which describes the program elements and processes needed for production (Department of Defense, 2018). For our purposes, it enables comparisons that make factor development and analysis possible. Without clearly defined elements consistent between programs, developing useful factors would require an analysis of each program's requirements and structure and may be misinterpreted. It also helps to delineate the different efforts within a program and prevent the double counting of effort or cost, as each element clearly defines a unique purpose within the program.

Changes in Acquisitions Influencing Factors

An analogy factor is a snapshot in time of a single program and how its costs are related to each other. Since these factors are typically based on completed or near-completed programs, they highlight this relationship in the year and environment of the final system. Typical parametric factors are the averages of many factors across a vast time period. For example, if calculating the factors for a new bomber program, an analyst may draw from data on the B-52 Stratofortress and the B-1 Lancer, among others. There is a several decade gap between the development of those aircraft. It is not prudent to assume the relationships between their cost elements have not diverged, as many aspects of DoD acquisitions have evolved and developed. Reforms such as the Nunn-McCurdy Act of 1982, the Packard Commission of 1986, the Defense Acquisition Workforce Improvement Act (DAWIA) of 1990, the Federal Acquisitions Streamlining Act (FASA) of 1994, and the Weapon Systems Acquisition Reform Act (WSARA) of 2009 have led to changes not only in reporting, but also the development of acquisitions programs. In addition, revisions to the acquisitions handbooks and standards, such as Military Standard Work Breakdown Structure for Defense Materiel Items (MIL-STD-881), may reflect differences in the definitions of certain WBS elements. Understanding the influences on program development due to the changing landscape of DoD acquisitions may shed light on future cost estimating and how the analyst may utilize cost factors.

The 1982 Defense Authorization Act first introduced the Nunn-McCurdy amendment to curb cost growth in DoD acquisitions programs. Cost growth is the difference between the baseline estimate cost per unit and the current reported cost per unit. It calls for congressional reporting when a program's costs reach a certain threshold.

A cost growth of at least 15% requires the notification of Congress, whereas a breach of 25% or more will trigger a certification process that may lead to program termination (Ritschel, 2012). In 1986, former Deputy Secretary of Defense David Packard led an investigation into funds mismanagement in the DoD. The Packard Commission recommended several broad structural changes to the acquisitions system. While it was widely praised and many of the recommendations were implemented, these changes appear as top-level reform and did not contest fraud, waste, and abuse at the lowest levels of acquisitions (Jones, 1999). The Defense Acquisitions Workforce Improvement Act passed by Congress in 1990 established standard education and training standards and courses for civilians and military working in DoD acquisitions (DAU, 2021). This act aimed to improve the effectiveness of the estimators working within the acquisitions field. The Federal Acquisitions Streamlining Act of 1994 sought to reduce the cost of government procurement and simplify the acquisitions process. One way it achieved this was by giving preference to Commercial off-the-shelf items (COTS) instead of specialized and costly solutions developed specifically for the DoD (Barry, 1994). Finally, the Weapon Systems Acquisition Reform Act of 2009 sought to improve weapons systems development at an early stage. It addressed many problems within the DoD acquisitions process by outlining organizational, policy, and congressional reporting changes to reduce costs and improve efficiencies within acquisitions. It also emphasized competition and limited organizational conflicts of interest in the acquisitions process (Berteau, 2010).

The DoD first published MIL-STD-881 in 1968, and it has had several revisions. They wrote it to create a standard criterion for preparing and using a WBS for defense material items (Department of Defense, 1975). As of the writing of this research, there have been five revisions designated MIL-STD-881A in 1975, MIL-STD-881B in 1993, MIL-STD-881C in 2011, MIL-STD-881D in 2018, and MIL-STD-881E in 2020. Of note are the changes implemented in MIL-STD-881D that defined the Common Elements within System Engineering, Program Management, and System Test and Evaluation and refined the definitions of Peculiar Support Equipment and Common Support Equipment (Department of Defense, 2018). These definitions help analysts determine where to allocate costs within the WBS, and it is possible miscommunication, or ill-defined elements may have changed which WBS element costs were in. Analysts may have mistakenly placed costs in one element, and new programs placed them in a different one after these changes.

This is just a small sample of the changes that affected DoD acquisitions. The purpose of this thesis is not to draw correlations between any specific changes in the acquisitions process and program factors, but to analyze any trends in cost factors that may have developed over the past decades.

Previous Cost Factor Research

In 1988, Ms. Joan Blair developed and published factors from avionics programs at the Engineering and Manufacturing Development (EMD) stage to estimate future programs. This may have been the first study of its kind and set the stage for developing factors in the future. However, two issues with the Blair study became apparent in the ten years following its publication. Firstly, the Blair study only focused on avionics systems and cannot apply to non-avionics systems. Secondly, Ms. Blair did not update the factors as more program data became available. To resolve one of these issues, Mr. Don Wren expanded the Blair factors using the data available in 1998. By averaging data from the Blair study and the more recent programs, he developed composite factors for each support element. These factors were the average of each program's analogy factor instead of a factor of the total PME and support element costs to limit weighting the factor towards more extensive programs. His factors also categorized programs by contractor and PME dollar value. Mr. Wren mentions that the need for updated cost factors arose as changes in the acquisitions landscape necessitated updated analysis. Some changes he mentions include the introduction of integrated product teams, Cost as an Independent Variable (CAIV), and the prevalence of lean manufacturing (Wren, 1998). These two studies have paved the way for future factor studies.

Further updates came in 2015 when Mr. Jim Otte expanded the research from just Air Force aeronautical programs. His factors provided updates to existing factors and created factors for new WBS elements such as System Test & Evaluation and common support equipment, among others. It also included data not only from the Air Force but also from the Navy, Army, and Foreign Military Sales (FMS) systems (Otte, 2015). Over the years, many departments have maintained Cost Factor handbooks that track common factors within an organization. They include the Marine Corps Cost Factors Manual, the Army Cost Analysis Handbook, the Air Force Cost and Planning Factors, and the Historical Air Force Construction Cost Handbook. Analysts utilize these handbooks within and between branches, and often, departments will develop internal Cost Factor handbooks for specific program types (Mislick & Nassbaum, 2015). However, there is room for expansion.

In 2019, Captain Matthew Markman updated the available factors within the EMD phase of the acquisition life cycle. He increased the levels of data to improve the utility and range of applicability of these factors. Markman generated 443 factors from 102 programs in categories of commodity, development type, contract type, and service branch (Markman et al., 2021). Captain Jordan S. Edwards expanded this effort by extending factors into the production phase and created 3,462 unique factors from 145 programs. (Edwards et al., 2021). Markman collected data from 1953 to 2018 within CADE and Edwards from 1961 to 2017.

Each of these efforts builds from the research that came before it, either by updating existing factors or expanding the scope of their use. However, when new data updates these factors, it requires an assumption that newer data can compare with the programs from the original factors. This is a necessary assumption when granularity in an estimate has not yet developed, and specific data is not available. Our research aims to expand the efforts of the previous cost factor research and give insight into the changing world of acquisitions. Our goal is not to replace the existing factors, but to provide additional consideration for applying those factors.

Utility of Factors

Cost estimation is the art of predicting the future using qualitative and quantitative assessments. A good cost estimate is anchored in historical performance, reflects potential future performance, is understandable, can be validated and audited, and addresses risks and uncertainties of the program (Mislick & Nassbaum, 2015). It is necessary to choose a methodology that reflects sound judgment and is also based on good practice and historical trends. It also requires an understanding of the program and the landscape in which it will operate. A good factor used incorrectly can be just as dangerous as a bad factor. However, in the absence of better data, a reasonable factor can fill a hole in early estimates or create a sanity check for other methodologies (Mislick & Nassbaum, 2015).

Cost underestimation is not unique to the DoD. A 2002 study of 258 transportation infrastructure projects across the globe found that actual costs are an average of 28% higher than the initial estimates. It also found that analysts underestimate nine out of ten projects. Errors of this magnitude can lead to mistrust of estimators and cost overruns in the billions. This has not shown improvement in the 70 years leading up to the study either. The authors of the study pointed to many explanations such as technical, economic, psychological, and political factors (Flyvbjerg et al., 2002), all of which can influence DoD estimates as well. Estimators must utilize the best tools available to ensure estimates are as robust and accurate as possible and minimize cost overruns. Factors can be one such tool.

A 10-year survey by Abdelrahman Osman Elfaki, Saleh Alatawi, and Eyad Abushandi1 (2014) investigated the cost estimation techniques used in construction projects. They found that estimates were based primarily on engineering expertise. The problem Elfaki et al. had with this type of SME estimate was that they had no documentation or authentication and were prone to subjectivity. They proposed a more standardized and stable approach that considers project-specific features. However, they concede that estimating based on a blend of expertise and project-specific factors is necessary to create justifiable and authenticated estimates (Elfaki et al., 2014). Elfaki et al. focused their survey on machine learning in construction projects. Still, analysts can apply these takeaways to factors in DoD cost estimation when the program lacks the data for a more dynamic and diverse estimate. Cost estimators must rely on SME input in determining which factors fit the program and which elements of the system fit the methodology. This mix of knowledge and historical data-driven estimation increases the accuracy and defensibility of estimates.

Industry and governments around the globe use cost estimation. The tools and techniques used in DoD acquisitions are common in many circles and have one important goal: to provide decision-makers with the best data for managing the program. In most cases, this involves utilizing experience and data from similar programs and accounting for changes in working practices. The level of accuracy of an estimate can be related to the quality, completeness, and relatability of the model used (Greves & Jourmier, 2003). Often estimates fail to properly account for the qualitative knowledge of past programs (Riquilme & Serpell, 2012). This qualitative knowledge is the assumptions estimators make when comparing new systems to past projects (Rush & Roy, 2001). This knowledge is necessary when choosing how a program fits with prior data and which factors an analyst should use for estimation. Often overlooked are the changes in the acquisitions landscape that influence changes to cost estimating relationships.

Every program has unique constraints and limitations while sharing some aspects with past projects. Finding a methodology that correctly estimates future costs requires the analyst to use reasonable comparisons and sound judgment. When used correctly, factors relate the historical relationships of program elements to new systems. Whether used early in the program or as a cross-check against other techniques, factors rely on sound reasoning and logical fit. They are also only one tool within the cost estimating toolbox, which works best when the data matches the application.

Chapter Summary

This chapter provided some background into the complex world of cost estimating and the tools and features needed to provide decision-makers with the information necessary to execute public funds efficiently and responsibly. Estimators use the four primary methodologies for estimating cost in combination and conjunction with historical data and expert judgment from many members of the acquisitions team. The WBS serves as the framework and repository for program costs and requirements. Standardized WBS elements enable effective comparisons between many programs across all branches of the DoD. The relationships between the WBS elements can create factors that serve as an early benchmark for similar programs or cross-checks for other estimating methodologies. Previous research into cost factors has focused on expanding and updating the database of factors to increase the utility and relevance of factors on current systems. However, many changes to the acquisitions environment and developments within the standards and definitions used in acquisitions have influenced the relationships that are the basis of these factors. This research aims to provide insight into how these changes over time may have manifested within program data to enhance the usefulness and defensibility of factors.

III. Methodology

Chapter Overview

This chapter explains the data and methodology utilized in this thesis. It starts with an overview of the data source, collection, and inclusion and exclusion criteria. Normalization and factor calculations are detailed next, followed by a discussion of the tools for comparison and statistical analysis. The purpose of this discussion is to facilitate a common understanding of the data and findings going forward and summarize the methodological components of this study.

Data

Cost Data Summary Reports (CDSR), from here on referred to as 1921s, contain the necessary cost data to develop and analyze factors. Appendix B contains an example of a DD Form 1921. The Defense Automated Cost Information Management System (DACIMS) stores 1921s within the Cost Assessment Data Enterprise (CADE) system. An existing Air Force Life Cycle Management Center cost staff (AFLCMC/FZC) database summarizes these reports. This research focuses on the Engineering, Manufacturing, and Development (EMD) life-cycle phase as the AFLCMC community has identified it as an area of interest. The dataset consists of 620 1921s spanning from 1951 until 2019, representing an extensive range of programs.

The AFLCMC/FZC cost library database contains 620 1921s in the EMD life-cycle, though we only included 408 1921s that fit the criteria for this research. These 408 1921s are listed in Appendix A. Qualified data was determined following previous factor research and research regarding estimating the final costs of a DoD contract. Table 1 details the exclusion criteria and the number of programs utilized for this research.

Table 1: Data Exclusion

Category	Number	Remaining
Development Programs in Database		620
Prototype/Experimental Programs	30	590
Unavailable Milestone B Date	11	579
Non-Final or Late Interim Data	168	411
No WBS Cost Values	2	409
Ground Vehicle	1	408
Final Dataset for Analysis		408

While we have excluded initial 1921 data, we included some interim 1921s based on input from AFLCMC/FZC. Any initial 1921s included in this dataset were practically complete from a cost perspective, but the 1921 does not administratively list them as such. We excluded surface vehicles to focus on the most relevant programs and prototype and experimental programs as their costs may not reflect traditional programs. There were 11 programs where Milestone B dates could not be determined and classified into decades. Finally, we excluded systems within CADE that had no EMD data or were in a non-readable format.

We classified the data into four categories: commodity, contract type, contractor type, and service. Within these categories are subcategories that form the basis for our comparisons. For example, the category of contract type contains the subcategories Cost Plus and Fixed. Table 2 lists the subcategories and the number of 1921s associated with each. We then categorized the data by decade. This resulted in multiple factors for most programs. Categories and decades with fewer than five data points did not contain enough data to test. Table 2 gives an overview of the data categorizations for this research. Table 3 shows the number of data points by decade and Level II WBS element and shows the excluded decade/WBS combinations not analyzed due to lack of data points in light gray. We will not include these decades in the Kruskal-Wallis or Wilcoxon tests, but we have included them in the Descriptive Statistics section for reference.

Table 2: Dataset Characteristics by Category

Category	**Total**	**% of Data**
1921s	408	100.0%
Commodity Type		
Aircraft	142	34.8%
Electronic/Automated Software	96	23.5%
Engine	14	3.4%
Missile	10	2.5%
Rotary Wing	87	21.3%
Space	24	5.9%
UAV	13	3.2%
Contract Type		
Cost Plus	212	52.0%
Fixed	110	27.0%
Contractor Type		
Prime	247	60.5%
Subcontractor	139	34.1%
Service		
Army	68	16.7%
Navy (including Marine Corps)	158	38.7%
Air Force (including Space Force)	150	36.8%
Joint	10	2.5%

Table 3: Dataset Characteristics by Decade

Decade	1950	1960	1970	1980	1990	2000	2010	Total
WBS								
SEPM	1	5	24	46	51	220	38	385
ST&E	8	6	22	46	48	174	28	332
Training	6	4	13	29	30	90	8	180
Data	6	5	23	44	35	129	21	263
Site Activation			2	15	6	31	4	58
Support Equipment	7	4	12	29	27	61	10	150
Spares	7	3	2	11	11	36	6	76
G&A		8	21	35	46	216	39	365
Grand Total	35	35	119	255	254	957	154	1809

Data Collection

AFLCMC/FZC collected the 1921 data and extracted the relevant information into a central database, normalizing the data to fiscal year 2021 dollars using Office of the Secretary of Defense (OSD) inflation indexes and each report's "report as of" date. For decadal analysis, we have further categorized the data points by Milestone B date and rounded them down to the decade. For example, the 1990s decade includes all data with a Milestone B year from 1990 through 1999. We selected Milestone B as this is when a program leaves the Technology Maturation & Risk Reduction phase and enters the Engineering & Manufacturing Development phase.

Factor Calculation

The parametric WBS element factors used in this analysis are the mean (average) of the analogy factors for all programs contained within each WBS element, subcategory, and decade. However, our tests compare the medians to determine if they are from the same distribution. We will see in Chapter Four that our distributions are skewed, and the median is a better representation of the expected value for a skewed distribution. We will show both the mean and the median in our reports. The analogy factors are the ratio, expressed as a percentage, of the WBS Level II elements to the Prime Mission Equipment (PME) values. The PME values do not include contractor fees, miscellaneous expenses (general and administrative (G&A), undistributed budget, management reserve, or facilities capital cost of money (FCCM)). Table 4 depicts an example of an analogous factor calculation created by dividing a System Engineering/Program Management (SEPM) by the program's PME value.

Table 4: Example of Analogy Factor Calculation

Prime Mission Equipment	$ 718.3 K
System Engineering/Program Management (SEPM)	$ 120.1 K
Analogy Factor = 120.1/718.3=0.167 or 16.7%	

We have categorized these Level II WBS factors and averaged them to develop parametric factors in each decade. Table 5 gives an example of how four programs in the same WBS element and decade calculate a single parametric factor. This parametric factor is useful when using a single analogy is not appropriate.

Table 5: Example of Parametric Factor Calculation

	PME	SEPM	Ratio
Program 1	$400.00 K	$60.00 K	0.150
Program 2	$280.00 K	$20.00 K	0.071
Program 3	$600.00 K	$220.00 K	0.367
Program 4	$180.00 K	$52.00 K	0.289
Total	$1,460.00 K	$352.00 K	0.877
Parametric Factor = 0.877 / 4 = 0.219 or 21.9%			

Comparison Analysis

After the establishment of the WBS element and decadal factors, we calculated the mean, median, and standard deviation values of the groups, as well as interquartile ranges, to examine variability within factors. We accomplished this descriptive analysis before beginning the statistical testing and analysis.

We compare each category using the hypothesis test shown in Equation 1, where *x* represents the different decades in each subcategory for each comparison and *y* represents a parametric factor for the entire subcategory for comparison. For example, when comparing the decades for aircraft within SEPM, *x* is defined as the 1970s, and y would be the aircraft SEPM overall factor. Failure to reject the null hypothesis, H_0, signifies that there is no difference between the medians of the WBS element and each decade. If we reject H_0, then a difference does exist.

$$H_0: \Delta_x = \Delta_y$$

$$H_a: \Delta_x \neq \Delta_y$$

Equation 1

Statistical Tests

We utilize several statistical tests to perform the hypothesis tests. These include descriptive statistics and the Kruskal-Wallis test. The Wilcoxon test serves as a multiple comparison test. We evaluated normality with Descriptive Statistics as any WBS categories found to be non-normally distributed needed non-parametric testing. This non-parametric testing indicates how each decade within a subcategory related to each other. A Kruskal-Wallis test accomplished this by comparing the locations of each datapoint within the samples. We use the results of this test to compare the medians. The final test was the Wilcoxon test between each decade and all data points not within the decade to identify which decades were statistically different from the overall subcategory. This research compares decadal factors to traditionally calculated factors and illustrates any difference between the decade and the remaining data comprising a traditional factor.

Descriptive analysis determines if the data came from normal distributions. Normality is a necessary condition in parametric tests, as parametric tests assume the population from which we draw the samples are normally distributed. Data that fails the normality test must use non-parametric tests. Visually inspecting the data distribution and comparing the mean, median, and standard deviation determined that none of the data categories appeared normally distributed. To avoid the violation of normality in our testing, we used non-parametric tests for the remainder of our analysis.

Analysts use Kruskal-Wallis tests to determine whether several datasets come from the same distributions and have the same median values. Since our datasets did not appear to be normally distributed, this test can determine if the dataset still matches the distribution of the other data sets.

We use Wilcoxon tests when comparing only two datasets. It is similar to a Student's t-test but without the assumption of normality. A Wilcoxon test compares the locations of the data points of two samples to determine if they are from the same distribution. To test each decade, we created a dummy variable to categorize the decade in question in one group and every other decade in the other. The Null Hypothesis of a Wilcoxon test is that the medians of the two samples are equal for equally shaped distributions, and rejecting this Null Hypothesis would indicate which decades are not of the same distribution as the rest of the subcategory. Analyzing medians is less prone to the impacts of outliers, and as our data is skewed, we tend to see many possible outliers in the data. Our tests compare the medians of the distributions, and the analysis in Chapter Five will focus on trends and changes in the medians between decades.

Chapter Summary

This chapter provided a breakdown of the methodological approach to establishing decadal EMD factors within the DoD. It also explained how we collected the data and why we chose the dataset. To make significant comparisons within the WBS elements and decades, we detailed the steps utilized to create the parametric factors and the analogous factors they consist of. We also described several statistical tests to identify trends and analyze the factors. The next chapter will provide a detailed analysis of these tests and the resultant factors produced.

IV. Analysis and Results

Chapter Overview

The results of the methodology we outlined in Chapter Three are below. There are four sections to this chapter. First, we outline the collected data to give insight into the underlying programs. Second, we organize the data by the WBS element and calculate the descriptive statistics. This includes the mean, median, interquartile range (IQR), and standard deviation (SD). The third section details the results of the statistical difference tests performed for each WBS element and subcategory by decade. The last section of this chapter compares each subcategory decadal factor by WBS element to a combined factor for each subcategory.

Dataset Characteristics

AFLCMC/FZC collected the data for this analysis into a central database. They used CADE to find 1921s and extract the relevant data points. Of the 620 1921s made available by AFLCMC/FZC, 408 contained the data necessary to make this analysis. Appendix A lists the programs used. Table 6 shows the number of 1921s that we excluded from the analysis and the basis for their exclusions.

Table 6: Dataset Exclusions

Category	Number	Remaining
Development Programs in Database		620
Prototype/Experimental Programs	30	590
Unavailable Milestone B Date	11	579
Non-Final or Late Interim Data	168	411
No WBS Cost Values	2	409
Ground Vehicle	1	408
Final Dataset for Analysis		408

Each 1921 contained some combination of Level II WBS cost data and the year of Milestone B. The resultant combination of decade of Milestone B and Level II WBS analogy factors resulted in 53 data groups, which we outline by WBS and decade in Table 7. We excluded data groups with less than 5 data points from factor calculation, which leaves 44 data groups for our analysis.

Table 7: Dataset Characteristics

Decade	1950	1960	1970	1980	1990	2000	2010	Total
WBS								
SEPM	1	5	24	46	51	220	38	385
ST&E	8	6	22	46	48	174	28	332
Training	6	4	13	29	30	90	8	180
Data	6	5	23	44	35	129	21	263
Site Activation			2	15	6	31	4	58
Support Equipment	7	4	12	29	27	61	10	150
Spares	7	3	2	11	11	36	6	76
G&A		8	21	35	46	216	39	365
Grand Total	35	35	119	255	254	957	154	1809

ST&E, Training, Data, Spares, and Support Equipment all have data groups starting from the 1950s. All the WBS elements except Site Activation extend into the 2010s. ST&E and Data have the most decades with seven each, and Site Activation has only three from the 1980s to the 2000s. SEPM has the most data points of all WBS elements with 386, with G&A and ST&E close behind with 365 and 333, respectively. Site Activation has the least with 58. The decade with the most data points is the 2000s with 957, and the least is a tie between 1950 and 1960 with 35 each. The low number of datapoints within the 2010s is likely due to missing data caused by reporting delays.

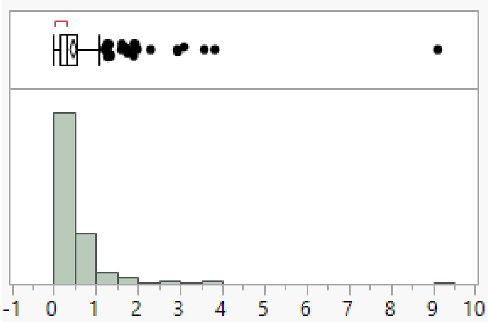
Descriptive Statistics

The analogy factors used to create parametric factors in this research are the ratio expressed as a percentage of the level II WBS elements to the program's PME value.

This PME value excludes the contractor's fee and miscellaneous expenses (undistributed budget, management reserve, facilities capital cost of money). One example of this ratio would be the value of a program's SEPM costs divided by the same program's PME value. We combined these analogy factors by decade to create parametric factors for each decade under examination. The average of the factors from a specific WBS element, subgroup, and decade can estimate future costs or an analyst can compare the results to other estimating techniques as a cross-check. The average parametric cost factor can represent a more accurate cost factor than an analogy factor as it guards against errors resulting from calculations based on a single data point.

SEPM

The Systems Engineering and Program Management (SEPM) WBS element is a prominent factor in the analysis. It contains the most 1921s of the available programs with 386, representing 94.6% of the programs. SEPM factors range from 0.0117% to 911.4% of PME. At the high end of the range, this 911.4% factor may indicate reporting anomalies and/or extreme issues in the upper value. Figure 3 shows the distribution of SEPM values and provides descriptive statistics used in further analysis. The distribution for SEPM contains many data points and a high standard deviation value. The mean value is 46.6%, and the median is 30.0%. The distribution is skewed right and far from normally distributed.



Quantiles

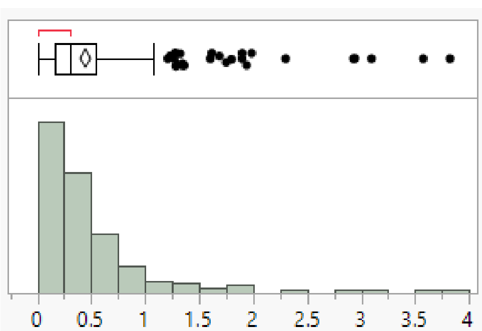
100.0%	maximum	9.11426877
99.5%		4.1676302549
97.5%		1.9119170113
90.0%		0.9124791091
75.0%	quartile	0.5478024383
50.0%	median	0.3004131575
25.0%	quartile	0.1632211443
10.0%		0.0646255393
2.5%		0.01101025
0.5%		0.0049684343
0.0%	minimum	0.000117357

Summary Statistics

Mean	0.465925
Std Dev	0.6625538
N	386
Median	0.3004132

Figure 3: SEPM Descriptive Statistics

Figure 4 shows the distribution with the 911.4% factor removed. We trimmed this factor as it is more than ten standard deviations from the mean. It is also visibly distinct from the remainder of the results. The distribution is still skewed, but the standard deviation is much smaller at 49.5%, and the mean and median are closer to each other at 44.3% and 29.5%, respectively. This factor originates from a navy electronics system and is one of many 1921s in that program. The factor is high due to the low value in the PME WBS element. Although the costs from this 1921 are accurate, we have excluded them as they skew the results and do not reflect the remainder of the data points in this category.



Quantiles

100.0%	maximum	3.823746294
99.5%		3.5936652342
97.5%		1.8986188693
90.0%		0.9062757226
75.0%	quartile	0.5463360985
50.0%	median	0.299544616
25.0%	quartile	0.1628021145
10.0%		0.0644294304
2.5%		0.01101025
0.5%		0.0049424927
0.0%	minimum	0.000117357

Summary Statistics

Mean	0.4434618
Std Dev	0.4948123
N	385
Median	0.2995446

Figure 4: SEPM Descriptive Statistics Minus Outlier

The individual descriptive statistics for each level II WBS element are shown by decade, and we will discuss them in the next section of Chapter Four. Table 8 displays individual descriptive statistics for SEPM broken out by decade. We have excluded decades with less than 5 data points and grayed them out, but included them here for comparison to other decades. Appendix C contains these charts for each WBS element.

Table 8: SEPM Summary by Decade

SEPM Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.26	0.11842	0.18893	0.34387	0.40447	0.47302	0.65357
Std Dev	.	0.08643	0.17072	0.29198	0.61088	0.49159	0.60133
N	1	5	24	46	51	220	38
Max	0.26	0.25175	0.65209	1.26801	3.82375	3.57635	3.09701
0.75	0.26	0.20532	0.26091	0.47241	0.44964	0.57181	0.83865
Median	0.26	0.0762	0.14311	0.27827	0.23298	0.34771	0.50689
0.25	0.26	0.05263	0.06816	0.11313	0.15362	0.19623	0.29008
Min	0.26	0.04866	0.0293	0.00597	0.00012	0.00531	0.01251

The SEPM factor appears to be growing from 1960 through 2010. The mean, median, and quartiles have, for the most part, consistently increased. The mean has grown from 11.8% to 65.3%, and the median has grown from 7.6% to 50.7%. The mean is consistently within the third quartile, confirming the right skew of the distribution. Due to this type of skew, the median may be a better measure of the distribution as the median is less affected by outliers and highly skewed distributions.

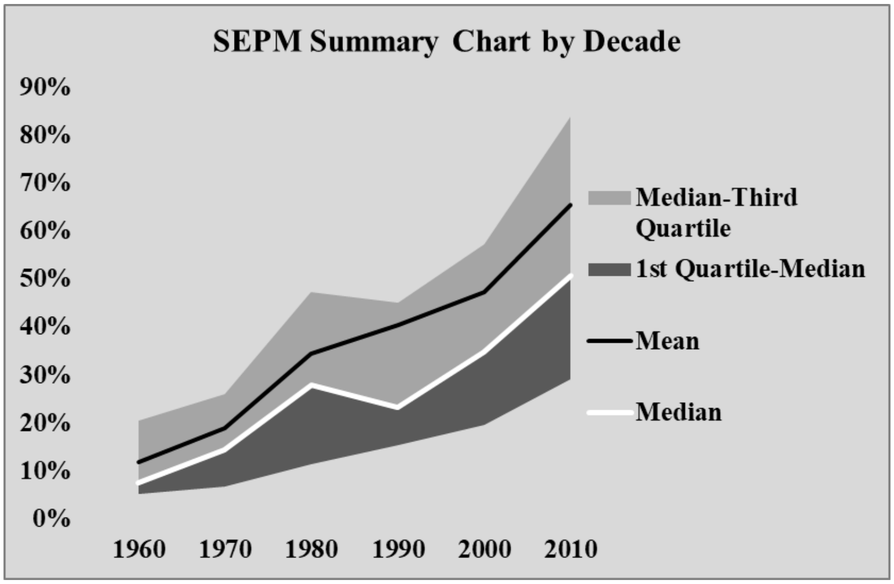
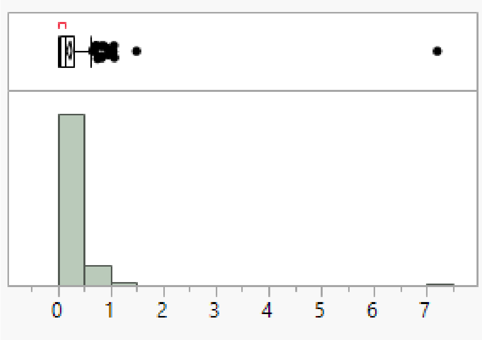


Figure 5: SEPM Summary By Decade

ST&E

The second level II WBS element under evaluation, System Test & Evaluation (ST&E), contains the third-largest number of data points at 333, representing 81.6% of the 1921s. ST&E factors range from $7.7*10^{-5}$% to 720.0%. This high factor of 720.0% may indicate reporting anomalies and/or extreme issues in the upper values. Figure 6 depicts ST&E factor distribution and accompanying descriptive statistics. The standard deviation is high, and the mean and median are far apart, with a mean of 38.3% and a median of 31.5%. The distribution is right-skewed.

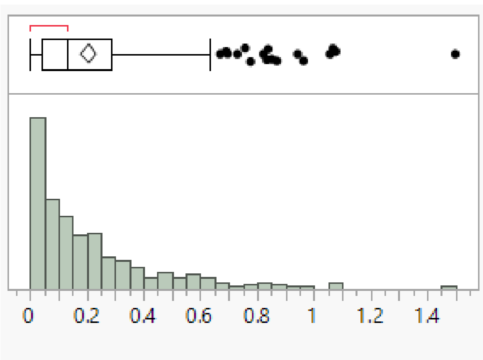


Quantiles		
100.0%	maximum	7.199841116
99.5%		3.3798183121
97.5%		0.8639539796
90.0%		0.5325173176
75.0%	quartile	0.2886744295
50.0%	median	0.129765573
25.0%	quartile	0.0407559425
10.0%		0.0099631744
2.5%		0.0015432088
0.5%		8.1002165e-6
0.0%	minimum	7.70044e-7

Summary Statistics	
Mean	0.2264904
Std Dev	0.4457185
N	333
Median	0.1297656

Figure 6: ST&E Descriptive Statistics

Figure 7 shows the distribution with the 720.0% factor removed. We trimmed this factor, much like the high factor in SEPM, as it is more than ten standard deviations from the mean. It is also visibly distinct from the remainder of the results. The distribution is still skewed, but the standard deviation is much smaller at 22.8%, and the mean and median are closer to each other at 20.5% and 13.0%, respectively. This factor originates from an aircraft radar system and is one of many 1921s in that program. The factor is high due to the low value in the PME WBS element. Although the costs from this 1921 are accurate, we excluded them as they skew the results and do not reflect the majority of the data points in this category.



Quantiles		
100.0%	maximum	1.498314543
99.5%		1.2185848752
97.5%		0.8481104143
90.0%		0.5185346062
75.0%	quartile	0.2869933778
50.0%	median	0.1297450845
25.0%	quartile	0.0405617268
10.0%		0.0098973718
2.5%		0.0015407691
0.5%		8.0455137e-6
0.0%	minimum	7.70044e-7

Summary Statistics	
Mean	0.2054863
Std Dev	0.2278408
N	332
Median	0.1297451

Figure 7: ST&E Descriptive Statistics Minus Outlier

Table 9 displays the individual descriptive statistics for ST&E broken out by decade. Appendix C contains these charts for each WBS element.

Table 9: ST&E Summary by Decade

ST&E Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.333203	0.38307	0.42179	0.28501	0.17351	0.15181	0.2186981
Std Dev	0.159237	0.26609	0.26592	0.27351	0.15695	0.18037	0.3231126
N	8	6	22	46	48	174	28
Max	0.593715	0.83931	1.06772	1.07767	0.60513	1.05752	1.4983145
0.75	0.472414	0.62385	0.60037	0.43902	0.26537	0.21052	0.3236347
Median	0.320089	0.29513	0.40791	0.19222	0.12392	0.09505	0.1023425
0.25	0.18537	0.16597	0.19156	0.07796	0.06399	0.03424	0.0034484
Min	0.129725	0.14332	0.02533	0.00405	0.0005	0.00011	0.0000008

The ST&E factors have been slightly decreasing, in contrast to the SEPM factors. There is also more variability in the ST&E factors through the decades, but overall, there has been a shift from higher to lower factors. The mean has changed from 33.3% to 21.9%, and the median has shifted from 32.0% to 10.2%. Again, the mean resides within the third quartile, except for the 1970s, where the mean and median are very close.

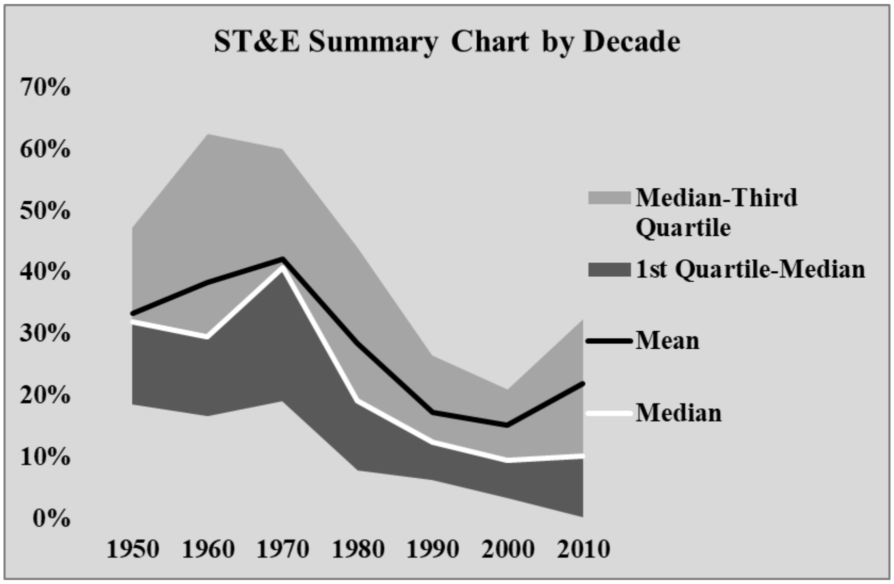
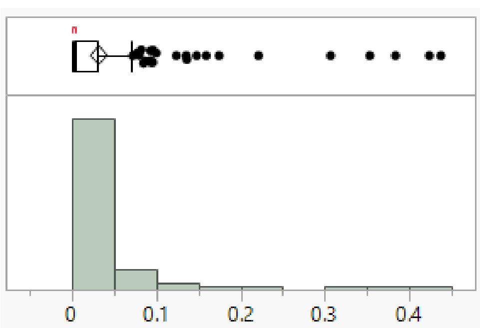


Figure 8: ST&E Summary by Decade

Training

The Training Level II WBS element does not contain as many data points as SEPM or ST&E, but with 180 factors, it represents 44.1% of the available 1921s. Figure 9 shows a mean of 3.2% and a median of 0.5%, indicating a significant separation and reinforces the relatively large standard deviation of 7.0%. This distribution is also right-skewed. The descriptive statistics for Training factors by decade are in Appendix C.



Quantiles

100.0%	maximum	0.437528958
99.5%		0.437528958
97.5%		0.3289498115
90.0%		0.0929393831
75.0%	quartile	0.0298245425
50.0%	median	0.0046433275
25.0%	quartile	0.0014879755
10.0%		0.0006034909
2.5%		0.0001392474
0.5%		8.04702e-6
0.0%	minimum	8.04702e-6

Summary Statistics

Mean	0.0324106
Std Dev	0.0701162
N	180
Median	0.0046433

Figure 9: Training Descriptive Statistics

Table 10 shows the individual descriptive statistics for Training broken out by decade. We have excluded from our analysis decades with less than 5 data points and have them shown grayed out but included them for comparison to other decades. These charts are also in Appendix C.

Table 10: Training Summary by Decade

Training Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.02025	0.11771	0.01742	0.02391	0.02462	0.036119	0.04154
Std Dev	0.01566	0.2133	0.02307	0.04265	0.06579	0.074399	0.06336
N	6	4	13	29	30	90	8
Max	0.04377	0.43753	0.0802	0.15949	0.3532	0.423778	0.14824
0.75	0.03313	0.33285	0.02471	0.02021	0.01591	0.03756	0.1114
Median	0.0202	0.01491	0.00384	0.00385	0.0035	0.005686	0.0028
0.25	0.00518	0.00537	0.0023	0.00112	0.00138	0.00121	0.00155
Min	0.00125	0.0035	0.00072	8.7E-05	0.0001	8.05E-06	0.00147

The mean and median values for Training diverge between 1950 and 2010. In 1950, the mean and median start off quite close at 2.0%, and the mean increases to 4.2% in 2010 while the median decreases to 0.1%. This may indicate that the distribution is becoming more right-skewed. This confirms the larger difference in the third quartile than in the first quartile.

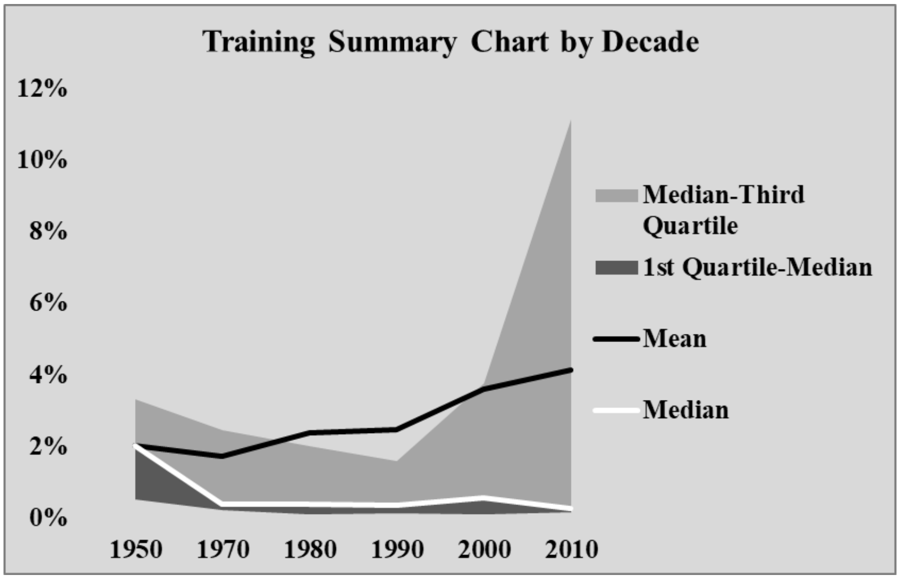


Figure 10: Training Summary by Decade

Data

With 263 data points, the Data level II WBS element represents 64.5% of the total programs in the analysis. This is the 4th largest WBS element in the analysis. Figure 11 shows the descriptive statistics for Data factors. The descriptive statistics for Data factors by decade are in Appendix C. Figure 11 shows a large standard deviation relative to the mean. Similarly to Training, this appears to be due to the right skew of the data set. The mean and median are also relatively separate at 3.4% and 1.8%, respectively.

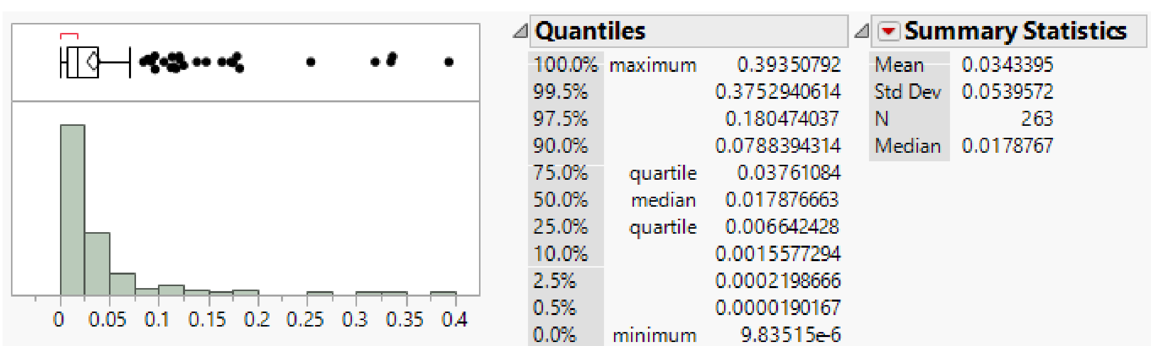


Figure 11: Data Descriptive Statistics

Table 11 shows the individual descriptive statistics for Data broken out by decade. These charts are also in Appendix C.

Table 11: Data Summary By Decade

Data Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.02097	0.02513	0.05793	0.04636	0.02855	0.03054	0.0223
Std Dev	0.01326	0.01725	0.07343	0.0649	0.05595	0.0493	0.02888
N	6	5	23	44	35	129	21
Max	0.04586	0.04473	0.31913	0.33659	0.33485	0.39351	0.11792
0.75	0.03082	0.04095	0.06179	0.05397	0.03338	0.03915	0.02658
Median	0.01514	0.02797	0.02694	0.01865	0.01753	0.01772	0.01201
0.25	0.01271	0.00788	0.01446	0.01012	0.00455	0.00453	0.00746
Min	0.01039	0.00249	0.00182	0.00025	0.00004	0.00001	0.00066

Data factors have not changed overall, except for the 1970s, when the mean and median are even more separated. The mean goes from 2.1% to 2.2%, and the median goes from 1.5% to 1.2% between 1950 and 2010. In the 1960s, the mean went from the third quartile to the first quartile, and the distribution became more normally distributed.

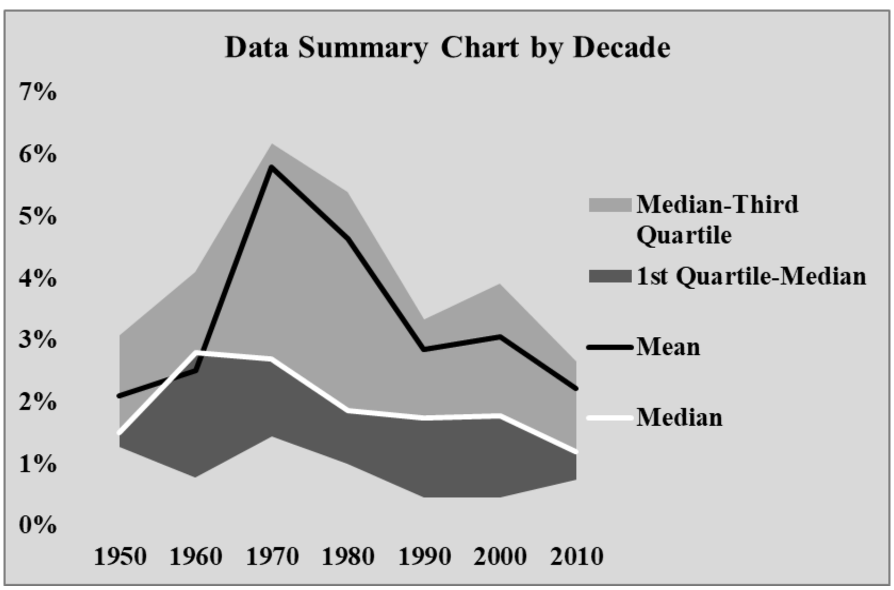
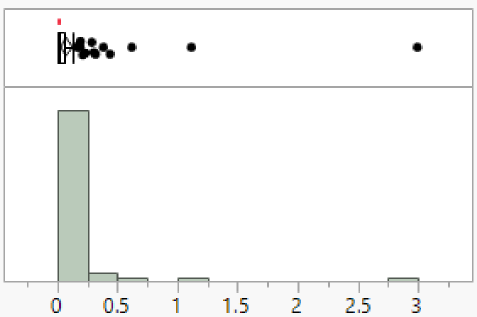


Figure 12: Data Summary by Decade

Support Equipment

Support Equipment accounts for 150 of the 1921s representing 36.8% of the 1921s available. Figure 13 shows the descriptive statistics for Support Equipment factors. The descriptive statistics for Support Equipment factors by decade are in Appendix C. The mean and median are very separated at 7.9% and 2.1%, respectively, and the standard deviation is high at 26.9%. From the distribution, we can see that the data is skewed right, which explains those measures.



Quantiles

100.0%	maximum	2.992462686
99.5%		2.992462686
97.5%		0.4806080369
90.0%		0.1363551732
75.0%	quartile	0.0641477038
50.0%	median	0.021280244
25.0%	quartile	0.0043565583
10.0%		0.0009917374
2.5%		0.0000816314
0.5%		3.53656e-7
0.0%	minimum	3.53656e-7

Summary Statistics

Mean	0.0793541
Std Dev	0.2692108
N	150
Median	0.0212802

Figure 13: Support Equipment Descriptive Statistics

Table 12 displays the individual descriptive statistics for Support Equipment broken out by decade. We have excluded decades with less than 5 data points from our analysis, shown grayed out, but have included them for visual comparison to other decades. These charts are also in Appendix C.

Table 12: Support Equipment Summary by Decade

Support Equipment Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.05428	0.13735	0.16303	0.06329	0.02743	0.10338	0.0135243
Std Dev	0.05589	0.16816	0.31089	0.07376	0.03953	0.39099	0.0255193
N	7	4	12	29	27	61	10
Max	0.16864	0.38462	1.11617	0.28876	0.13597	2.99246	0.0767991
0.75	0.08418	0.31382	0.11757	0.07868	0.03529	0.06071	0.0153095
Median	0.03544	0.06949	0.05869	0.0322	0.00839	0.0194	0.0025869
0.25	0.01377	0.02874	0.02169	0.01233	0.00097	0.00436	0.0005833
Min	0.01083	0.02582	0.00132	0.00012	0.00005	0.00004	0.0000004

Support Equipment appears to shrink, but with a significant degree of variability. The mean went from 5.4% in 1950 to 1.3% in 2010. In 1970 and 2000, the mean is well above the 3rd quartile. The median also shrinks, going from 3.5% in 1950 to 0.06% in 2010, with less variability. The mean is consistently higher than the median, so each decade is highly right-skewed.

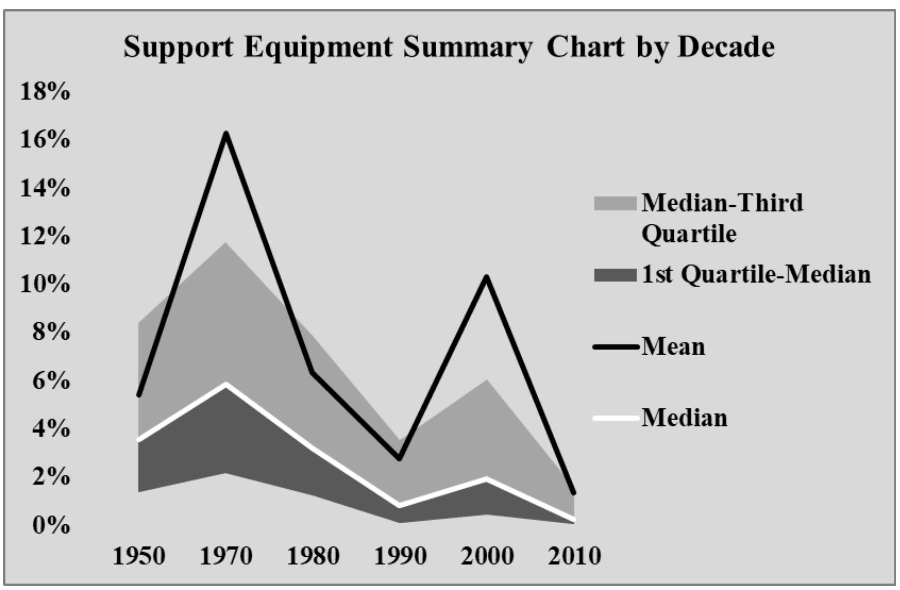
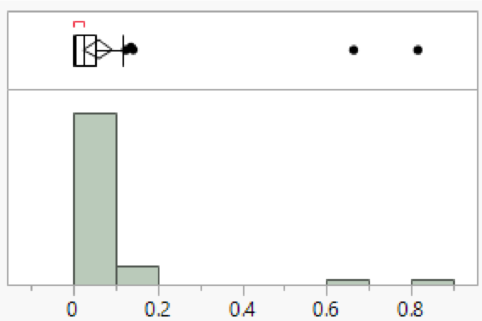


Figure 14: Support Equipment Summary by Decade

Site Activation

Site Activation cost data is in 58 of the 1921s available for analysis, for a total of 14.2% of the 1921s. This is the smallest data set of our analysis. The factors range from 81.6% t0 9.3x10^-4%. Figure 15 shows the descriptive statistics for Site Activation, and the details by decade are in Appendix C. The median is very low at 2.5% and far from the mean of 5.9%. The standard deviation is also relatively high at 13.6% likely due to the right skew of the data.



Quantiles

100.0%	maximum	0.816332689
99.5%		0.816332689
97.5%		0.744209904
90.0%		0.1176862466
75.0%	quartile	0.0515381508
50.0%	median	0.025453976
25.0%	quartile	0.0040235585
10.0%		0.0004166404
2.5%		0.0000555536
0.5%		9.29461e-6
0.0%	minimum	9.29461e-6

Summary Statistics

Mean	0.0588432
Std Dev	0.1357735
N	58
Median	0.025454

Figure 15: Site Activation Descriptive Statistics

In the next section of Chapter Four, we will discuss the individual descriptive statistics for each level II WBS element broken out by decade. Table 8 displays an example of the individual descriptive statistics broken out by decade. We excluded from our analysis decades with less than 5 data points (shown grayed out), but have included the data for completeness. These charts are also in Appendix C.

Table 13: Site Activation Summary by Decade

Site Activation Summary Table by Decade					
Decade	1970	1980	1990	2000	2010
Mean	0.0314009	0.0179952	0.040844	0.06313	0.21954
Std Dev	0.0066344	0.0303863	0.0539735	0.14376	0.3005
N	2	15	6	31	4
Max	0.0360921	0.11063149	0.1250588	0.81633	0.6645
0.75	0.0360921	0.03117317	0.09983243	0.05984	0.53266
Median	0.0314009	0.00184945	0.01418127	0.0397	0.09474
0.25	0.0267096	0.00047073	0.00015964	0.01002	0.03122
Min	0.0267096	0.00010668	0.0000093	0.00044	0.0242

Only three of the decades for Site Activation had enough factors for analysis. Within these three decades, the mean and median increased, mean from 3.0% to 6.3% and median from 0.2% to 4.0% between 1980 and 2000. The mean is also higher than the median in all three decades, and the distributions are right-skewed. In the 2000s, the mean was slightly above the 3rd quartile, so it is highly skewed.

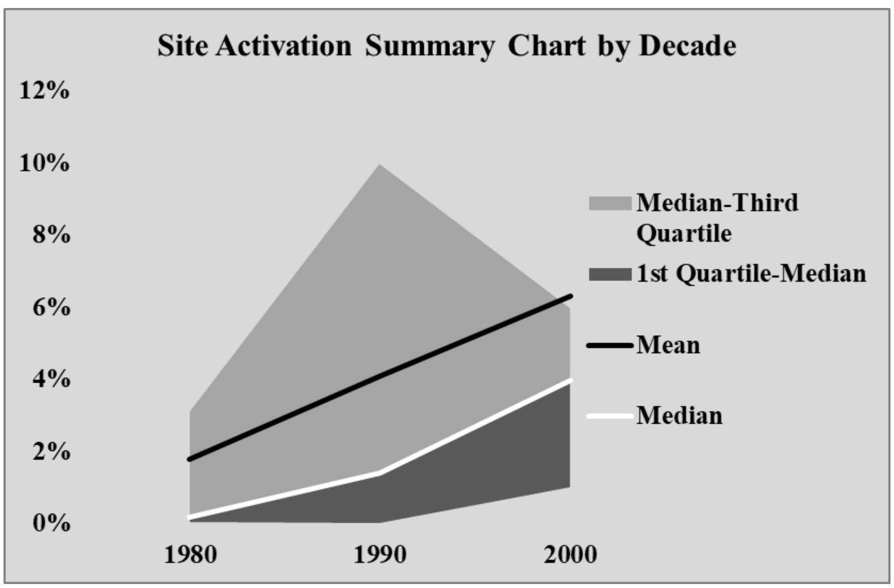
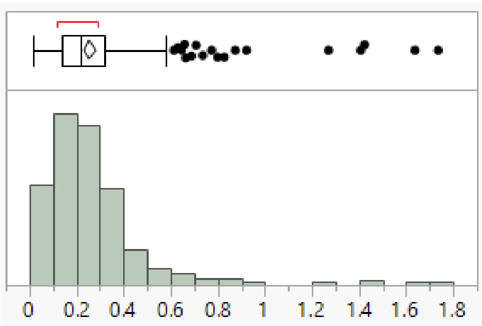


Figure 16: Site Activation Summary by Decade

G&A

The Level II WBS element G&A contains 365 programs representing 89.5% of the total data set, making it the second-largest WBS element in the analysis. Figure 17 displays the descriptive statistics for the G&A WBS element, and the individual decades' descriptive statistics are in Appendix C. The data has a standard deviation of 21.4%, with a Mean of 25.6% and a median of 21.5%. Again, the distribution appears to be right-skewed, but not nearly as much as the other distributions.



Quantiles

100.0%	maximum	1.736386557
99.5%		1.6545642556
97.5%		0.796115003
90.0%		0.4541411762
75.0%	quartile	0.316137307
50.0%	median	0.215649387
25.0%	quartile	0.1394123075
10.0%		0.062335732
2.5%		0.0195631343
0.5%		0.0153960284
0.0%	minimum	0.013021361

Summary Statistics

Mean	0.2563827
Std Dev	0.2141096
N	365
Median	0.2156494

Figure 17: G&A Descriptive Statistics

Table 14: G&A Summary by Decade

G&A Summary Table by Decade						
Decade	1960	1970	1980	1990	2000	2010
Mean	0.10259	0.22292	0.16983	0.25699	0.26065	0.35927
Std Dev	0.03099	0.08423	0.09136	0.25033	0.18162	0.37873
N	8	21	35	46	216	39
Max	0.17297	0.42382	0.36154	1.63781	1.27058	1.73639
0.75	0.10647	0.26996	0.25657	0.30379	0.3389	0.3638
Median	0.09959	0.21565	0.17944	0.18294	0.23172	0.25863
0.25	0.08012	0.16724	0.10494	0.13543	0.14306	0.16282
Min	0.07323	0.08448	0.01629	0.02124	0.01302	0.01588

Table 14 displays the individual descriptive statistics broken out by decade. These charts are also in Appendix C. The G&A factors have steadily increased in most decades. Between the 1960s and the 2010s, the mean has increased from 10.3% to 35.9%, and the median has increased from 10.0% to 25.9%. The distributions have become more right-skewed, with the first three decades showing the mean and median very close and further apart with the mean higher in the last decades.

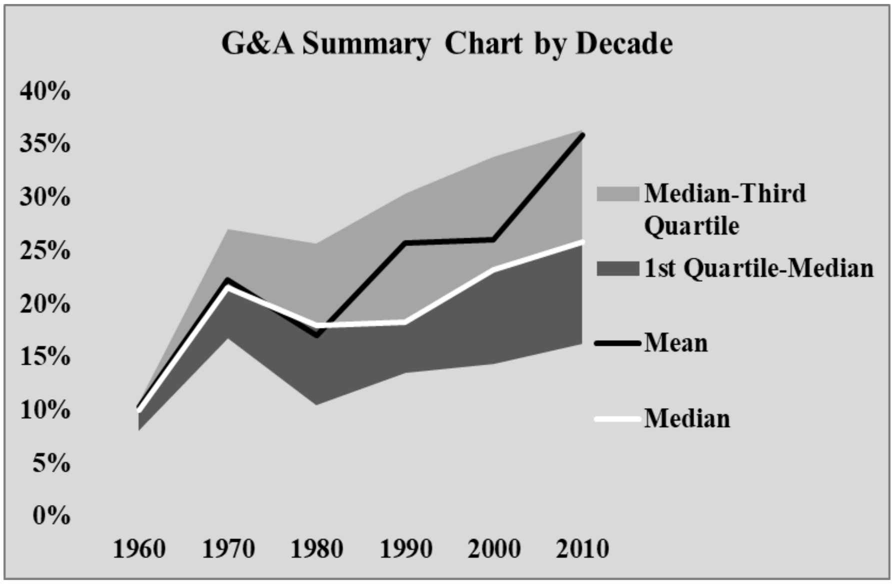
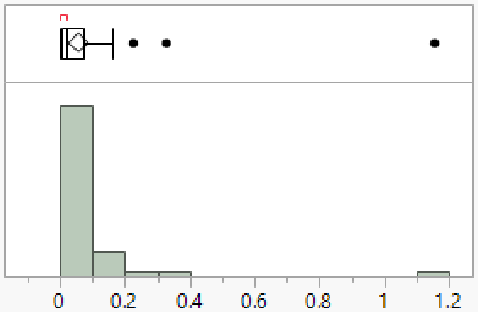


Figure 18: G&A Summary by Decade

Spares

Our dataset's last Level II WBS element is Spares with 76 1921s. This is 18.6% of the 1921s in our total data set. Figure 19 shows the descriptive statistics for Spares. A summary of descriptive statistics by decade for Spares is in Appendix C. The mean and median are highly dispersed at 5.8% and 2.1% and have a high standard deviation of 14.0%. The distribution also appears right-skewed.



Quantiles

100.0%	maximum	1.155972803
99.5%		1.155972803
97.5%		0.3901698568
90.0%		0.1234715074
75.0%	quartile	0.0741468593
50.0%	median	0.0208952765
25.0%	quartile	0.003555311
10.0%		0.000953188
2.5%		0.0000550914
0.5%		0.000025983
0.0%	minimum	0.000025983

Summary Statistics

Mean	0.0583122
Std Dev	0.1398251
N	76
Median	0.0208953

Figure 19: Spares Descriptive Statistics

Table 15 displays an example of the individual descriptive statistics broken out by decade. We have excluded from our analysis decades with less than five data points and show them grayed out, but have included the data for comparison to other decades. These charts are also in Appendix C.

Table 15: Spares Summary By Decade

Spares Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.08881	0.02414	0.05388	0.053816	0.06264	0.06267	0.01545
Std Dev	0.03354	0.03057	0.05749	0.076878	0.09612	0.19118	0.01717
N	7	3	2	11	11	36	6
Max	0.13198	0.05943	0.09452	0.22603	0.32808	1.15597	0.04198
0.75	0.11187	0.05943	0.09452	0.09987	0.076	0.05603	0.0327
Median	0.10101	0.00699	0.05388	0.015006	0.02364	0.01685	0.01019
0.25	0.04802	0.00598	0.01323	0.001311	0.00483	0.00322	0.00045
Min	0.04079	0.00598	0.01323	0.000026	0.00014	0.00048	0.00022

The Spares factors appear to be shrinking. The mean goes from 8.9% in the 1950s to 1.5% in the 2010s and the median from 10.1% to 1.0% in the same timeframe. There is a slight rise in both mean and median in the 1990s, and the mean increases again in the 2000s, increasing beyond the 3rd quartile. The distribution is left-skewed in the 1950s but flips and becomes right-skewed in the 1980s and beyond.

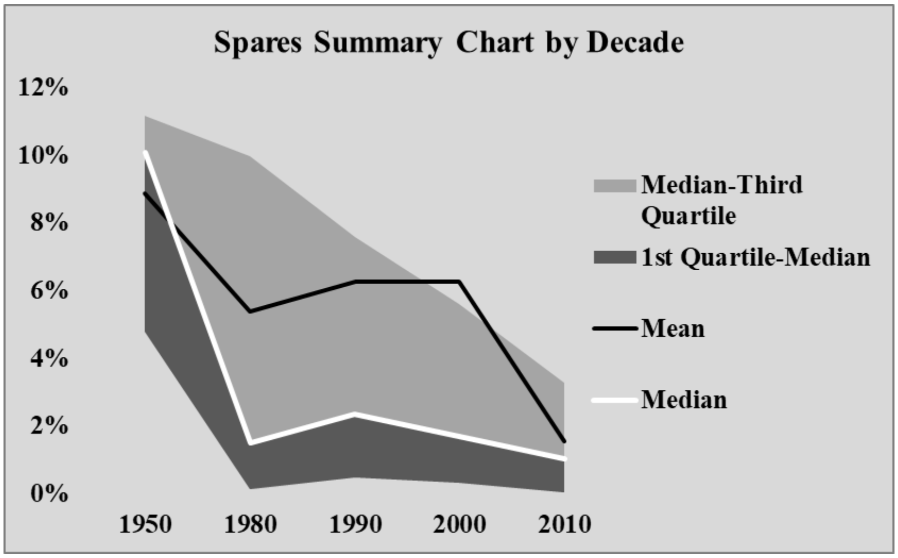


Figure 20: Spares Summary by Decade

Results by WBS, Category, and Decade

This section presents the statistical findings for each WBS element and subcategory within each WBS element. The first test is the Kruskal-Wallis Test, which tests the locations of datapoints within each decade of a sample to determine if they are likely to belong to the same distribution. Rejecting the null hypothesis indicates the data sets are not from the same distribution. We use the Wilcoxon test to determine which of the decades within a data group is the most different from the others and does not fit with the rest of the distribution. Since this research is exploratory, we use an alpha value of 0.10 for all tests, but we also evaluate the results at both 0.10 and 0.05.

Kruskal-Wallis Test Results

The Kruskal-Wallis test determines if all the decades within the WBS element or subgroup are from the same distribution. We used this test on each WBS element and subcategory and summarized the results in the following sections. If the p-value for a subgroup is below 0.10, we reject the null hypothesis, and at minimum, one decade is significantly different. These subgroups are the only groups that have further testing to determine which decades are different. It is advisable with Chi-Square tests, such as a Kruskal-Wallis test, to exclude samples with fewer than five observations because of low power issues unless an exact Chi-Squared table is used (Kruskal & Wallis, 1952; Howell, 2010). Above 5 observations, the Kruskal-Wallis calculations adequately approximate the table values. Table 16 shows the number of factors available in each decade per WBS element, and Table 18 lists each subgroup and how many decades have five or more factors per decade. A detailed breakdown of the number of factors per decade for every subgroup is in Appendix F. Since we are comparing between decades, we need at least two decades to compare. All WBS elements had at least two decades to compare, but any subgroups with less than two decades that have five or more factors we show grayed out and will not include in the Kruskal-Wallis tests nor the Wilcoxon tests for that subgroup.

Results by WBS Element

To understand any overall trends, we start by testing each WBS element before breaking them up by subcategory. We have excluded the decades with fewer than five data points and depict them as light gray in Table 16. The 1950s and 1960s have the most excluded data due to the low number of 1921s collected in those decades.

Table 16: Number of Factors per WBS Elements

Decade	1950	1960	1970	1980	1990	2000	2010	Total
WBS								
SEPM	1	5	24	46	51	220	38	385
ST&E	8	6	22	46	48	174	28	332
Training	6	4	13	29	30	90	8	180
Data	6	5	23	44	35	129	21	263
Site Activation			2	15	6	31	4	58
Support Equipment	7	4	12	29	27	61	10	150
Spares	7	3	2	11	11	36	6	76
G&A		8	21	35	46	216	39	365
Grand Total	35	35	119	255	254	957	154	1809

We use the Kruskal-Wallis test in our analysis to determine which WBS elements have statistically different decades from the overall distribution of the WBS element data. Overall, six of our eight WBS elements have significant decades at an alpha level of 0.10. As seen in Table 17, all decades within Training and Data elements are within a similar distribution and will not need further testing. These decades may have experienced trends or changes, but our tests did not show that those changes were significant. Therefore the distribution of the whole element is a representation of the distribution. For SEPM, ST&E, Site Activation, Support Equipment, Spares, and G&A, we will test each decade to determine which decades are not representative of the overall WBS element later in this chapter.

Table 17: Kruskal-Wallis Results by Decade for WBS elements

WBS	SEPM	ST&E	Training	Data	Site Activation	Support Equipment	Spares	G&A
P-value	0.0001**	0.0001**	0.7339	0.1213	0.0176**	0.0010**	0.0987*	0.0008**
n	385	332	180	263	58	150	76	365

Results by Subcategory

We next ran tests on each subcategory within the WBS elements. Of note in Table 18 are the groups lacking WBS elements with two or more significant decades. Engine, missile, space, and UAV commodities lack the number of decades for further analysis, as well as the Joint service group. Aircraft, both cost-plus and fixed contracts, prime contractors, and Navy service programs have at least two decades in each WBS element, and we will thoroughly test them, while the other categories are missing at least one WBS element. Site Activation and Spares have the least number of groups with sufficient decades. All factors not tested in one subgroup may qualify and test in another subgroup as a factor that we do not use in the Space or UAV commodities may be used in the Cost Plus or Fixed contract subgroups.

Table 18: Number of Decades per Category With Five or More Factors

WBS	SEPM	ST&E	Training	Data	Site Activation	Support Equipment	Spares	G&A
Commodity ID								
Aircraft	**6**	**7**	**5**	**6**	2	**5**	4	**5**
Electronic/Automated Software	3	3	2	2	1	1	1	3
Engine	0	1	0	0	0	0	0	1
Missile	0	0	0	0	0	0	0	0
Rotary Wing	3	3	3	3	1	2	1	3
Space	1	1	1	1	0	1	0	1
UAV	1	1	0	1	0	1	1	1
ContractCat								
Cost Plus	**5**	**5**	3	4	2	3	2	**6**
Fixed	4	4	2	4	2	2	2	4
Prime or Sub								
Prime	**6**	**7**	**6**	**7**	3	**6**	4	**6**
Sub	3	2	2	2	1	2	1	3
Service ID								
Air Force	**5**	**6**	**5**	**6**	1	**6**	3	**5**
Army	3	3	3	3	0	1	0	3
Joint	1	1	0	0	0	0	0	1
Navy	**5**	**5**	3	**5**	2	3	3	**5**

Table 20 shows a summary of the results of the Kruskal-Wallis tests results, the p-value for each subgroup, along with the number of factors in that subgroup. More results are in Appendix D -- Kruskal Wallis Test Results by WBS Element and Category. We did not test subgroups with less than five factors. Tests with a p-value below 0.10 have an asterisk next to the p-value, while test results below 0.05 have two asterisks, as seen in Table 19.

Table 19: Kruskal-Wallis Results Key

Key	Format
Not Significant (p>0.10)	x.xx%
Moderately Significant (0.10≥p>0.05)	x.xx%*
Significant (0.05≥p>0.01)	x.xx%**

Table 20: Kruskal-Wallis Test Results

Kruskal-Wallis Test Results	P-Value	n	P-Value	n	P-Value	n	P-Value	n	P-Value	n	P-Value	n	P-Value	n	P-Value	n
Decade	SEPM		ST&E		Training		Data		Site Activation		Support Equipment		Spares		G&A	
Commodity Type																
Aircraft	0.0066**	141	0.0001**	140	0.1887	66	0.1249	110	0.3545	19	0.0073**	74	0.0473**	31	0.0676*	122
Electronic/Automated Software	0.8295	88	0.2196	74	0.5551	41	0.2568	44							0.6684	97
Rotary Wing	0.7035	87	0.0045**	59	0.0258**	40	0.0399**	66			0.0345**	26			0.1849	83
Contract Type																
Cost Plus	0.0001**	209	0.0007**	183	0.1424	94	0.4080	112	0.2179	13	0.0291**	67	0.8997	25	0.0141**	211
Fixed	0.0443**	106	0.0001**	78	0.0358**	38	0.0013**	82	0.0338**	16	0.3775	9	0.8474	8	0.2703	91
Contractor Type																
Prime	0.0001**	216	0.0001**	235	0.0888*	133	0.1602	184	0.1594	32	0.0003**	120	0.0674*	42	0.0003**	222
Sub	0.5362	125	0.0409**	92	0.0772*	42	0.4121	75			0.7341	25			0.1533	141
Service																
Air Force	0.0002**	149	0.0001**	133	0.3690	69	0.2337	97			0.0373**	77	0.0977*	17	0.2746	134
Navy	0.0873*	152	0.0002**	119	0.7070	52	0.4865	110	0.0011**	30	0.0887*	37	0.0606*	40	0.0211**	150
Army	0.7331	55	0.1253	60	0.4155	43	0.3218	43							0.6187	62

The ST&E subgroup has eight significant subgroups. SEPM and Support Equipment follow with six significant subgroups each. Each WBS element had at least one significant subgroup. There is a total of 36 significant subgroups that will require further analysis. Prime contractor and Navy service factors each had the most factors with six. Second is Aircraft commodity and Fixed contract with five each. Electronic/Automated Software commodity and Army service had no significant subgroups and will not need further testing. The following section discusses the results of the tests for each significant subgroup.

Wilcoxon Test Results

We assigned a dummy variable to each decade to determine which decades were significant within each subgroup. Each dummy variable is 1 for the decade in question and 0 for every other decade. For example, if a 1921 has a Milestone B decade of the 2000s, the 2000 dummy variable would be 1 and all other dummy variables (1950, 1960, 1970, etc.) is 0. Conversely, the 2000 dummy variable would be 1 for all the 1921s with a 2000 milestone B decade and a 0 for all others. This allows us to compare each decade to all the data, not within that decade. Since our analysis tries to determine if a decade does not represent the overall WBS element or subgroup, we need to test each decade against the whole distribution.

We use the Wilcoxon test to make this comparison. Unlike with the Kruskal-Wallis test, the results of the Wilcoxon test that have a p-value less than 0.05 reject the null hypothesis and are determined to not belong to the same distribution as the other decades. This is due to the Wilcoxon test not accounting for the multiple tests used by this research on each subcategory. A Bonferroni correction factor may be appropriate to account for spurious positives that may result from this type of multiple-comparison. However, since each subgroup would need a different correction, and therefore a different alpha, we have simplified the process by applying a quasi-Bonferroni corrected alpha of 0.05 for all subgroups and specified groups between 0.05 and 0.01, 0.01 and 0.005, and below 0.005. The p-values under 0.05 have one asterisk, below 0.01 have two asterisks, and below 0.005 the results have three asterisks. We describe these results as moderately significant, significant, and highly significant, respectively. The key in Table 21 displays an example of these formats. The p-value results of each WBS element and subcategory are summarized in Table 22 through Table 30. A more detailed view of the results is shown in Appendix E -- Wilcoxon Results.

Table 21: Wilcoxon Results Key

Key	Format
Not Significant ($p>0.05$)	x.xx%
Moderately Significant ($0.05\geq p>0.01$)	x.xx%*
Significant ($0.01\geq p>0.005$)	x.xx%**
Highly Significant ($p\leq 0.005$)	x.xx%***

The Wilcoxon test determines if any one decade within the element is significant. Any significant decade is not representative of the overall WBS element and may indicate a trend or anomaly within the element. Our Wilcoxon test compares all the data points within each decade to the data points in the remaining decades. Based on an analysis of the trends and significance levels, the analyst may determine that these significant decades result from a trend. In this case, the most recent data will likely be best suited for future estimates, as it better represents more current policies, processes, or techniques. In the case that the significant decade indicates a spike or temporary shift in the element or subcategory, the analyst should exclude any factors from that decade that are unrepresentative of the future estimates. These shifts may indicate anomalies in the dataset or temporary changes in program composition that do not accurately represent programs within that category.

Table 22: Wilcoxon Results by Decade for WBS Elements

WBS	1950 P-value	1950 n	1960 P-value	1960 n	1970 P-value	1970 n	1980 P-value	1980 n	1990 P-value	1990 n	2000 P-value	2000 n	2010 P-value	2010 n
Commodity Type														
SEPM			0.0152*	5	0.0001***	24	0.2180	46	0.0980	51	0.0140*	220	0.0016***	38
ST&E	0.0130*	8	0.0292*	6	0.0001***	22	0.0146*	46	0.8530	48	0.0001***	174	0.2400	28
Training														
Data														
Site Activation							0.0089**	15	0.7311	6	0.0083**	31		
Support Equipment	0.2392	7			0.0230*	12	0.0722	29	0.0336*	27	0.9005	61	0.0052**	10
Spares	0.0043***	7					0.6000	11	0.6000	11	0.3398	36	0.1790	6
G&A			0.0016***	8	0.9745	21	0.0059**	35	0.6029	46	0.0619	216	0.0826	39

We have summarized the test results of each WBS element's decades in Table 22. Of note are the significant and highly significant results in both the early and late decades. This is most prominent in SEPM and ST&E, and to a lesser extent, in Site Activation. Spares and G&A have significant and highly significant decades in earlier and few in later decades. We will explore the implications of these patterns in Chapter Five when we compare these results to the changes in the median over the decades.

Table 23: SEPM Wilcoxon Results by Decade

SEPM	1960	1970	1980	1990	2000	2010
Commodity Type						
Aircraft	0.0230*	0.0036***	0.7429	0.8985	0.0388*	0.4023
Contract Type						
Cost Plus		0.0002***	0.1600	0.0197*	0.0022***	0.0074**
Fixed		0.1229	0.3753		0.1450	0.0278*
Contractor Type						
Prime	0.0118*	0.0001***	0.1377	0.1393	0.0031***	0.0003***
Service						
Air Force		0.0016***	0.3415	0.0957	0.0111*	0.0073**
Navy		0.0185*	0.7503	0.5614	0.9718	0.1025

Within the SEPM WBS element, we have many significant and highly significant results. The Cost Plus contract type has one significant and two highly significant results, and Prime contractor types have three highly significant results. It also appears that the older and newer decades are both significant in most categories. The decades of the 1980s and 1990s have no significant or highly significant results.

Table 24: ST&E Wilcoxon Results by Decade

ST&E	1950	1960	1970	1980	1990	2000	2010
Commodity Type							
Aircraft	0.0319*	0.0557	0.0002***	0.3908	0.0008***	0.1254	0.0631
Rotary Wing				0.1651	0.0053**	0.0012***	
Contract Type							
Cost Plus			0.0002***	0.1302	0.3037	0.0026***	0.5145
Fixed			0.0015***	0.0273*		0.0002***	0.3231
Contractor Type							
Prime	0.0381*	0.0662	0.0001***	0.2802	0.0734	0.0085**	0.3718
Sub					0.0409*	0.0409*	
Service							
Air Force	0.0418*		0.0002***	0.0464*	0.0005***	0.0293*	0.8246
Navy			0.0068**	0.1288	0.0090**	0.0077**	0.0433*

ST&E has even more highly significant results than SEPM. However, these are more evenly spread across the categories. Aircraft commodity, both Fixed and Cost Plus contract types, and Air Force service type groups have no significant results but two highly significant results. The 1980s also have no significant or highly significant results like SEPM, but ST&E also has no significant or highly significant results in the decade 2010.

Table 25: Training Wilcoxon Results by Decade

Training	1950	1970	1980	1990	2000	2010
Commodity Type						
Rotary Wing			0.0258*	0.2793	0.0125*	
Contract Type						
Fixed			0.0358*		0.0358*	
Contractor Type						
Prime	0.5084	0.7792	0.1291	0.0574	0.0074**	0.9849
Sub				0.0772	0.0772	

As there were few testable decades within the Training WBS element, there are few significant results and no highly significant results. Only the Prime contractor type group has a significant result, and that is in the decade 2000.

Table 26: Data Wilcoxon Results by Decade

Data	1970	1980	1990	2000	2010
Commodity Type					
Rotary Wing		0.0130*	0.7984	0.0626	
Contract Type					
Fixed	0.0134*	0.0191*		0.0009***	0.4932

As with Training, the Data WBS element had few testable decades and even fewer testable categories. We only tested the Rotary Wing commodity type and Fixed contract type, with the Fixed contract type having one highly significant result in the decade 2000.

Table 27: Site Activation Wilcoxon Results by Decade

Site Activation	1980	2000
Contract Type		
Fixed	0.0338*	0.0338*
Service		
Navy	0.0011***	0.0011***

The Site Activation WBS has the fewest categories and categories that qualified for the Wilcoxon test. Fixed contract type and Navy service type categories both had two decades tested, so the results of each decade are identical. The Navy service type results are highly significant, and the Fixed contract type results were moderately significant.

Table 28: Support Equipment Wilcoxon Results by Decade

Support Equipment	1950	1970	1980	1990	2000	2010
Commodity Type						
Aircraft	0.3277	0.0300*	0.2564	0.0574	0.0906	
Rotary Wing				0.0345*	0.0345*	
Contract Type						
Cost Plus		0.0491*		0.0300*	0.4401	
Contractor Type						
Prime	0.1566	0.0085**	0.0213*	0.0305*	0.2649	0.0083**
Service						
Air Force		0.2407	0.0297*	0.0967	0.9167	0.0218*
Navy			0.8463	0.0290*	0.1267	

Support Equipment WBS element has two significant results, both within the Prime contractor category and no highly significant results. The Prime contractor category's highly significant results are near the early and late decades, in the 1970s.

Table 29: Spares Wilcoxon Results by Decade

Spares	1950	1980	1990	2000	2010
Contractor Type					
Prime	0.0119*	0.5385	0.8421	0.1183	
Service					
Air Force	0.0107*	0.7520	0.2594	0.0986	
Navy		0.0209*		0.0507	0.8862

The Spares WBS element has only three tested categories and no significant or highly significant results. The moderately significant results are in the early decades, in the 1950s and 1980s.

Table 30: G&A Wilcoxon Results by Decade

G&A	1960	1970	1980	1990	2000	2010
Commodity Type						
Aircraft		0.8584	0.0198*	0.5346	0.0093**	0.7763
Contract Type						
Cost Plus	0.0056**	0.5141	0.6194	0.0893	0.0595	0.1029
Contractor Type						
Prime	0.0019***	0.7602	0.0069**	0.7255	0.5258	0.0040***
Service						
Navy	0.0086**		0.0495*	0.8147	0.1354	0.4110

The final WBS element, G&A, has few testable categories but some significant and highly significant results. Prime contractor type has one significant result in 1980 and two highly significant results in the 1960s and 2010s. The other significant results are in the 1960s with Cost Plus contract type and Navy service type, and in the 2000s with the Aircraft commodity type. This appears to reinforce the trend of having the most significant results in the upper and lower decades with few in the middle decades.

Chapter Summary

This chapter presented the data and statistical analysis used within this research in preparation for Chapter Five, where we will further discuss the results and possible implications. Firstly, we explored the dataset and explained vital characteristics, such as exclusions. Next was a broad descriptive summary at the WBS level and a look at the decadal distribution of each element. We followed this with a more detailed view of the

WBS elements by commodity, contract, contractor, and service type and tested them using non-parametric analysis. We analyzed each of these subgroups for significant decades, discussed in the final chapter.

V. Conclusions

Chapter Overview

Our final chapter provides the major findings based on the literature, data, and statistical tests. We address the answers to our research questions first and then analyze the specific results for each WBS element. Next, we state the significance of this research for use in cost estimating. Limitations and recommendations for future research are at the end of the chapter.

Conclusions of Research

Research Questions Answered

Our research questions address the creation and statistical significance of factors between decades within several categories in each WBS element. Our first question was:

1. In each decade, what are the level II WBS factors for various DoD commodities, contract types, contractor types, and service branches?

Only three commodities had enough data to create robust factors for commodity type. These commodities are Aircraft, Electronic Systems, and Rotary Wing. Cost Plus and Fixed contract type both have robust factors, as do Prime and Fixed contractor types. For service type, Air Force, Navy, and Army have factors but not the Joint service type. We display these factors by WBS element in the next section.

Our second question was:

2. What are the statistical differences between decades in level II WBS factors for various DoD commodities, contract types, contractor types, and service branches?

We found clear trends with statistically significant decadal differences in several subcategories within SEPM and ST&E. There are also several spikes in the data marked with significant decades. We explore in detail which decades and subcategories are significant in the next section.

For decades and subgroups with five or more data points, we display the mean and median. However, our analysis and discussion will focus on the medians of the distributions due to the manner of our tests and the skew of our distributions. Also, we chose the median versus mean as a point of comparison as the median is less affected by extreme values. We exclude all subgroups with less than two decades as we would not be able to compare them. We indicate the results of the Wilcoxon tests on these numbers with asterisks. The p-values under 0.05 are moderately significant and have a single asterisk next to the mean and median values. P-values below 0.01 are significant and have two asterisks. P-values below 0.005 are highly significant have three asterisks. We have also marked those decades we would recommend using for future factor creation using bold format. Table 31 illustrates these significance levels. We will explore graphs of the medians by decade within some of the WBS sections to highlight changes to factor composition.

Table 31: Wilcoxon Results Significance Levels Key

Key	**Significance**	**Recommended**
Not Significant ($p>0.05$)	x.xx%	**x.xx%**
Moderately Significant ($0.05\geq p>0.01$)	x.xx%*	**x.xx%***
Significant ($0.01\geq p>0.005$)	x.xx%**	**x.xx%****
Highly Significant ($p\leq 0.005$)	x.xx%***	**x.xx%*****

WBS Results

We see some interesting trends within the WBS elements at a top-level view. Table 32 displays the mean and median. A more detailed view of these results, including the standard deviation, are included in Appendix H -- Summary Tables and Significance Results. SEPM factors appear to increase from the 1960s to the 2010s, with highly significant factors in the 1970s and 2010s. Having significant factors early and late in the decades corresponds with an upward or downward trend. ST&E shows an opposite trend, decreasing in the median from a high in the 1970s to a low in the 2010s. ST&E has highly significant factors in the 1970s and 2000s. G&A factors increased from the 1960s to the 2010s but were only significant in the early decades. Figure 21 illustrates the shifts in the median for these WBS elements. The relationship between an increase or decrease in the factors marked with significant decades will appear in these same WBS elements when discussing them at the subcategory level. Site Activation saw an increase between the 1980s and the 2000s, with the 2000s being significant. Support Equipment saw a decline with significant factors in the 2010s. Spares had highly significant factors in the 1960s, where the median was much higher than the other decades.

Table 32: WBS Summary Table and Significance Results

WBS	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1960		1970		1980		1990		2000		2010	
SEPM			11.8%*	7.6%*	18.9%***	14.3%***	**34.4%**	**27.8%**	**40.4%**	**23.3%**	**47.3%***	**34.8%***	**65.4%*****	**50.7%*****
ST&E	33.3%*	32.0%*	38.3%*	29.5%*	42.2%***	40.8%***	28.5%*	19.2%*	**17.4%**	**12.4%**	**15.2%*****	**9.5%*****	**21.9%**	**10.2%**
Training	**2.0%**	**2.0%**			**1.7%**	**0.4%**	**2.4%**	**0.4%**	**2.5%**	**0.3%**	**3.6%**	**0.6%**	**4.2%**	**0.3%**
Data	**2.1%**	**1.5%**	**2.5%**	**2.8%**	**5.8%**	**2.7%**	**4.6%**	**1.9%**	**2.9%**	**1.8%**	**3.1%**	**1.8%**	**2.2%**	**1.2%**
Site Activation							1.8%**	0.2%**	**4.1%**	**1.4%**	**6.3%****	**4.0%****		
Support Equipment	5.4%	3.5%			16.3%*	5.9%*	**6.3%**	**3.2%**	**2.7%***	**0.8%***	**10.3%**	**1.9%**	**1.4%****	**0.3%****
Spares	8.9%***	10.1%***					**5.4%**	**1.5%**	**6.3%**	**2.4%**	**6.3%**	**1.7%**	**1.5%**	**1.0%**
G&A			10.3%***	10.0%***	22.3%	21.6%	17.0%**	17.9%**	**25.7%**	**18.3%**	**26.1%**	**23.2%**	**35.9%**	**25.9%**

Since Training and Data had no significant decades, all the data appears to be from the same distribution. Future analysts could use all decades' data to develop factors as none of the decades contain data that differ greatly from the distribution.

For significant decades with visible trends such as SEPM, ST&E, and G&A, an analyst should consider using the most recent decades as the older decades may not reflect newer programs. In WBS elements like Spares, where one decade is significant, and the median is dissimilar from the remaining decades, we recommend excluding data from that decade and using the remaining decades to develop an estimate. In general, our recommendations are to exclude early decades if they have significant Wilcoxon results, or later decades if they appear to represent an anomaly, such as with Spares. We will recommend all decades when no decades are significant. These recommendations apply in the remaining analysis by subcategories unless we specifically outline decades in the analysis.

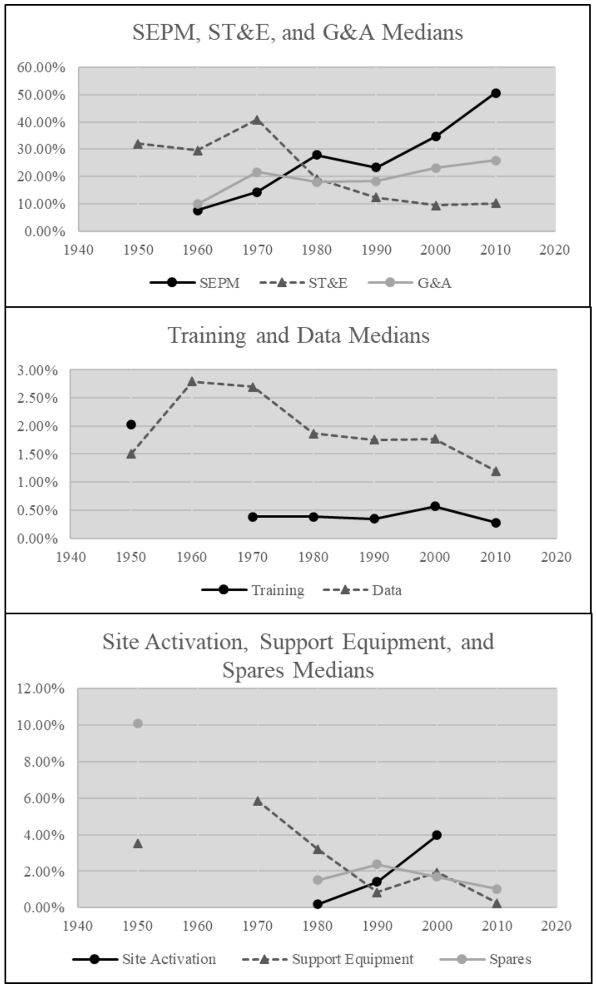


Figure 21: WBS Medians by Decade

SEPM

Chapter Four analyzed the overall trend within the SEPM WBS element. From a more constituent view, we see some similar attributes. Both the mean and the median saw growth from the 1950s through into the 2010s in subcategories such as Aircraft commodity, Cost Plus and Fixed contract, Prime contractor, and Air Force service. As seen from Table 33, the significant and highly significant results appear most often in the early or late decades. These decades are most different from the rest of the subgroup.

Table 33: SEPM Summary Table and Significance Results

SEPM	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1960		1970		1980		1990		2000		2010	
Commodity Type												
Aircraft	11.8%***	7.6%***	17.1%***	12.3%***	35.5%***	25.6%***	40.1%***	23.3%***	35.2%***	30.0%***	60.4%***	35.8%***
Electronic/Automated Software							53.1%	46.9%	61.5%*	53.5%*	62.6%	48.8%
Rotary Wing					28.1%	27.7%	37.4%	28.7%	40.1%	22.5%		
Contract Type												
Cost Plus			16.4%***	16.2%***	29.2%***	27.7%***	31.4%***	23.2%***	53.9%***	38.7%***	87.4%***	64.1%***
Fixed			17.9%***	9.9%***	34.1%	26.8%			32.3%***	21.1%***	48.4%**	48.8%**
Contractor Type												
Prime	11.8%***	7.6%***	18.9%***	14.3%***	34.4%***	27.8%***	38.2%***	24.1%***	48.7%***	39.0%***	70.2%***	52.9%***
Sub							31.7%	22.1%	46.1%***	29.7%***	33.6%***	22.7%***
Service												
Air Force			16.9%***	14.3%***	34.0%***	24.1%***	36.4%***	22.1%***	51.9%***	38.0%***	69.0%***	61.3%***
Navy			12.4%***	9.1%***	36.0%	29.0%	26.3%	23.3%	40.3%*	27.0%*	69.9%**	47.7%**
Army							51.1%	46.9%	60.5%	50.7%	52.0%	43.0%

Using the Cost Plus contract type as our example, the 1970s were highly significant and had the lowest medians. Compared to the rest of the subgroup, this indicates this decade's data is different from the rest of the data points. Alternatively, the same is accurate at the high end of the decades. The 2000s are highly significant and have very high medians. The 2010s are also significant, with the highest medians for that subgroup. Since these decades are much higher than the rest of the subgroup, they are also far from the remaining decades. Contrast this to the middle decades of the 1980s and 1990s. Since their medians are between the upper and lower decades, they are closer to many more data points in the distribution above and below. They are also closer to the middle of the total subgroup and are less significant. Figure 22 shows a visible rise in medians in the Aircraft commodity, Prime Contractor, Cust Plus and Fixed contract, and both in the Air Force and Navy services. Most of these subcategories are also the same that have significant decades at the end. As we will see in other WBS elements, the analysis often remains similar when decades are far from the middle of the data.

When significant decadal differences exist, we recommend estimating using decades that mark the end of a trend as they represent the most recent comparison for future programs. We recommend using all decades for subcategories that did not have significant decadal factors and do not represent a trend. Data from the 2000s are most significant from that subcategory, and the low significance in the 2010s might be because the few programs in those years were most similar to the older data and dissimilar to newer factors.

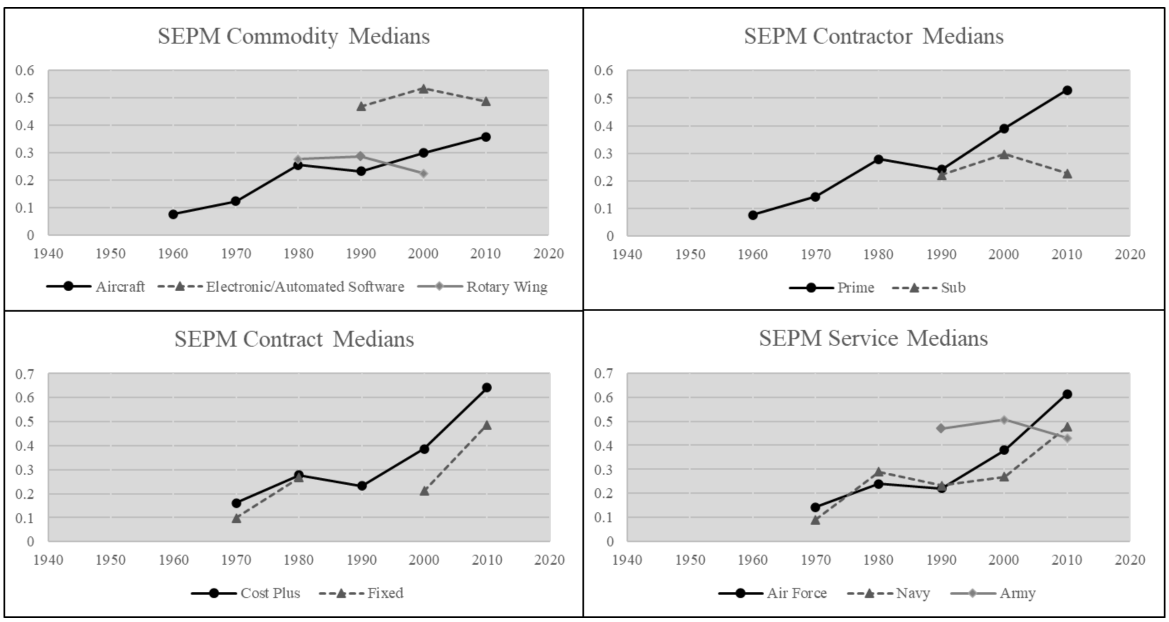


Figure 22: SEPM Medians by Decade

ST&E

ST&E factors have an inverse relationship between decades, with a similar distribution of significant factors, as we saw with SEPM. Chapter Four noted a decrease from decade to decade of both the mean and median at the WBS level. Between the

1970s and the 2000s, we see several subgroups that share this relationship, such as the Aircraft commodity, Prime contractor, Cost Plus and Fixed contract, and Air Force and Navy services. Before the 1970s, there were some minor fluctuations but no significant results. Our most significant results are in the 1970s, 1990s. The 2000s and the 1980s have few significant subgroups. Table 34 shows the decades that have significant results.

Table 34: ST&E Summary Table and Significance Results

ST&E	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1960		1970		1980		1990		2000		2010	
Commodity Type														
Aircraft	33.3%***	32.0%***	38.3%***	29.5%***	41.0%***	40.8%***	28.6%***	19.2%***	10.7%***	8.7%***	18.3%***	12.8%***	18.8%***	0.4%***
Electronic/Automated Software									31.2%***	17.3%***	14.4%	8.6%	24.2%	16.5%
Rotary Wing							34.0%	26.5%	31.7%	34.5%	13.6%	4.4%		
Contract Type														
Cost Plus					44.2%***	46.8%***	23.5%***	25.1%***	18.3%***	14.4%***	14.5%***	9.7%***	33.2%***	1.7%***
Fixed					51.5%***	58.1%***	29.8%	22.4%			10.8%***	4.6%***	14.6%	9.6%
Contractor Type														
Prime	33.3%***	32.0%***	38.3%***	29.5%***	42.2%***	40.8%***	27.8%***	18.9%***	16.1%***	11.6%***	17.8%***	12.9%***	24.5%***	16.5%***
Sub									22.0%	14.2%	12.3%**	5.0%**		
Service														
Air Force	35.7%***	33.6%***			48.4%***	56.7%***	33.2%***	23.6%***	9.9%***	8.4%***	17.4%***	10.2%***	29.2%***	25.7%***
Navy					32.6%***	30.0%***	23.2%*	15.3%*	23.4%***	19.4%***	12.3%*	6.6%*	18.7%	1.8%
Army									31.5%**	27.7%**	18.3%**	15.5%**	20.4%*	23.0%*

Similar to SEPM, the ST&E factors are most significant at the tails, except for the 1950s and 1960s. This could be because there were few programs in those decades with ST&E factors or due to the spike we see in the 1970s. The lack of significant subgroups in the 1980s could be because those factors lie closer to the middle of the total subgroup and represent the overall distribution. In Figure 23, we see the decrease in several subgroups' medians starting from the 1970s. The 1970s are particularly significant with an apparent spike. We see between the 1960s to 1980s a consistent reduction without that spike. Aircraft commodity, Cost Plus contracts and Navy service appear to shrink consistently until the 2010s. Prime contractors, Air Force service, and Fixed contract also have a steep decline but appear to rebound slightly near the later decades. We recommend using the most recent decades for ST&E factors such as with Aircraft and Rotary Wing commodity and Cost Plus contracts.

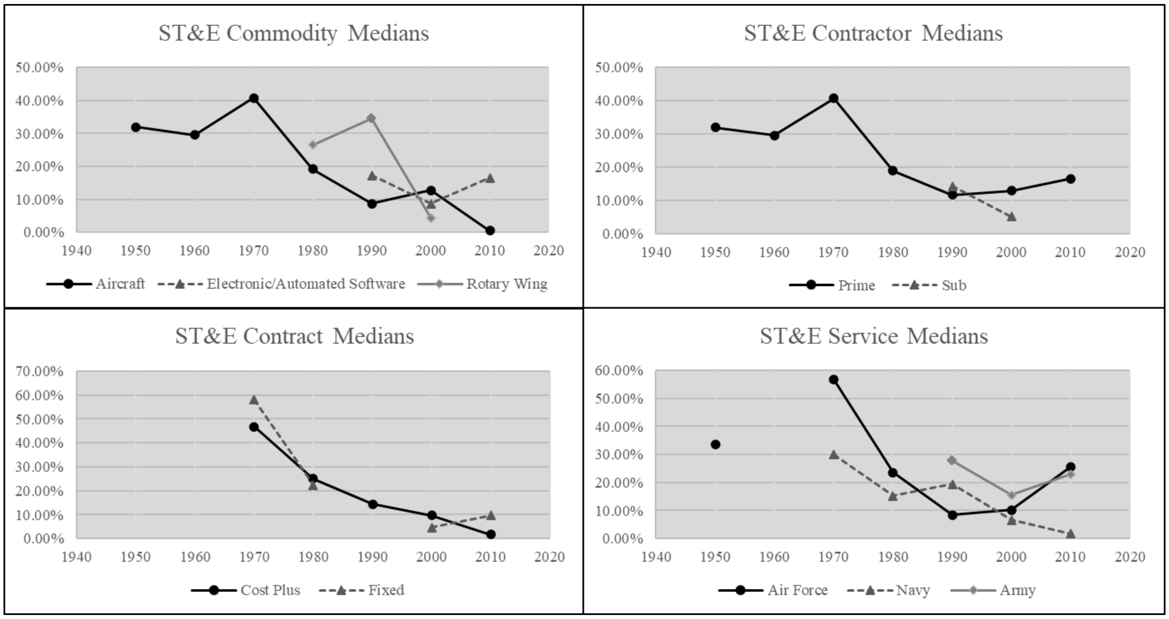


Figure 23: ST&E Medians by Decade

Training

There are few significant decades in the subgroups of the Training WBS element. Prime contracts are significant in the 2000s, and there are some moderately significant decades in the 1980s and 2000s from the Rotary Wing commodity and Fixed contract, as seen in Table 35. In Chapter Four, the overall Training WBS factors saw a divergence between the mean and the median, becoming more variable and more right-skewed. This appears to remain valid at the subgroup level as well.

Table 35: Training Summary Table and Significance Results

Training	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1970		1980		1990		2000		2010	
Commodity Type												
Aircraft	2.02%***	2.02%***	0.77%***	0.38%***	1.86%***	0.18%***	1.25%***	0.23%***	5.19%***	1.13%***		
Electronic/Automated Software									4.18%	1.46%	0.94%	0.28%
Rotary Wing					5.09%	0.93%	0.68%	0.35%	2.83%	0.16%		
Contract Type												
Cost Plus			0.95%***	0.38%***			2.54%***	0.35%***	4.01%***	1.33%***		
Fixed					2.25%	0.38%			0.24%	0.12%		
Contractor Type												
Prime	2.02%***	2.02%***	1.74%***	0.38%***	2.46%***	0.38%***	2.46%***	0.35%***	5.07%***	1.39%***	2.63%***	0.28%***
Sub							2.77%	0.35%	1.52%**	0.16%**		
Service												
Air Force	1.84%***	1.60%***	1.26%***	0.38%***	1.21%***	0.31%***	1.32%***	0.24%***	3.66%***	0.94%***		
Navy					3.99%	0.36%	0.34%	0.34%	2.93%	0.19%		
Army							6.62%	1.66%	4.15%	1.61%	2.89%	0.16%

In Figure 24, we see that Rotary Wing commodity and Army service subgroups appear to have a slight decrease in their medians, while only Rotary Wing commodity has significant decades. The spike we see in the 2000s for Prime contractor corresponds with our most significant result. The mean and median are both higher in the 2000s than in decades prior. There is no general overall trend in the Training factors, but we can consider some anomalies. We recommend using the later decades for Rotary Wing commodity factors and Fixed contract. As the 2000s appears as an anomaly in Prime contracts, we recommend excluding data from the 2000s.

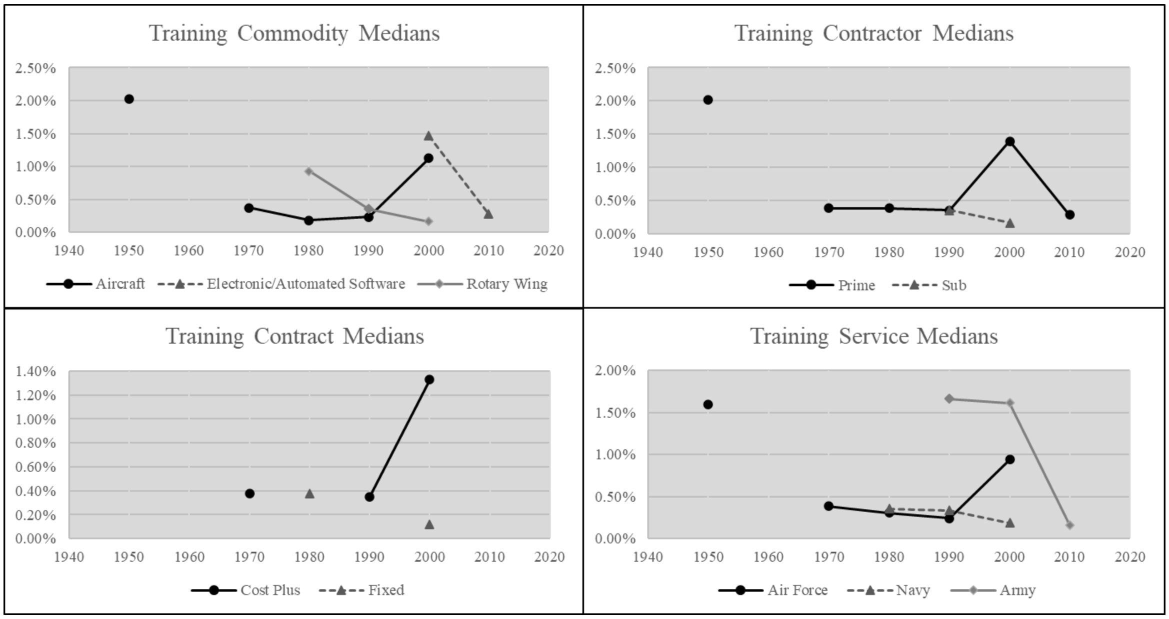


Figure 24: Training Medians by Decade

Data

We see a similar result from Data as we saw in Training. There are few significant results and no consistent trends. In Table 36, we see that only the Rotary Wing commodity and Fixed contract have significant results, although the 2000s decade is highly significant for Fixed contract.

Table 36: Data Summary Table and Significance Results

Data	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1960		1970		1980		1990		2000		2010	
Commodity Type														
Aircraft	2.10%***	1.51%***	2.51%***	2.80%***	4.98%***	3.38%***	3.71%***	1.76%***	1.44%***	0.95%***	3.03%***	2.18%***		
Electronic/Automated Software											4.37%	1.89%	1.25%	1.09%
Rotary Wing							11.20%	5.99%	2.43%	2.37%	2.49%	1.34%		
Contract Type														
Cost Plus					3.44%***	2.47%***	5.23%***	2.88%***	1.65%***	0.99%***	3.73%***	2.06%***		
Fixed					6.51%	4.69%	4.92%	1.87%			1.37%	0.79%	2.13%	1.11%
Contractor Type														
Prime	2.10%***	1.51%***	2.51%***	2.80%***	5.79%***	2.69%***	4.81%***	1.99%***	1.94%***	1.75%***	3.67%***	2.30%***	2.28%***	1.20%***
Sub									2.00%	1.92%	2.52%	0.89%		
Service														
Air Force	1.60%***	1.47%***			4.82%***	2.69%***	6.25%***	2.67%***	1.54%***	0.95%***	4.54%***	2.27%***	2.11%***	2.44%***
Navy					2.53%	2.22%	2.27%	1.42%	1.89%	1.76%	2.88%	1.64%	0.97%	0.78%
Army									3.09%	3.05%	2.26%	1.22%	3.60%	1.14%

In Figure 25, we see the Rotary Wing commodity median drop. This would explain the moderately significant result in the 1980s, as that decade is much higher than the other two tested in that subgroup. Fixed contract medians also see a drop between the 1970s and 1980s and the 2000s. The remainder of the subgroups have no significant results, and their medians do not appear in any consistent trend. We recommend using recent programs for Rotary Wing commodity and Fixed contract factors.

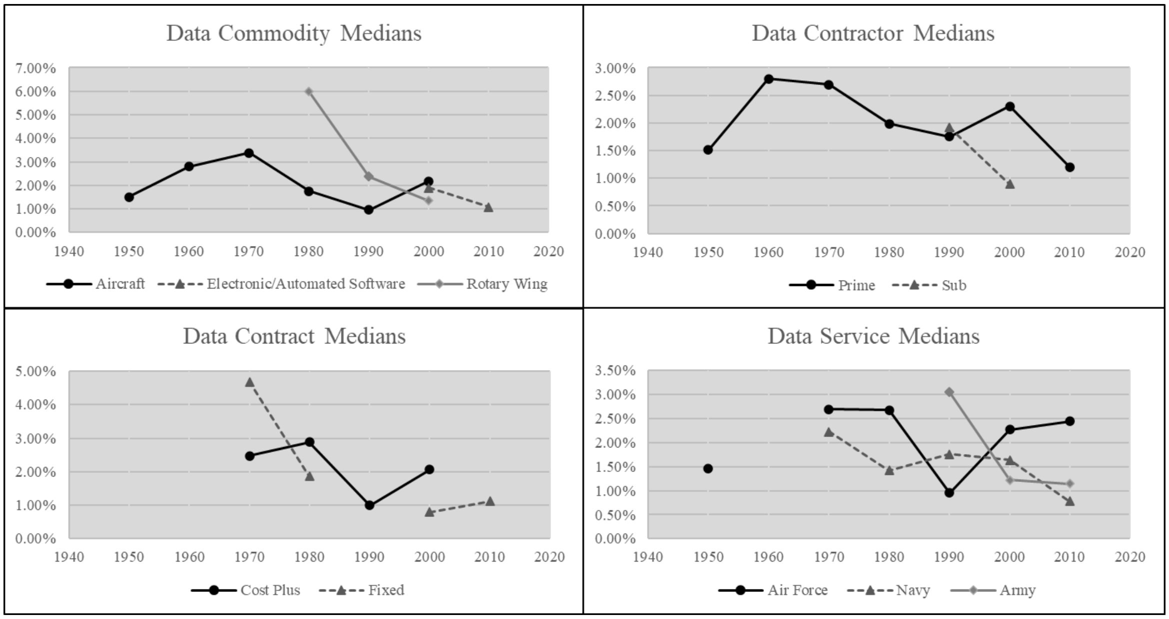


Figure 25: Data Medians by Decade

Support Equipment

The Support Equipment WBS element has more moderately significant and significant results than either Data or Training, but no highly significant results, as seen in Table 37. Prime contract stands out with two moderately significant and two significant decades. The 1970s and 2010s were the most significant and the middle decades less so for Prime contract.

Table 37: Support Equipment Summary Table and Significance Results

Support Equipment	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1970		1980		1990		2000		2010	
Commodity Type												
Aircraft	5.43%***	3.54%***	22.03%***	7.49%***	6.29%***	3.22%***	3.39%***	1.21%***	2.22%***	1.94%***		
Rotary Wing							0.44%	0.08%	3.18%	0.82%		
Contract Type												
Cost Plus			9.35%***	6.23%***			1.96%***	0.79%***	12.04%***	1.47%***		
Fixed					6.83%	4.15%			3.20%	2.01%		
Contractor Type												
Prime	5.43%***	3.54%***	16.30%***	5.87%***	6.46%***	3.57%***	2.19%***	0.73%***	10.81%***	1.34%***	1.35%***	0.26%***
Sub							5.52%*	2.15%*	9.37%	5.63%		
Service												
Air Force	3.52%***	3.27%***	18.74%***	5.04%***	8.32%***	4.22%***	3.74%***	1.37%***	6.65%***	2.84%***	1.03%***	0.21%***
Navy					2.20%*	0.77%*	0.42%	0.06%	5.79%	0.81%		

In Figure 26, we see a drop in Aircraft commodity. This may coincide with the moderately significant result in the 1970s for that subgroup, as it is the highest median for that subgroup. The Air Force service medians also see a drop, and the moderately significant results from that subgroup are at the higher and lower ends of that drop. The Prime contract subgroup is similar, with a decline between the 1970s and 2010s marked with significant results at the extremes. We recommend using the most recent factor data for most subcategories within Support Equipment.

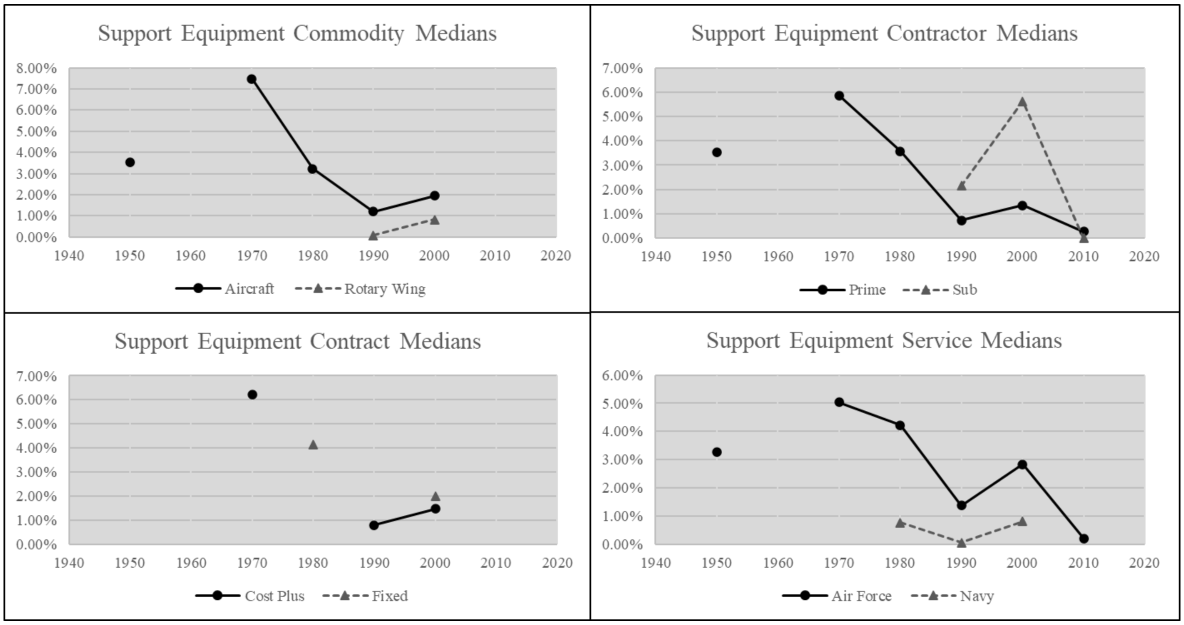


Figure 26: Support Equipment Medians by Decade

Site Activation

Site Activation has few subgroups and decades and even fewer significant results. Chapter Four states that this is our smallest WBS element, with only 58 1921s tested. In Table 38, we see the only highly significant results are between the Navy service decades of the 1980s and the 2000s. It is also noteworthy that the mean and median are very different, going from fractions of a percent to nearly 4%. This shift could explain the significance. The Fixed contract decades of the 1980s to 2000s are moderately significant, and we see an increase in mean and median, but not as extreme. We recommend only using the most recent data for Fixed contract and Navy branch factors, but the other categories are not significant, and no decades need to be excluded.

Table 38: Site Activation Summary Table and Significance Results

Site Activation	Mean	Median	Mean	Median	Mean	Median
Decade	1980		1990		2000	
Commodity Type						
Aircraft	**1.92%*** **	**0.31%*** **			**2.17%*** **	**1.60%*** **
Contract Type						
Cost Plus			**3.07%*** **	**0.48%*** **	**10.30%*** **	**2.37%*** **
Fixed	2.40%	1.29%			**3.76%**	**4.16%**
Contractor Type						
Prime	**1.80%*** **	**0.18%*** **	**4.90%*** **	**2.35%*** **	**10.00%*** **	**1.99%*** **
Service						
Navy	0.14%	0.09%			**3.65%**	**3.92%**

G&A

The G&A WBS element has many subgroups and decades but few significant results. Table 39 shows that Aircraft commodity, Cost Plus contract, Prime Contractor, and Navy service are the only subgroups with significant results. Most of the significant and highly significant results are in the decades 1960 and 1980, with a few in the 2000s and 2010s. Prime contractor has two highly significant results in the 1960s and the 2010s and a significant result in the 1980s.

Table 39: G&A Summary Table and Significance Results

G&A	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1960		1970		1980		1990		2000		2010	
Commodity Type												
Aircraft			**20.8%*****	**18.3%*****	**15.9%*****	**17.1%*****	**20.3%*****	**17.2%*****	24.2%***	23.2%***	**37.9%*****	**16.5%*****
Electronic/Automated Software							**30.2%**	**29.9%**	**28.0%****	**24.0%****	**32.9%**	**26.1%**
Rotary Wing					**22.7%**	**25.7%**	**33.1%**	**28.9%**	**26.2%**	**22.4%**		
Contract Type												
Cost Plus	9.9%***	10.1%***	**20.9%*****	**19.4%*****	**20.0%*****	**25.7%*****	**21.2%*****	**17.3%*****	**27.9%*****	**25.0%*****	**39.9%*****	**24.8%*****
Fixed			**24.2%**	**23.6%**	**17.7%**	**18.6%**			**21.7%**	**19.1%**	**24.8%**	**26.7%**
Contractor Type												
Prime	10.3%***	10.0%***	22.3%***	21.6%***	16.6%***	17.2%***	**23.2%*****	**21.4%*****	**24.5%*****	**21.4%*****	**35.6%*****	**26.1%*****
Sub							**21.1%**	**17.2%**	**27.3%**	**24.2%**	**17.9%*****	**15.0%*****
Service												
Air Force			**20.6%*****	**20.6%*****	**18.2%*****	**19.3%*****	**19.2%*****	**17.1%*****	**25.1%*****	**21.5%*****	**26.9%*****	**24.9%*****
Navy	9.2%	9.4%			14.7%	15.0%	**25.2%**	**18.1%**	**26.5%**	**22.9%**	**37.9%**	**24.6%**
Army							**30.2%**	**29.4%**	**27.1%**	**24.1%**	**27.7%**	**26.0%**

In Figure 27, we note that Prime contractor shows a steady incline in the medians between decades. As we have seen in previous WBS elements, this increase is marked with the most significant results near the beginning and end of the decades. The Navy service medians have a similar increase, and the earlier decades, the 1960s and 1980s, are significant or moderately significant. Cost Plus contract also shows a slight increase between the 1960s through the 1980s, and the 1960s is significant. Aircraft commodity also shows a significant decade in the 2000s, corresponding with a spike in the median values. We recommend using the most recent factor data for most subcategories in G&A except for Aircraft, where the 2000s show a spike, which the analyst should exclude.

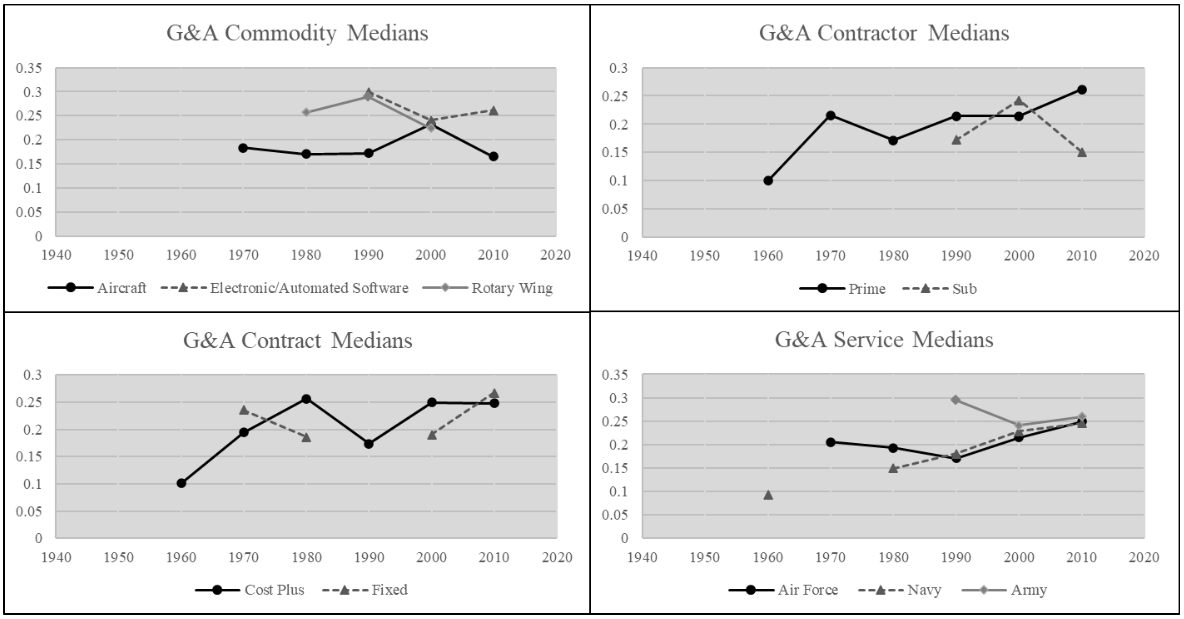


Figure 27: G&A Medians by Decade

Spares

Our last WBS element has few subgroups and only three moderately significant decades. These decades, however, are early, and none are in the late decades. The Prime contract and Air Force service results from the 1950s are both moderately significant, and they also have much higher medians than the remaining decades in those subgroups. The Navy commodity results from the 1980s are much lower than the 2000s and 2010s, and the moderately significant result in the 1980s reflects that. We recommend excluding the early decades that are significant. In the next section of Chapter Five, we will discuss how these significant results may impact the use and development of factors.

Table 40: Spares Summary Table and Significance Results

Spares	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Decade	1950		1980		1990		2000		2010	
Commodity Type										
Aircraft	**8.88%*** **	**10.10%*** **	**7.21%*** **	**4.11%*** **	**3.15%*** **	**0.72%*** **	**2.96%*** **	**2.05%*** **		
Contract Type										
Cost Plus					**2.03%*** **	**0.91%*** **	**6.81%*** **	**1.04%*** **		
Fixed			**6.52%**	**3.40%**			**5.33%**	**2.51%**		
Contractor Type										
Prime	8.88%***	10.10%***	**5.38%*** **	**1.50%*** **	**6.72%*** **	**1.09%*** **	**9.37%*** **	**1.04%*** **		
Service										
Air Force	8.63%***	9.27%***			**8.09%*** **	**1.54%*** **	**2.21%*** **	**0.18%*** **		
Navy			0.69%	0.14%			**3.40%**	**2.05%**	**1.85%**	**1.56%**

Significance of Research

We can interpret the findings of this research in many ways. First, analysts should avoid grouping the decades with significant differences with the other decades in that subcategory without justification. With several of the WBS elements, clear time trends were present in the data, and the significant results were indicative of the extreme ends of those trends. Also, as was the case with Training Prime contractor factors in the 2000s, significant results may indicate anomalies in the trends. Where trends exist, using older data for a modern system may not be appropriate as the relationships those factors represented may no longer be most representative. Second, decades that have no significant differences are more likely to fully represent the subcategory in question, and a factor of all decades may be appropriate.

We discovered an interesting relationship while analyzing these trends. The SEPM and ST&E decadal factors appear to change by decade in opposite directions. These two WBS elements are often the most significant cost drivers outside of PME. It is not apparent that these trends will continue, but it is interesting that as SEPM has become a larger cost driver, ST&E has become smaller. This further reinforces the idea of using only the most recent or relevant programs to develop parametric factors. Not doing so could result in older or less relevant data points diminishing or overemphasizing the factors when used in new programs.

Analysts can use the factors developed in this research in future estimation efforts with the following considerations. First, the use of decadal time periods in this research was somewhat arbitrary from a statistical standpoint. As decades are a convention of society, they offered easily understood markers of the passage of time. Using a yearly model would not have been possible due to the few data points in some years. Second, the programs within each decade are not fully representative of that point in time. Each analyst must research their data to ensure the programs contained within a decade fully represent the program for which we compared it. Third, when this research failed to find differences in decades, analysts should not assume they do not exist. Often, we found little significance due to few samples or few decades to compare. Last, our data were highly skewed, with many data points at the distribution's high end. We performed non-parametric tests which compared the medians of the test distributions. For these reasons, the medians are the best representation of our research. With a right-skewed distribution, the mean is also consistently higher than the median, and using the mean may overstate the costs. An analyst may find it more useful to exclude more outliers from the dataset, in which case the mean may prove a more reasonable metric.

Table 41 and Table 42 display an overview of the recommended decades for each WBS element and subcategory. An "X" in a decade indicates the decade within a subcategory that is most representative of future factors. Blank decades are either not recommended for use due to not being representative or were not evaluated due to lack of datapoints.

Table 41: Recommended Decades Part 1

Decade	SEPM 1950	SEPM 1960	SEPM 1970	SEPM 1980	SEPM 1990	SEPM 2000	SEPM 2010	ST&E 1950	ST&E 1960	ST&E 1970	ST&E 1980	ST&E 1990	ST&E 2000	ST&E 2010	Training 1950	Training 1960	Training 1970	Training 1980	Training 1990	Training 2000	Training 2010	Data 1950	Data 1960	Data 1970	Data 1980	Data 1990	Data 2000	Data 2010
Commodity Type																												
Aircraft				X	X	X	X				X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X
Electronic/Automated Software					X	X	X					X	X	X						X	X						X	X
Rotary Wing				X	X	X						X	X						X	X						X	X	
Contract Type																												
Cost Plus				X	X	X	X				X	X	X	X			X		X	X				X	X	X	X	
Fixed						X	X				X		X	X						X							X	X
Contractor Type																												
Prime				X	X	X	X				X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X
Sub					X	X	X					X	X						X	X						X	X	
Service																												
Air Force				X	X	X	X					X	X	X	X		X	X	X	X		X		X	X	X	X	X
Navy				X	X	X	X				X	X	X	X				X	X	X				X	X	X	X	X
Army					X	X	X					X	X	X					X	X	X					X	X	X

Table 42: Recommended Decades Part 2

Decade	Site Activation 1950	Site Activation 1960	Site Activation 1970	Site Activation 1980	Site Activation 1990	Site Activation 2000	Site Activation 2010	Support Equipment 1950	Support Equipment 1960	Support Equipment 1970	Support Equipment 1980	Support Equipment 1990	Support Equipment 2000	Support Equipment 2010	Spares 1950	Spares 1960	Spares 1970	Spares 1980	Spares 1990	Spares 2000	Spares 2010	G&A 1950	G&A 1960	G&A 1970	G&A 1980	G&A 1990	G&A 2000	G&A 2010
Commodity Type																												
Aircraft				X		X					X	X	X		X			X	X	X				X	X	X		X
Electronic/Automated Software																										X	X	X
Rotary Wing													X												X	X	X	
Contract Type																												
Cost Plus					X	X						X	X						X	X				X	X	X	X	X
Fixed						X					X		X					X		X				X	X		X	X
Contractor Type																												
Prime				X	X	X						X	X	X				X	X	X						X	X	X
Sub												X	X													X	X	X
Service																												
Air Force												X	X	X					X	X				X	X	X	X	X
Navy						X					X	X	X							X	X					X	X	X
Army																										X	X	X

Limitations

A primary limitation of this research was the lack of data for specific subgroups and decades. Older decade data was lacking as we could not transcribe all the 1921s into the AFLCMC/FZC database. We excluded 168 interim or initial 1921s and 11 programs that lacked a date for Milestone B. Due to breaking the data up by decade, we excluded several data points if the decade contained less than five data points. Commodities such as Engine, Missile, Space, UAV, and Joint programs, lacked sufficient data, and we did not test them. Any conclusions we have drawn may not apply to those subcategories. Furthermore, the database only included Acquisitions Category I (ACAT) programs as we did not have ACAT II and lower 1921 data.

Recommendations for Future Research

There are many avenues for the expansion of this research. Increasing the program data points in the database would allow for the analysis of more groups and decades. Researchers could accomplish this by adding data from outside the AFLCMC/FZC database used in this research, by including specific incomplete programs based on some measure of completion, or including ACAT II and lower programs. Researchers could also conduct this analysis for Production factors using the same methodology. Researchers may also find year-to-year trends using regression analysis which they can use to determine future factors.

Finally, future research could test for correlations between shifts in factors and the changes to the acquisitions rules and guidelines by comparing changes to MIL-STD-881 and shifts in factor composition. Input from subject matter experts could enhance this analysis by describing how quickly programs apply these changes to estimates. Our research focused on the "how" factors have changed, and this type of analysis could lead to a better understanding of "why" the factors have changed.

Summary

This research utilized data from the AFLCMC/FZC database derived from CADE to develop and analyze decadal factors in eight WBS elements and across several commodities, contract types, contractor types, and service branches. The creation of robust factors requires utilizing the most extensive database available to the analyst. However, understanding changes in factor composition over time can assist in the creation of more defensible estimates in the future. The factors tested in this research highlight decadal differences between programs within categories. Analysts should consider these differences when creating parametric factors for cost estimates.

Our research provides a framework for creating and improving parametric factors for cost estimates. Efficient and effective cost estimating relies on the most relevant and useful data. The importance of this research is in informing cost estimators to take into consideration the decade from which they calculate factors. As we have demonstrated, some WBS element factors have increased, decreased, or had spikes, indicating that not all decades represent the overall WBS element or subcategory.

Appendix A -- List of Programs

Aircraft	F-15E	G/ATOR	AH-1Z & UH-1Y
A-10A	F-16A	GCSS-A	AH-64D
A-6A	F-16A/B	GSE	AH-64E
A-6E	F-16C/D	IAMD	ARH-70A
A-6F	F-22A	ITEP	CH-47D
AC-130U	F-35A/B/C	JATAS	CH-47F
ASIP	F-4A	JLENS	CH-53K
AV-8B	F-4C	JMPS	CV-22
B-1A	F-5E	JPALS	H-1/AH-1Z
B-1B	F-5F	JTRS	H-1/UH-1Y
B-2A	KC-135A	JTRS GMR	HH-60A
B-52H	KC-135R	JTRS MIDS	MH-60R
B-58A	KC-46A	JTRS NED - MUOS Waveform	MH-60S
C-130 AMP	LVT MIDS	LMP	OH-58D
C-130J	P-8A	LVT MIDS	RAH-66A
C-17A	RQ-4/E-10	MUOS	SH-60B
C-5A	S-3A	N/A	SH-60F
C-5A/B	S-3B	WIN-T	UH-1N
C-5M	T-45TS	**Engine**	UH-60M
E-2C	T-46A	A-10A	V-22
E-2D	VC-25A	A-4A	V-22/CV-22
E-3 FMS	**Electronic/Automated Software**	A-6F	**Space**
E-3A	3DELRR	A-7A	AEHF
E-6A	AMDR	B-1B	EPS
E-7A	AMF JTRS	CH-53K	GPS - OCX
E-8A	AN/TSC-154	F/A-18A	GPS-IIIA
E-8C	AN/TVQ-2	F/A-18E/F	GT - EPS
EA-18G	B-1B	F-111F	NAVSTAR GPS - Block IIR
EA-6B	CAC2S	F-14A	NAVSTAR GPS - MUE
F/A-18A	CANES	F-15A	NAVSTAR GPS - OCS
F/A-18A/B/C	CIRCM	F-16A/B	NAVSTAR GPS Blk IIF
F/A-18C/D/E/F	CNS/ATM	F-22A	NPOESS
F/A-18D	Cobra Judy	F-35A/B/C	SBIRS HIGH
F/A-18E/F	DCGS	F-5E	TSAT
F-101A	Distributed Battle Command System	V-22	**UAV**
F-102A	EA-18G	**Missile**	MQ-1C
F-104A	F-15E	AGM-129A	MQ-4C
F-105A	F-16 Blk 30	AIM-9X	MQ-9A
F-106A	F-16 Blk30	ER	RQ-1A
F-14A	F-16 Blk40/50	JAGM	RQ-4A/B
F-14D	F-22A	MALD-J	RQ-5A
F-14D, F/A18C/D	FAB-T	N/A	RQ-7A
F-15A	FBCB2	**Rotary Wing**	RQ-8A

Appendix B -- Sample DD Form 1921

SECURITY CLASSIFICATION **Unclassified**

COST DATA SUMMARY REPORT

Form Approved OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 8 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Executive Services Directorate (0704-0188). Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE ABOVE ORGANIZATION.

1. MAJOR PROGRAM a. NAME: P-49 - Phoenix Fighter
b. PHASE/MILESTONE: ☐ Pre-A ☐ A ☐ B ☐ C-LRIP ☒ C-FRP ☐ O&S

2. PRIME MISSION PRODUCT: P-49 - Phoenix Fighter

3. REPORTING ORGANIZATION TYPE: ☒ PRIME / ASSOCIATE CONTRACTOR ☐ DIRECT-REPORTING SUBCONTRACTOR ☐ GOVERNMENT

4. NAME/ADDRESS (Include ZIP Code)
a. PERFORMING ORGANIZATION: Vandelay Industries, 352 Stork Rd, Los Angeles, CA 90040
b. DIVISION: Integrated Systems, 325 Stork Rd, Los Angeles, CA 90040

5. APPROVED PLAN NUMBER: N-12-X-C1

6. CUSTOMER (Direct-reporting subcontractor use only):

7. CONTRACT TYPE: FFP

8. CONTRACT PRICE: $867,992.5

9. CONTRACT CEILING:

10. TYPE ACTION
a. CONTRACT NO.: XXXXXX-13-C-0019
b. LATEST MODIFICATION: P00421
c. SOLICITATION NO.: N/A
d. NAME: Phoenix Fighter
e. TASK ORDER/DELIVERY ORDER/LOT NO.: Lot 9

11. PERIOD OF PERFORMANCE
a. START DATE *(YYYYMMDD)*: 20150601
b. END DATE *(YYYYMMDD)*: 20181230

12. APPROPRIATION: ☐ RDT&E ☒ PROCUREMENT ☐ O&M

13. REPORT CYCLE: ☐ INITIAL ☐ INTERIM ☒ FINAL

14. SUBMISSION NUMBER: 2

15. RESUBMISSION NUMBER: 0

16. REPORT AS OF *(YYYYMMDD)*: 20160630

17. NAME (Last, First, Middle Initial): Bellows, Drew R

18. DEPARTMENT: Finance

19. TELEPHONE NUMBER (Include Area Code): (310) 555-0559

20. EMAIL ADDRESS: andrew_bellows@vandelayindustries.com

21. DATE PREPARED *(YYYYMMDD)*: 20160814

WBS ELEMENT CODE	WBS REPORTING ELEMENTS	NUMBER OF UNITS TO DATE	COSTS INCURRED TO DATE (thousands of U.S. Dollars)			NUMBER OF UNITS AT COMPLETION	COSTS INCURRED AT COMPLETION (thousands of U.S. Dollars)		
			NONRECURRING	RECURRING	TOTAL		NONRECURRING	RECURRING	TOTAL
A	B	C	D	E	F	G	H	I	J
1.0	P-49 - Phoenix Fighter	10.0	$4,959.9	$693,202.0	$698,161.9	10.0	$5,106.7	$702,468.1	$707,574.8
1.1	Air Vehicle	10.0	$4,950.6	$531,246.0	$536,196.6	10.0	$5,026.2	$535,245.8	$540,272.0
1.1.1	Airframe	10.0	$4,072.6	$154,155.7	$158,228.3	10.0	$4,074.8	$155,555.8	$159,630.6
1.1.1.1	Airframe Integration, Assembly, Test and Checkout	10.0	$40.7	$5,051.4	$5,092.1	10.0	$42.9	$6,451.5	$6,494.4
1.1.1.2	Fuselage	10.0	$4,025.5	$99,587.2	$103,612.7	10.0	$4,025.5	$99,587.2	$103,612.7
1.1.1.2.1	Forward Fuselage	10.0	$1,355.1	$44,255.2	$45,610.3	10.0	$1,355.1	$44,255.2	$45,610.3
1.1.1.2.2	Center Fuselage	10.0	$1,677.3	$35,124.2	$36,801.5	10.0	$1,677.3	$35,124.2	$36,801.5
1.1.1.2.3	Aft Fuselage	10.0	$993.1	$20,207.8	$21,201.0	10.0	$993.1	$20,207.8	$21,201.0
1.1.1.3	Wing	10.0	$0.0	$35,021.5	$35,021.5	10.0	$0.0	$35,021.5	$35,021.5
1.1.1.4	Empennage	10.0	$6.4	$14,495.6	$14,502.0	10.0	$6.4	$14,495.6	$14,502.0
1.1.1.5	Nacelle	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.2	Propulsion (P-429 Engine)	10.0	$0.0	$22,587.0	$22,587.0	10.0	$0.0	$22,587.0	$22,587.0
1.1.3	Vehicle Subsystems	10.0	$5.2	$72,108.0	$72,113.2	10.0	$5.2	$72,108.0	$72,113.2
1.1.3.1	Vehicle Subsystem Integration, Assembly, Test, and Checkout	10.0	$5.2	$2,105.0	$2,110.2	10.0	$5.2	$2,105.0	$2,110.2
1.1.3.2	Flight Control Subsystem	10.0	$0.0	$4,025.1	$4,025.1	10.0	$0.0	$4,025.1	$4,025.1
1.1.3.3	Auxiliary Power Subsystem	10.0	$0.0	$5,048.6	$5,048.6	10.0	$0.0	$5,048.6	$5,048.6
1.1.3.4	Hydraulic Subsystem	10.0	$0.0	$3,589.7	$3,589.7	10.0	$0.0	$3,589.7	$3,589.7
1.1.3.5	Electrical Subsystem	10.0	$0.0	$9,486.5	$9,486.5	10.0	$0.0	$9,486.5	$9,486.5
1.1.3.6	Crew Station Subsystem	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.3.7	Environmental Control Subsystem	10.0	$0.0	$12,120.8	$12,120.8	10.0	$0.0	$12,120.8	$12,120.8
1.1.3.8	Fuel Subsystem	10.0	$0.0	$8,049.5	$8,049.5	10.0	$0.0	$8,049.5	$8,049.5
1.1.3.9	Landing Gear	10.0	$0.0	$14,204.8	$14,204.8	10.0	$0.0	$14,204.8	$14,204.8
1.1.3.10	Rotor Group	10.0	$0.0	$3,905.0	$3,905.0	10.0	$0.0	$3,905.0	$3,905.0
1.1.3.11	Drive Group	10.0	$0.0	$9,573.0	$9,573.0	10.0	$0.0	$9,573.0	$9,573.0
1.1.3.12	Vehicle Subsystem Software	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.4	Avionics	10.0	$770.1	$249,416.5	$250,186.6	10.0	$810.8	$252,016.2	$252,827.0
1.1.4.1	Avionics Integration, Assembly, Test, and Checkout	10.0	$111.1	$4,536.1	$4,647.2	10.0	$151.9	$5,612.8	$5,764.7
1.1.4.2	Communication/Identification	10.0	$501.6	$55,786.5	$56,288.1	10.0	$501.6	$55,786.5	$56,288.1
1.1.4.3	Navigation/Guidance	10.0	$0.0	$22,579.9	$22,579.9	10.0	$0.0	$22,579.9	$22,579.9
1.1.4.4	Mission Computer/Processing	10.0	$0.0	$10,052.0	$10,052.0	10.0	$0.0	$10,052.0	$10,052.0
1.1.4.5	Fire Control (AN/AX-1 Radar)	10.0	$10.5	$113,294.9	$113,305.4	10.0	$10.5	$114,817.9	$114,828.4
1.1.4.6	Data Display and Controls	10.0	$0.0	$11,453.9	$11,453.9	10.0	$0.0	$11,453.9	$11,453.9
1.1.4.7	Survivability	10.0	$0.0	$5,205.8	$5,205.8	10.0	$0.0	$5,205.8	$5,205.8
1.1.4.8	Reconnaissance	10.0	$146.9	$15,982.8	$16,129.7	10.0	$146.8	$15,982.8	$16,129.6
1.1.4.9	Automatic Flight Control	10.0	$0.0	$10,524.6	$10,524.6	10.0	$0.0	$10,524.6	$10,524.6
1.1.4.10	Health Monitoring System	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.4.11	Stores Management	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.4.12	Avionics Software	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.5	Armament/Weapons Delivery	10.0	$0.0	$26,953.8	$26,953.8	10.0	$0.0	$26,953.8	$26,953.8
1.1.6	Auxiliary Equipment	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.7	Furnishings and Equipment	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.8	Air Vehicle Software	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.1.9	Air Vehicle Integration, Assembly, Test, and Checkout	10.0	$102.7	$6,025.0	$6,127.7	10.0	$135.4	$6,025.0	$6,160.4
1.2	Systems Engineering	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.3	Program Management	10.0	$8.0	$58,732.5	$58,740.5	10.0	$25.9	$64,958.9	$64,984.8
1.4	System Test and Evaluation	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.5	Training	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.6	Data	0.0	$1.3	$12.3	$13.6	0.0	$2.5	$15.9	$18.4
1.7	Peculiar Support Equipment	0.0	$0.0	$23,465.6	$23,465.6	0.0	$0.0	$23,465.6	$23,465.6
1.7.1	Test and Measurement Equipment	0.0	$0.0	$10,214.0	$10,214.0	0.0	$0.0	$10,214.0	$10,214.0
1.7.2	Support and Handling Equipment	0.0	$0.0	$13,251.6	$13,251.6	0.0	$0.0	$13,251.6	$13,251.6
1.8	Common Support Equipment	0.0	$0.0	$1.2	$1.2	0.0	$0.0	$1.2	$1.2
1.9	Operational/Site Activation	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.10	Industrial Facilities	0.0	$0.0	$0.0	$0.0	0.0	$0.0	$0.0	$0.0
1.11	Initial Spares and Repair Parts	0.0	$0.0	$56,202.2	$56,202.2	0.0	$52.1	$62,502.4	$62,554.5
	Subtotal Cost				$698,161.9				$707,574.8
	Reporting Contractor G&A				$82,057.0				$68,124.2
	Reporting Contractor Undistributed Budget								$0.0
	Reporting Contractor Management Reserve								$2,452.0
	Reporting Contractor FCCM				$6,124.4				$7,292.1
	Total Cost				$786,343.3				$785,443.1
	Reporting Contractor Profit/Loss or Fee				$70,548.5				$82,549.4
	Total Price				$856,891.8				$867,992.5

22. REMARKS
The data contained in this report is for 10 air vehicles built in Lot 9, which began on June 1, 2015. The final delivery for Lot 9 was made on June 30, 2016.

DD FORM 1921, MAY 2011 PREVIOUS EDITION IS OBSOLETE. SECURITY CLASSIFICATION **Unclassified**

Appendix C -- Descriptive Statistics by WBS Element and Decade

SEPM Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.26	0.11842	0.18893	0.34387	0.40447	0.47302	0.65357
Std Dev	.	0.08643	0.17072	0.29198	0.61088	0.49159	0.60133
N	1	5	24	46	51	220	38
Max	0.26	0.25175	0.65209	1.26801	3.82375	3.57635	3.09701
0.75	0.26	0.20532	0.26091	0.47241	0.44964	0.57181	0.83865
Median	0.26	0.0762	0.14311	0.27827	0.23298	0.34771	0.50689
0.25	0.26	0.05263	0.06816	0.11313	0.15362	0.19623	0.29008
Min	0.26	0.04866	0.0293	0.00597	0.00012	0.00531	0.01251

ST&E Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.333203	0.38307	0.42179	0.28501	0.17351	0.15181	0.2186981
Std Dev	0.159237	0.26609	0.26592	0.27351	0.15695	0.18037	0.3231126
N	8	6	22	46	48	174	28
Max	0.593715	0.83931	1.06772	1.07767	0.60513	1.05752	1.4983145
0.75	0.472414	0.62385	0.60037	0.43902	0.26537	0.21052	0.3236347
Median	0.320089	0.29513	0.40791	0.19222	0.12392	0.09505	0.1023425
0.25	0.18537	0.16597	0.19156	0.07796	0.06399	0.03424	0.0034484
Min	0.129725	0.14332	0.02533	0.00405	0.0005	0.00011	0.0000008

Training Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.02025	0.11771	0.01742	0.02391	0.02462	0.036119	0.04154
Std Dev	0.01566	0.2133	0.02307	0.04265	0.06579	0.074399	0.06336
N	6	4	13	29	30	90	8
Max	0.04377	0.43753	0.0802	0.15949	0.3532	0.423778	0.14824
0.75	0.03313	0.33285	0.02471	0.02021	0.01591	0.03756	0.1114
Median	0.0202	0.01491	0.00384	0.00385	0.0035	0.005686	0.0028
0.25	0.00518	0.00537	0.0023	0.00112	0.00138	0.00121	0.00155
Min	0.00125	0.0035	0.00072	8.7E-05	0.0001	8.05E-06	0.00147

Data Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.02097	0.02513	0.05793	0.04636	0.02855	0.03054	0.0223
Std Dev	0.01326	0.01725	0.07343	0.0649	0.05595	0.0493	0.02888
N	6	5	23	44	35	129	21
Max	0.04586	0.04473	0.31913	0.33659	0.33485	0.39351	0.11792
0.75	0.03082	0.04095	0.06179	0.05397	0.03338	0.03915	0.02658
Median	0.01514	0.02797	0.02694	0.01865	0.01753	0.01772	0.01201
0.25	0.01271	0.00788	0.01446	0.01012	0.00455	0.00453	0.00746
Min	0.01039	0.00249	0.00182	0.00025	0.00004	0.00001	0.00066

Support Equipment Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.05428	0.13735	0.16303	0.06329	0.02743	0.10338	0.0135243
Std Dev	0.05589	0.16816	0.31089	0.07376	0.03953	0.39099	0.0255193
N	7	4	12	29	27	61	10
Max	0.16864	0.38462	1.11617	0.28876	0.13597	2.99246	0.0767991
0.75	0.08418	0.31382	0.11757	0.07868	0.03529	0.06071	0.0153095
Median	0.03544	0.06949	0.05869	0.0322	0.00839	0.0194	0.0025869
0.25	0.01377	0.02874	0.02169	0.01233	0.00097	0.00436	0.0005833
Min	0.01083	0.02582	0.00132	0.00012	0.00005	0.00004	0.0000004

Site Activation Summary Table by Decade					
Decade	1970	1980	1990	2000	2010
Mean	0.0314009	0.0179952	0.040844	0.06313	0.21954
Std Dev	0.0066344	0.0303863	0.0539735	0.14376	0.3005
N	2	15	6	31	4
Max	0.0360921	0.11063149	0.1250588	0.81633	0.6645
0.75	0.0360921	0.03117317	0.09983243	0.05984	0.53266
Median	0.0314009	0.00184945	0.01418127	0.0397	0.09474
0.25	0.0267096	0.00047073	0.00015964	0.01002	0.03122
Min	0.0267096	0.00010668	0.0000093	0.00044	0.0242

G&A Summary Table by Decade						
Decade	1960	1970	1980	1990	2000	2010
Mean	0.10259	0.22292	0.16983	0.25699	0.26065	0.35927
Std Dev	0.03099	0.08423	0.09136	0.25033	0.18162	0.37873
N	8	21	35	46	216	39
Max	0.17297	0.42382	0.36154	1.63781	1.27058	1.73639
0.75	0.10647	0.26996	0.25657	0.30379	0.3389	0.3638
Median	0.09959	0.21565	0.17944	0.18294	0.23172	0.25863
0.25	0.08012	0.16724	0.10494	0.13543	0.14306	0.16282
Min	0.07323	0.08448	0.01629	0.02124	0.01302	0.01588

Spares Summary Table by Decade							
Decade	1950	1960	1970	1980	1990	2000	2010
Mean	0.08881	0.02414	0.05388	0.053816	0.06264	0.06267	0.01545
Std Dev	0.03354	0.03057	0.05749	0.076878	0.09612	0.19118	0.01717
N	7	3	2	11	11	36	6
Max	0.13198	0.05943	0.09452	0.22603	0.32808	1.15597	0.04198
0.75	0.11187	0.05943	0.09452	0.09987	0.076	0.05603	0.0327
Median	0.10101	0.00699	0.05388	0.015006	0.02364	0.01685	0.01019
0.25	0.04802	0.00598	0.01323	0.001311	0.00483	0.00322	0.00045
Min	0.04079	0.00598	0.01323	0.000026	0.00014	0.00048	0.00022

Appendix D -- Kruskal Wallis Test Results by WBS Element and Category

Kruskal-Wallis Test Results	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n	Chi-Square	P-Value	n
Decade	SEPM			ST&E			Training			Data			Site Activation			Support Equipment			Spares			G&A		
Commodity Type																								
Aircraft	16.0877	0.0066**	141	34.6764	0.0001**	140	6.1426	0.1887	66	8.6270	0.1249	110	0.8571	0.3545	19	17.6141	0.0073**	74	7.9397	0.0473**	31	8.7511	0.0676*	122
Electronic/Automated Software	0.3739	0.8295	88	3.0319	0.2196	74	0.3483	0.5551	41	1.2857	0.2568	44										0.8058	0.6684	97
Rotary Wing	2.1755	0.7035	87	10.7995	0.0045**	59	7.3110	0.0258**	40	6.4427	0.0399**	66				4.4709	0.0345**	26				3.3755	0.1849	83
Contract Type																								
Cost Plus	29.5982	0.0001**	209	19.2708	0.0007**	183	3.8981	0.1424	94	2.8953	0.4080	112	1.5182	0.2179	13	7.0726	0.0291**	67	0.0159	0.8997	25	14.2468	0.0141**	211
Fixed	8.0864	0.0443**	106	21.3084	0.0001**	78	4.4065	0.0358**	38	15.6317	0.0013**	82	4.5024	0.0338**	16	0.7788	0.3775	9	0.0370	0.8474	8	3.9192	0.2703	91
Contractor Type																								
Prime	35.0450	0.0001**	216	29.6747	0.0001**	235	9.5584	0.0888*	133	9.2469	0.1602	184	3.6729	0.1594	32	23.2199	0.0003**	120	7.1470	0.0674*	42	23.0137	0.0003**	222
Sub	1.2465	0.5362	125	4.1808	0.0409**	92	3.1229	0.0772*	42	0.6728	0.4121	75				0.1154	0.7341	25				3.7512	0.1533	141
Service																								
Air Force	22.1572	0.0002**	149	31.6288	0.0001**	133	4.2836	0.3690	69	6.8292	0.2337	97				11.8214	0.0373**	77	4.6523	0.0977*	17	5.1261	0.2746	134
Navy	8.1197	0.0873*	152	21.5524	0.0002**	119	0.6935	0.7070	52	3.4435	0.4865	110	10.6694	0.0011**	30	4.8456	0.0887*	37	5.6054	0.0606*	40	11.5454	0.0211**	150
Army	0.6210	0.7331	55	4.1541	0.1253	60	1.7566	0.4155	43	2.2679	0.3218	43										0.9603	0.6187	62

Appendix E -- Wilcoxon Results

WBS	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
SEPM				5.8917	0.0152*	5	14.5602	0.0001***	24	1.5173	0.2180	46	2.7384	0.0980	51	6.0392	0.0140*	220	10.0112	0.0016***	38
ST&E	6.1667	0.0130*	8	4.7544	0.0292*	6	19.3165	0.0001***	22	5.9674	0.0146*	46	0.0344	0.8530	48	19.7025	0.0001***	174	1.3803	0.2400	28
Training																					
Data																					
Site Activation										6.8415	0.0089**	15	0.1181	0.7311	6	6.9637	0.0083**	31			
Support Equipment	1.3853	0.2392	7				5.1661	0.0230*	12	3.2317	0.0722	29	4.5139	0.0336*	27	0.0156	0.9005	61	7.8224	0.0052**	10
Spares	8.1488	0.0043***	7							0.2750	0.6000	11	0.2750	0.6000	11	0.9112	0.3398	36	1.8056	0.1790	6
G&A				9.9932	0.0016***	8	0.0010	0.9745	21	7.5885	0.0059**	35	0.2706	0.6029	46	3.4866	0.0619	216	3.0135	0.0826	39

SEPM	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
Aircraft				5.1718	0.023*	5	8.4805	0.0036***	16	0.1076	0.7429	37	0.0163	0.8985	29	4.2713	0.0388*	48	0.7015	0.4023	6
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing																					
Space																					
UAV																					
Contract Type																					
Cost Plus							14.1741	0.0002***	13	1.9738	0.1600	7	5.4371	0.0197*	40	9.3878	0.0022***	137	7.1797	0.0074**	12
Fixed							2.3805	0.1229	8	0.7862	0.3753	34				2.1243	0.1450	51	4.8433	0.0278*	13
Contractor Type																					
Prime				6.3425	0.0118*	5	16.5633	0.0001**	24	2.2031	0.1377	44	2.1858	0.1393	39	8.7311	0.0031**	100	12.8587	0.0003**	33
Sub																					
Service																					
Air Force							9.9709	0.0016***	16	0.9047	0.3415	27	2.7766	0.0957	30	6.4514	0.0111*	63	7.2037	0.0073**	13
Navy							5.5512	0.0185*	6	0.1012	0.7503	16	0.3373	0.5614	12	0.0012	0.9718	102	2.6667	0.1025	16
Army																					
Joint																					

ST&E	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
Aircraft	4.6036	0.0319*	8	3.6621	0.0557	6	13.5524	0.0002***	14	0.7365	0.3908	36	11.2521	0***	26	2.3490	0.1254	45	3.4535	0.0631	5
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing										1.9267	0.1651	5	7.7826	0.005**	8	10.4782	0.001***	46			
Space																					
UAV																					
Contract Type																					
Cost Plus							13.4649	0.0002***	11	2.2902	0.1302	7	1.0578	0.3037	37	9.0495	0.003***	119	0.4248	0.5145	9
Fixed							10.1037	0.0015***	8	4.8698	0.0273*	34				13.4435	2E-04***	28	0.9765	0.3231	8
Contractor Type																					
Prime	4.3025	0.0381*	8	3.3752	0.0662	6	15.0832	0.0001**	22	1.1660	0.2802	44	3.2058	0.0734	38	6.9192	0.0085**	92	0.7978	0.3718	25
Sub													4.1808	0.0409*	10	4.1808	0.0409*	82			
Service																					
Air Force	4.1430	0.0418*	7				13.4711	0.0002***	15	3.9658	0.0464*	26	12.0279	0***	27	4.7504	0.0293*	51	0.0491	0.8246	7
Navy							7.3347	0.0068**	6	2.3068	0.1288	17	6.8237	0.009**	12	7.0952	0.0077**	72	4.0842	0.0433*	12
Army																					
Joint																					

Training	1950 ChiSquare	1950 P-value	1950 n	1960 ChiSquare	1960 P-value	1960 n	1970 ChiSquare	1970 P-value	1970 n	1980 ChiSquare	1980 P-value	1980 n	1990 ChiSquare	1990 P-value	1990 n	2000 ChiSquare	2000 P-value	2000 n	2010 ChiSquare	2010 P-value	2010 n
Commodity Type																					
Aircraft																					
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing										4.9677	0.0258*	5	1.1707	0.2793	8	6.2391	0.0125*	27			
Space																					
UAV																					
Contract Type																					
Cost Plus																					
Fixed										4.4065	0.0358*	22				4.4065	0.0358*	16			
Contractor Type																					
Prime	0.4373	0.5084	6				0.0786	0.7792	13	2.3035	0.1291	28	3.6119	0.0574	25	7.1787	0.007**	53	0.0004	0.9849	8
Sub													3.1229	0.0772	5	3.1229	0.0772	37			
Service																					
Air Force																					
Navy																					
Army																					
Joint																					

Data	1950 ChiSquare	1950 P-value	1950 n	1960 ChiSquare	1960 P-value	1960 n	1970 ChiSquare	1970 P-value	1970 n	1980 ChiSquare	1980 P-value	1980 n	1990 ChiSquare	1990 P-value	1990 n	2000 ChiSquare	2000 P-value	2000 n	2010 ChiSquare	2010 P-value	2010 n
Commodity Type																					
Aircraft																					
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing										6.1697	0.013*	5	0.0652	0.7984	8	3.4678	0.0626	53			
Space																					
UAV																					
Contract Type																					
Cost Plus																					
Fixed							6.1146	0.0134*	9	5.4941	0.0191*	32				10.9589	0.0009***	40	0.4696	0.4932	10
Contractor Type																					
Prime																					
Sub																					
Service																					
Air Force																					
Navy																					
Army																					
Joint																					

Site Activation	1950 ChiSquare	1950 P-value	1950 n	1960 ChiSquare	1960 P-value	1960 n	1970 ChiSquare	1970 P-value	1970 n	1980 ChiSquare	1980 P-value	1980 n	1990 ChiSquare	1990 P-value	1990 n	2000 ChiSquare	2000 P-value	2000 n	2010 ChiSquare	2010 P-value	2010 n
Commodity Type																					
Aircraft																					
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing																					
Space																					
UAV																					
Contract Type																					
Cost Plus																					
Fixed										4.5024	0.0338*	11				4.5024	0.0338*	16			
Contractor Type																					
Prime																					
Sub																					
Service																					
Air Force																					
Navy										10.6694	0***	6				10.6694	0***	24			
Army																					
Joint																					

Support Equipment	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
Aircraft	0.9580	0.3277	7				4.7087	0.03*	8	1.2881	0.2564	21	3.6122	0.0574	15	2.8645	0.0906	17			
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing													4.4709	0.0345*	5	4.4709	0.0345*	21			
Space																					
UAV																					
Contract Type																					
Cost Plus							3.8723	0.0491*	7				4.7090	0.03*	19	0.5960	0.4401	41			
Fixed																					
Contractor Type																					
Prime	2.0063	0.1566	7				6.9330	0.009**	12	5.2990	0.0213*	28	4.6809	0.0305*	22	1.2432	0.2649	41	6.9678	0.008**	10
Sub																					
Service																					
Air Force			6				1.3766	0.2407	9	4.7265	0.0297*	19	2.7588	0.0967	18	0.0109	0.9167	20	5.2654	0.0218*	5
Navy										0.0376	0.8463	7	4.7691	0.029*	6	2.3320	0.1267	24			
Army																					
Joint																					

Spares	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
Aircraft																					
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing																					
Space																					
UAV																					
Contract Type																					
Cost Plus																					
Fixed																					
Contractor Type																					
Prime	6.3221	0.0119*	7							0.3783	0.5385	11	0.0397	0.8421	9	2.4394	0.1183	15			
Sub																					
Service																					
Air Force	6.5089	0.0107*	7							0.0999	0.7520	8	1.2721	0.2594	5	2.7273	0.0986	11			
Navy										5.3386	0.0209*	6				3.8170	0.0507	29	0.0205	0.8862	5
Army																					
Joint																					

G&A	1950			1960			1970			1980			1990			2000			2010		
	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n	ChiSquare	P-value	n
Commodity Type																					
Aircraft							0.0318	0.8584	13	5.4317	0.0198*	29	0.3856	0.5346	28	6.7551	0.009**	46	0.0807	0.7763	6
Electronic/Automated Software																					
Engine																					
Missile																					
Rotary Wing																					
Space																					
UAV																					
Contract Type																					
Cost Plus				7.6869	0.006**	5	0.4256	0.5141	12	0.2467	0.6194	5	2.8878	0.0893	39	3.5516	0.0595	136	2.6598	0.1029	14
Fixed																					
Contractor Type																					
Prime				9.6470	0.002**	8	0.0932	0.7602	21	7.2946	0.007**	33	0.1233	0.7255	34	0.4025	0.5258	94	8.2761	0.004**	32
Sub																					
Service																					
Air Force																					
Navy				6.9054	0.009**	6				3.8595	0.0495*	11	0.0549	0.8147	11	2.2292	0.1354	103	0.6759	0.4110	19
Army																					
Joint																					

Appendix F -- Count of Factors per Category, WBS element and Decade

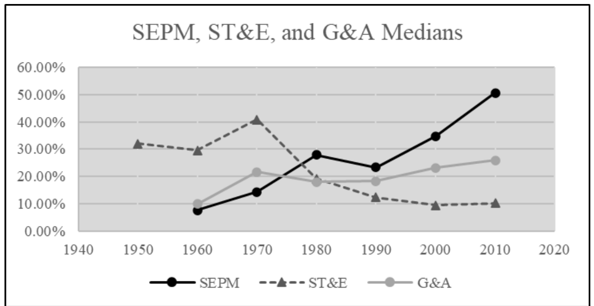
Decade	1950	1960	1970	1980	1990	2000	2010	1950	1960	1970	1980	1990	2000	2010
	SEPM							ST&E						
Commodity ID														
Aircraft	1	5	16	37	29	48	6	8	6	14	36	27	45	5
Electronic/Automated Software	0	0	2	0	5	65	24	0	0	2	0	5	54	15
Engine	0	0	4	2	3	4	1	0	0	5	3	3	4	1
Missile	0	0	0	1	1	4	4	0	0	0	1	1	4	4
Rotary Wing	0	0	2	5	8	71	1	0	0	1	5	8	46	1
Space	0	0	0	0	2	19	3	0	0	0	0	2	13	2
UAV	0	0	0	1	3	9	0	0	0	0	1	3	8	0
ContractCat														
Cost Plus	1	1	13	7	40	137	13	4	1	11	7	38	119	9
Fixed	0	3	8	34	1	51	13	2	4	8	34	1	28	8
Prime or Sub														
Prime	1	5	24	44	39	100	34	8	6	22	44	39	92	25
Sub	0	0	0	2	12	120	5	0	0	0	2	10	82	3
Service ID														
Air Force	0	1	16	27	30	63	13	7	2	15	26	28	51	7
Army	0	0	2	2	9	46	9	0	0	1	2	9	42	9
Joint	0	0	0	1	0	9	0	0	0	0	1	0	9	0
Navy	1	4	6	16	12	102	17	1	4	6	17	12	72	12

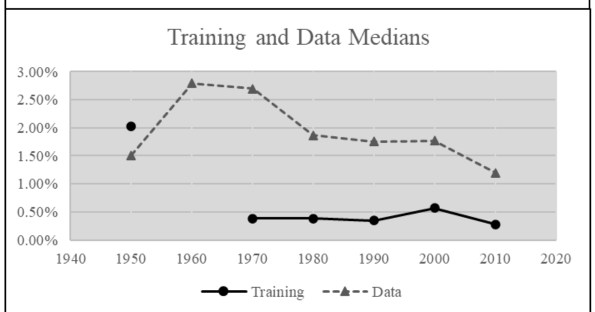
Decade	1950	1960	1970	1980	1990	2000	2010	1950	1960	1970	1980	1990	2000	2010
	Training							Data						
Commodity ID														
Aircraft	6	4	9	21	14	16	0	6	5	16	35	19	29	2
Electronic/Automated Software	0	0	2	0	4	35	6	0	0	1	0	3	30	14
Engine	0	0	1	1	2	0	0	0	0	4	2	3	2	0
Missile	0	0	0	1	0	3	1	0	0	0	1	0	3	3
Rotary Wing	0	0	1	5	8	27	1	0	0	2	5	8	53	1
Space	0	0	0	0	1	5	0	0	0	0	0	0	5	1
UAV	0	0	0	1	1	4	0	0	0	0	1	2	7	0
ContractCat														
Cost Plus	2	1	6	3	25	63	4	2	1	12	7	28	77	4
Fixed	2	3	4	22	0	16	2	2	3	9	32	0	40	10
Prime or Sub														
Prime	6	4	13	28	25	53	8	6	5	23	42	29	60	19
Sub	0	0	0	1	5	37	0	0	0	0	2	6	69	2
Service ID														
Air Force	5	2	9	16	14	25	0	5	1	15	25	19	26	7
Army	0	0	2	2	8	30	5	0	0	2	2	7	29	7
Joint	0	0	0	1	0	1	0	0	0	0	1	0	2	0
Navy	1	2	2	10	8	34	3	1	4	6	16	9	72	7

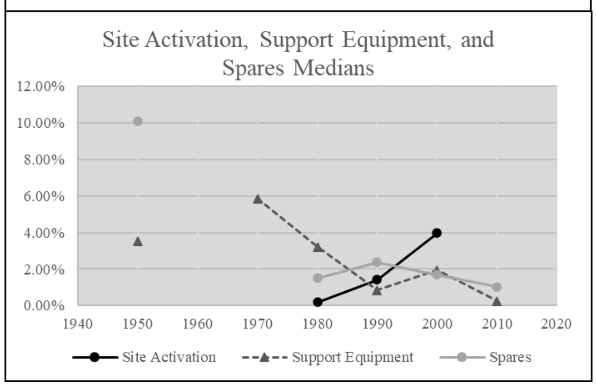
Decade	1950	1960	1970	1980	1990	2000	2010	1950	1960	1970	1980	1990	2000	2010
	Site Activation							Support Equipment						
Commodity ID														
Aircraft	0	0	2	14	2	5	1	7	4	8	21	15	17	2
Electronic/Automated Software	0	0	0	0	1	5	3	0	0	1	0	1	8	4
Engine	0	0	0	0	2	2	0	0	0	2	2	3	0	0
Missile	0	0	0	0	0	0	0	0	0	0	1	0	3	2
Rotary Wing	0	0	0	1	0	16	0	0	0	1	4	5	21	1
Space	0	0	0	0	0	1	0	0	0	0	0	0	5	1
UAV	0	0	0	0	1	2	0	0	0	0	1	3	7	0
ContractCat														
Cost Plus	0	0	0	1	5	13	1	3	0	7	4	19	41	3
Fixed	0	0	2	11	0	16	0	2	4	4	21	0	9	3
Prime or Sub														
Prime	0	0	2	15	5	12	4	7	4	12	28	22	41	10
Sub	0	0	0	0	1	19	0	0	0	0	1	5	20	0
Service ID														
Air Force	0	0	2	9	3	4	3	6	1	9	19	18	20	5
Army	0	0	0	0	2	3	0	0	0	2	2	3	15	3
Joint	0	0	0	0	0	0	0	0	0	0	1	0	2	0
Navy	0	0	0	6	1	24	1	1	3	1	7	6	24	2

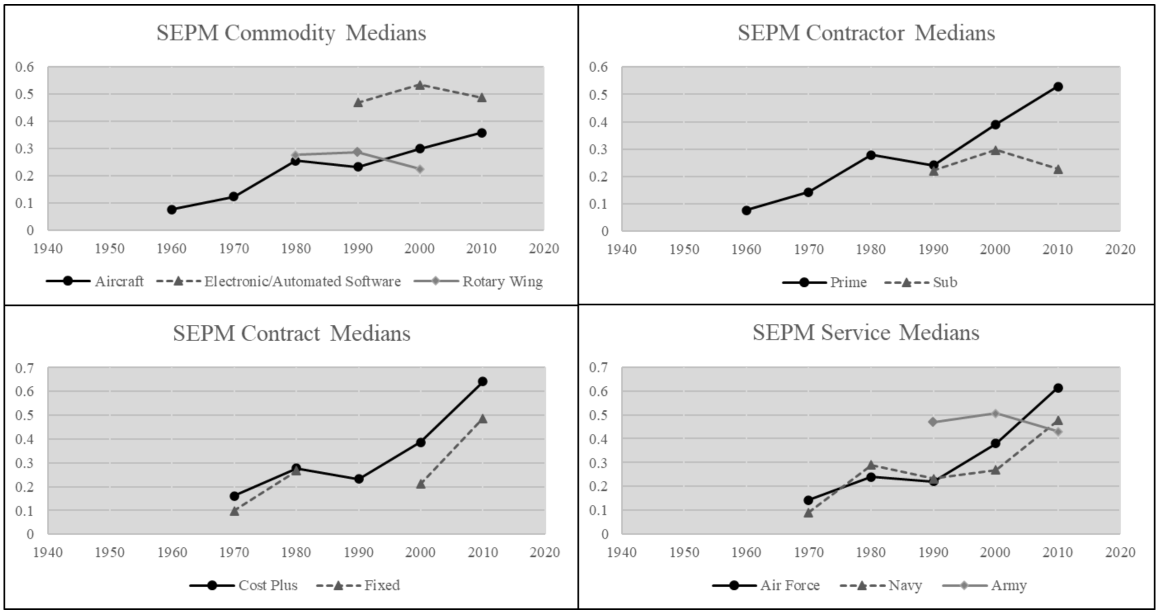
Decade	1950	1960	1970	1980	1990	2000	2010	1950	1960	1970	1980	1990	2000	2010
	Spares							G&A						
Commodity ID														
Aircraft	7	3	1	8	5	11	0	0	4	13	29	28	46	6
Electronic/Automated Software	0	0	0	0	2	4	6	0	0	1	0	5	66	26
Engine	0	0	0	0	1	0	0	0	4	5	1	2	4	1
Missile	0	0	0	0	0	0	0	0	0	0	0	1	2	4
Rotary Wing	0	0	1	3	1	14	0	0	0	2	5	7	71	1
Space	0	0	0	0	0	1	0	0	0	0	0	2	18	1
UAV	0	0	0	0	2	6	0	0	0	0	0	1	9	0
ContractCat														
Cost Plus	3	0	2	0	8	25	2	0	5	12	5	39	136	14
Fixed	2	3	0	9	0	8	2	0	3	8	26	0	51	14
Prime or Sub														
Prime	7	3	2	11	9	15	3	0	8	21	33	34	94	32
Sub	0	0	0	0	2	21	3	0	0	0	2	12	122	7
Service ID														
Air Force	6	0	0	4	6	5	1	0	2	15	22	27	59	11
Army	0	0	0	1	4	2	0	0	0	2	2	8	45	9
Joint	0	0	0	0	0	0	0	0	0	0	0	0	9	0
Navy	1	3	2	6	1	29	5	0	6	4	11	11	103	19

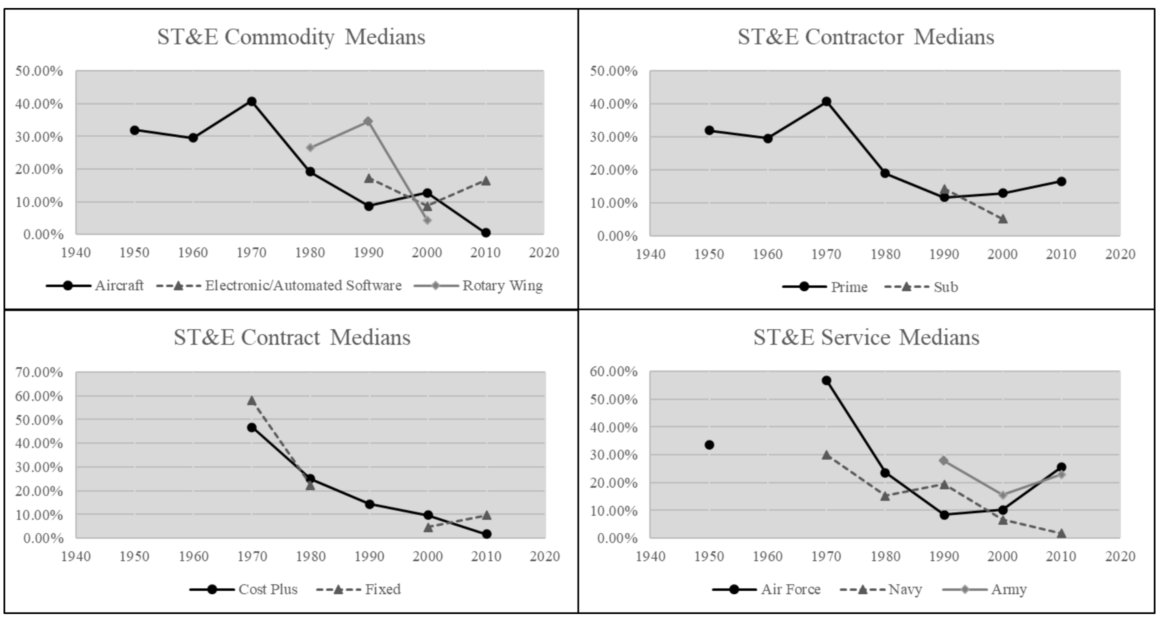
Appendix G -- Graphs of Medians by Category, WBS element and Decade

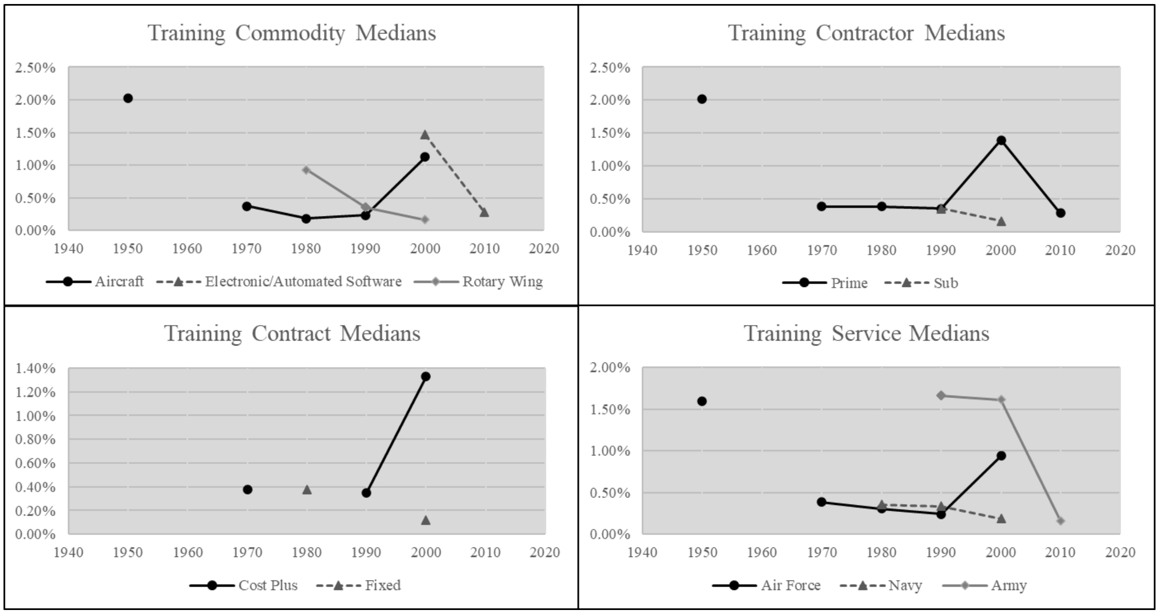


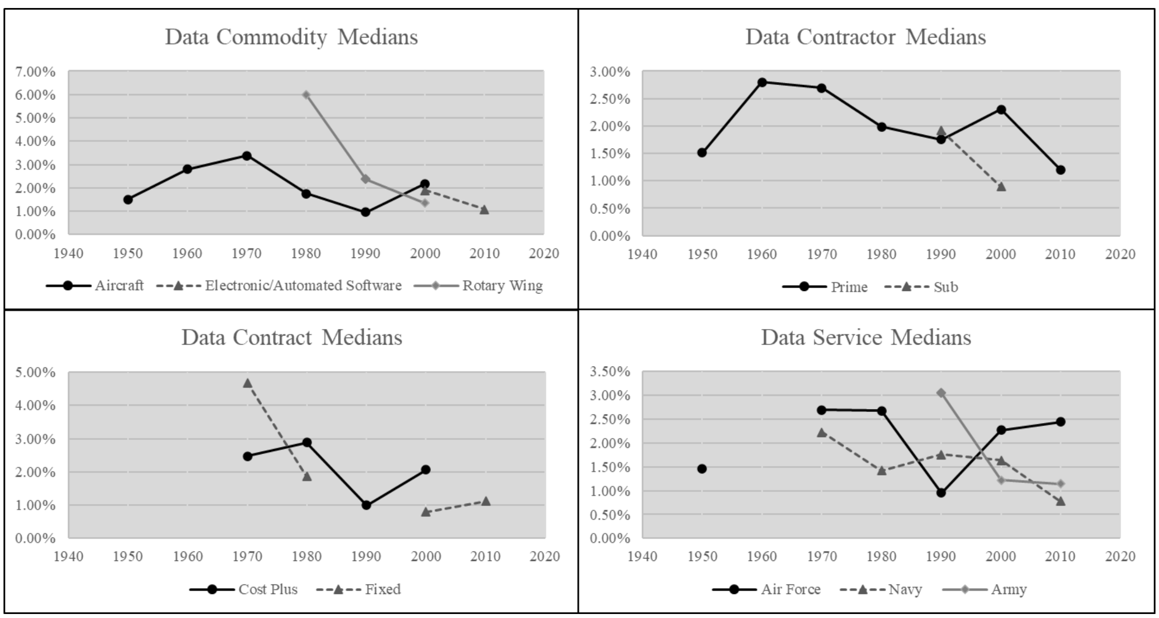


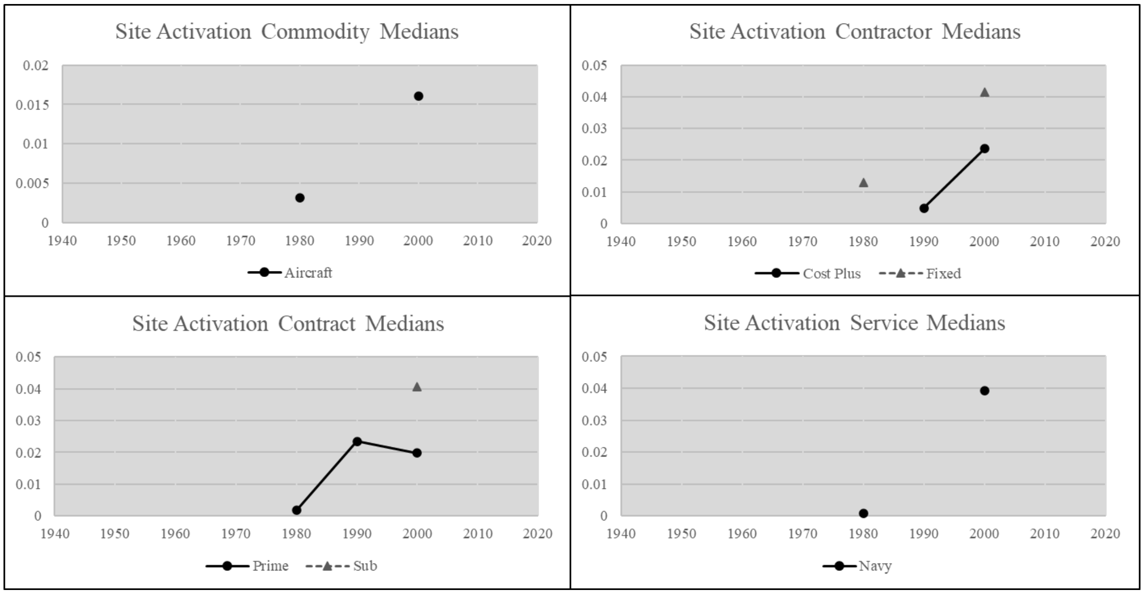


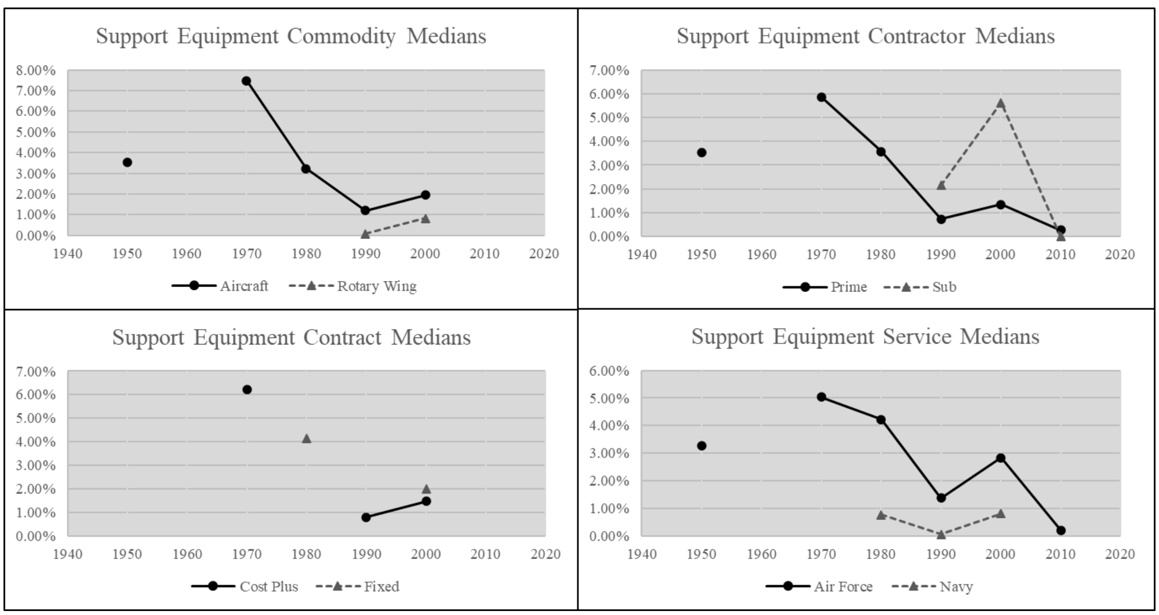

SEPM Commodity Medians
Aircraft
Electronic/Automated Software
Rotary Wing
SEPM Contractor Medians
Prime
Sub
SEPM Contract Medians
Cost Plus
Fixed
SEPM Service Medians
Air Force
Navy
Army
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1940
1950
1960
1970
1980
1990
2000
2010
2020

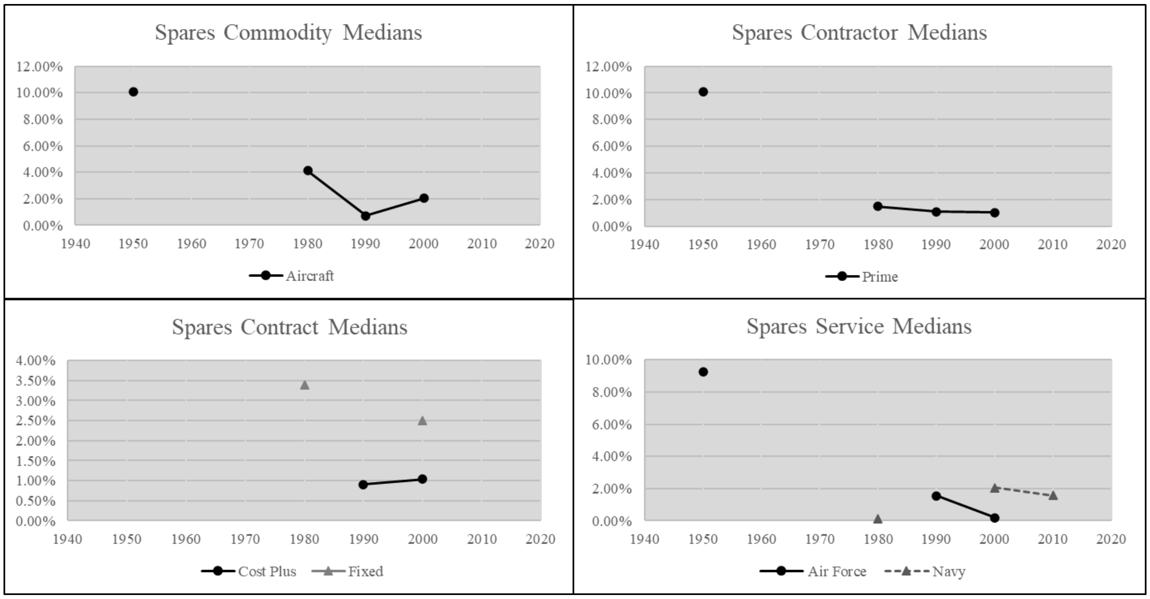

ST&E Commodity Medians
Aircraft
Electronic/Automated Software
Rotary Wing
ST&E Contractor Medians
Prime
Sub
ST&E Contract Medians
Cost Plus
Fixed
ST&E Service Medians
Air Force
Navy
Army
0.00%
10.00%
20.00%
30.00%
40.00%
50.00%
60.00%
70.00%
1940
1950
1960
1970
1980
1990
2000
2010
2020

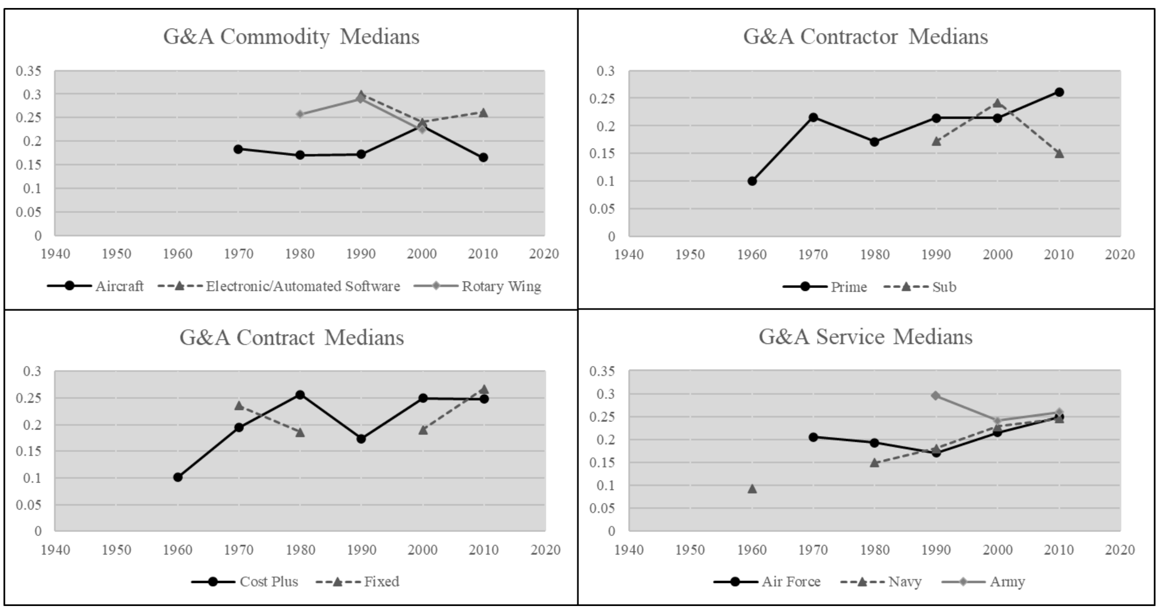

Training Commodity Medians
Aircraft
Electronic/Automated Software
Rotary Wing
Training Contractor Medians
Prime
Sub
Training Contract Medians
Cost Plus
Fixed
Training Service Medians
Air Force
Navy
Army


Data Commodity Medians
Aircraft
Electronic/Automated Software
Rotary Wing
Data Contractor Medians
Prime
Sub
Data Contract Medians
Cost Plus
Fixed
Data Service Medians
Air Force
Navy
Army


Site Activation Commodity Medians
0.02
0.015
0.01
0.005
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Aircraft
Site Activation Contractor Medians
0.05
0.04
0.03
0.02
0.01
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Cost Plus
Fixed
Site Activation Contract Medians
0.05
0.04
0.03
0.02
0.01
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Prime
Sub
Site Activation Service Medians
0.05
0.04
0.03
0.02
0.01
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Navy


Support Equipment Commodity Medians
8.00%
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Aircraft
Rotary Wing
Support Equipment Contractor Medians
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Prime
Sub
Support Equipment Contract Medians
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Cost Plus
Fixed
Support Equipment Service Medians
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Air Force
Navy


Spares Commodity Medians
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Aircraft
Spares Contractor Medians
12.00%
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Prime
Spares Contract Medians
4.00%
3.50%
3.00%
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Cost Plus
Fixed
Spares Service Medians
10.00%
8.00%
6.00%
4.00%
2.00%
0.00%
1940 1950 1960 1970 1980 1990 2000 2010 2020
Air Force
Navy


G&A Commodity Medians
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Aircraft
Electronic/Automated Software
Rotary Wing
G&A Contractor Medians
0.3
0.25
0.2
0.15
0.1
0.05
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Prime
Sub
G&A Contract Medians
0.3
0.25
0.2
0.15
0.1
0.05
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Cost Plus
Fixed
G&A Service Medians
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1940 1950 1960 1970 1980 1990 2000 2010 2020
Air Force
Navy
Army

Appendix H -- Summary Tables and Significance Results

WBS	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
SEPM				11.8%*	7.6%*	8.6%*	18.9%***	14.3%***	17.1%***	34.4%	27.8%	29.2%	40.4%	23.3%	61.1%	47.3%*	34.8%*	49.2%*	65.4%***	50.7%***	60.1%***
ST&E	33.3%*	32.0%*	15.9%*	38.3%*	29.5%*	26.6%*	42.2%***	40.8%***	26.6%***	28.5%*	19.2%*	27.4%*	17.4%	12.4%	15.7%	15.2%***	9.5%***	18.0%***	21.9%	10.2%	32.3%
Training	2.0%	2.0%	1.6%				1.7%	0.4%	2.3%	2.4%	0.4%	4.3%	2.5%	0.3%	6.6%	3.6%	0.6%	7.4%	4.2%	0.3%	6.3%
Data	2.1%	1.5%	1.3%	2.5%	2.8%	1.7%	5.8%	2.7%	7.3%	4.6%	1.9%	6.5%	2.9%	1.8%	5.6%	3.1%	1.8%	4.9%	2.2%	1.2%	2.9%
Site Activation										1.8%**	0.2%**	3.0%**	4.1%	1.4%	5.4%	6.3%**	4.0%**	14.4%**			
Support Equipment	5.4%	3.5%	5.6%				16.3%*	5.9%*	31.1%*	6.3%	3.2%	7.4%	2.7%*	0.8%*	4.0%*	10.3%	1.9%	39.1%	1.4%**	0.3%**	2.6%**
Spares	8.9%***	10.1%***	3.4%***							5.4%	1.5%	7.7%	6.3%	2.4%	9.6%	6.3%	1.7%	19.1%	1.5%	1.0%	1.7%
G&A				10.3%***	10.0%***	3.1%***	22.3%	21.6%	8.4%	17.0%**	17.9%**	9.1%**	25.7%	18.3%	25.0%	26.1%	23.2%	18.2%	35.9%	25.9%	37.9%

SEPM	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft				11.8%***	7.6%***	7.7%***	17.1%***	12.3%***	14.9%***	35.5%***	25.6%***	30.7%***	40.1%***	23.3%***	75.6%***	35.2%***	30.0%***	24.2%***	60.4%***	35.8%***	59.4%***
Electronic/Automated Software													53.14%	46.93%	40.88%	61.5%*	53.5%*	48.4%*	62.59%	48.76%	63.45%
Engine																					
Missile																					
Rotary Wing										28.08%	27.71%	19.17%	37.42%	28.71%	20.61%	40.09%	22.48%	57.77%			
Space																61.82%	46.48%	61.11%			
UAV																48.95%	38.88%	30.43%			
Contract Type																					
Cost Plus							16.4%***	16.2%***	13.6%***	29.2%***	27.7%***	28.0%***	31.4%***	23.2%***	39.9%***	53.9%***	38.7%***	52.4%***	87.4%***	64.1%***	77.3%***
Fixed							17.9%***	9.9%***	19.3%***	34.09%	26.76%	28.30%				32.3%***	21.1%***	47.3%***	48.4%**	48.8%**	30.4%**
Contractor Type																					
Prime				11.8%***	7.6%***	7.7%***	18.9%***	14.3%***	16.7%***	34.4%***	27.8%***	29.1%***	38.2%***	24.1%***	66.7%***	48.7%***	39.0%***	38.1%***	70.2%***	52.9%***	61.0%***
Sub													31.68%	22.12%	31.23%	46.1%***	29.7%***	56.5%***	33.6%***	22.7%***	32.7%***
Service																					
Air Force							16.9%***	14.3%***	14.6%***	34.0%***	24.1%***	31.5%***	36.4%***	22.1%***	75.5%***	51.9%***	38.0%***	54.3%***	69.0%***	61.3%***	44.4%***
Navy							12.4%***	9.1%***	8.9%***	35.98%	29.03%	25.30%	26.29%	23.26%	10.48%	40.3%*	27.0%*	50.8%*	69.9%**	47.7%**	79.9%**
Army													51.12%	46.93%	34.48%	60.50%	50.68%	36.40%	52.04%	42.99%	21.08%
Joint																26.81%	22.81%	13.96%			

ST&E	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft	33.3%***	32.0%***	14.9%***	38.3%***	29.5%***	24.3%***	41.0%***	40.8%***	18.4%***	28.6%***	19.2%***	28.4%***	10.7%***	8.7%***	9.2%***	18.3%***	12.8%***	18.9%***	18.8%***	0.4%***	33.4%***
Electronic/Automated Software													31.2%***	17.3%***	22.7%***	14.42%	8.65%	18.84%	24.19%	16.51%	36.24%
Engine							56.03%	56.71%	36.98%												
Missile																					
Rotary Wing										33.97%	26.51%	25.97%	31.74%	34.51%	10.71%	13.60%	4.36%	17.95%			
Space																11.5%***	4.5%***	13.7%***			
UAV																15.37%	12.88%	11.15%			
Contract Type																					
Cost Plus							44.2%***	46.8%***	26.4%***	23.5%***	25.1%***	13.8%***	18.3%***	14.4%***	15.5%***	14.5%***	9.7%***	16.9%***	33.2%***	1.7%***	49.0%***
Fixed							51.5%***	58.1%***	20.3%***	29.82%	22.38%	26.44%				10.8%***	4.6%***	13.5%***	14.65%	9.62%	14.24%
Contractor Type																					
Prime	33.3%***	32.0%***	14.9%***	38.3%***	29.5%***	24.3%***	42.2%***	40.8%***	26.0%***	27.8%***	18.9%***	26.8%***	16.1%***	11.6%***	14.4%***	17.8%***	12.9%***	17.8%***	24.5%***	16.5%***	32.6%***
Sub													22.04%	14.22%	18.63%	12.3%**	5.0%**	17.8%**			
Service																					
Air Force	35.7%***	33.6%***	14.4%***				48.4%***	56.7%***	27.3%***	33.2%***	23.6%***	28.0%***	9.9%***	8.4%***	9.7%***	17.4%***	10.2%***	19.3%***	29.2%***	25.7%***	28.3%***
Navy							32.6%***	30.0%***	14.4%***	23.2%*	15.3%*	26.3%*	23.4%***	19.4%***	13.6%***	12.3%*	6.6%*	16.3%*	18.71%	1.77%	40.70%
Army													31.5%**	27.7%**	18.5%**	18.3%**	15.5%**	19.4%**	20.4%*	23.0%*	15.6%*
Joint																10.60%	8.44%	10.59%			

Training	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft	2.0%***	2.0%***	1.4%***				0.8%***	0.4%***	0.8%***	1.9%***	0.2%***	3.6%***	1.3%***	0.2%***	2.2%***	5.2%***	1.1%***	8.1%***			
Electronic/Automated Software																4.18%	1.46%	7.80%	0.94%	0.28%	5.34%
Engine																					
Missile																					
Rotary Wing										5.09%	0.93%	6.11%	0.68%	0.35%	0.60%	2.83%	0.16%	7.68%			
Space																1.6%*	1.1%*	1.5%*			
UAV																					
Contract Type																					
Cost Plus							1.0%***	0.4%***	1.1%***				2.5%***	0.4%***	6.9%***	4.0%***	1.3%***	7.7%***			
Fixed										2.25%	0.38%	4.31%				0.24%	0.12%	0.32%			
Contractor Type																					
Prime	2.0%***	2.0%***	1.4%***				1.7%***	0.4%***	2.2%***	2.5%***	0.4%***	4.2%***	2.5%***	0.3%***	6.9%***	5.1%***	1.4%***	8.8%***	2.6%***	0.3%***	5.9%***
Sub													2.77%	0.35%	3.29%	1.5%**	0.2%**	3.8%**			
Service																					
Air Force	1.8%***	1.6%***	1.5%***				1.3%***	0.4%***	1.3%***	1.2%***	0.3%***	2.3%***	1.3%***	0.2%***	2.2%***	3.7%***	0.9%***	5.5%***			
Navy										3.99%	0.36%	5.85%	0.34%	0.34%	0.19%	2.93%	0.19%	8.30%			
Army													6.62%	1.66%	11.13%	4.15%	1.61%	7.69%	2.89%	0.16%	5.35%
Joint																					

Data	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft	2.1%***	1.5%***	1.2%***	2.5%***	2.8%***	1.5%***	5.0%***	3.4%***	4.6%***	3.7%***	1.8%***	4.8%***	1.4%***	1.0%***	7.3%***	3.0%***	2.2%***	3.0%***			
Electronic/Automated Software																4.37%	1.89%	7.62%	1.25%	1.09%	0.81%
Engine																					
Missile																					
Rotary Wing										11.20%	5.99%	11.70%	2.43%	2.37%	1.92%	2.49%	1.34%	3.85%			
Space																1.63%	0.42%	2.40%			
UAV																4.14%	2.47%	5.17%			
Contract Type																					
Cost Plus							3.4%***	2.5%***	3.5%***	5.2%***	2.9%***	6.4%***	1.6%***	1.0%***	6.1%***	3.7%***	2.1%***	5.8%***			
Fixed							6.51%	4.69%	5.42%	4.92%	1.87%	6.81%				1.37%	0.79%	1.36%	2.13%	1.11%	3.30%
Contractor Type																					
Prime	2.1%***	1.5%***	1.2%***	2.5%***	2.8%***	1.5%***	5.8%***	2.7%***	7.2%***	4.8%***	2.0%***	6.5%***	1.9%***	1.8%***	6.0%***	3.7%***	2.3%***	4.4%***	2.3%***	1.2%***	2.9%***
Sub													2.00%	1.92%	1.36%	2.52%	0.89%	5.25%			
Service																					
Air Force	1.6%***	1.5%***	0.5%***				4.8%***	2.7%***	4.8%***	6.2%***	2.7%***	7.8%***	1.5%***	1.0%***	7.3%***	4.5%***	2.3%***	8.0%***	2.1%***	2.4%***	0.8%***
Navy							2.53%	2.22%	1.54%	2.27%	1.42%	2.74%	1.89%	1.76%	1.27%	2.88%	1.64%	3.98%	0.97%	0.78%	0.85%
Army													3.09%	3.05%	1.98%	2.26%	1.22%	2.84%	3.60%	1.14%	4.36%
Joint																					

Site Activation	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft										1.9%***	0.3%***	3.0%***				2.2%***	1.6%***	2.4%***			
Electronic/Automated Software																20.79%	6.88%	30.83%			
Engine																					
Missile																					
Rotary Wing																3.76%	4.16%	1.68%			
Space																					
UAV																					
Contract Type																					
Cost Plus													3.1%***	0.5%***	4.8%***	10.3%***	2.4%***	21.1%***			
Fixed										2.40%	1.29%	3.23%				3.76%	4.16%	1.68%			
Contractor Type																					
Prime										1.8%***	0.2%***	2.9%***	4.9%***	2.4%***	5.0%***	10.0%***	2.0%***	21.9%***			
Sub																3.98%	4.07%	3.03%			
Service																					
Air Force										2.9%***	1.6%***	3.4%***									
Navy										0.14%	0.09%	0.15%				3.65%	3.92%	3.06%			
Army																					
Joint																					

Support Equipment	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft	5.4%***	3.5%***	5.2%***				22.0%***	7.5%***	35.0%***	6.3%***	3.2%***	7.4%***	3.4%***	1.2%***	4.4%***	2.2%***	1.9%***	2.2%***			
Electronic/Automated Software																47.97%	5.14%	96.96%			
Engine																					
Missile																					
Rotary Wing													0.44%	0.08%	0.66%	3.18%	0.82%	5.52%			
Space																16.9%*	4.8%*	17.7%*			
UAV																6.18%	5.79%	5.86%			
Contract Type																					
Cost Plus							9.4%***	6.2%***	9.5%***				2.0%***	0.8%***	3.2%***	12.0%***	1.5%***	46.6%***			
Fixed										6.83%	4.15%	7.76%				3.20%	2.01%	2.91%			
Contractor Type																					
Prime	5.4%***	3.5%***	5.2%***				16.3%***	5.9%***	29.8%***	6.5%***	3.6%***	7.3%***	2.2%***	0.7%***	3.1%***	10.8%***	1.3%***	46.6%***	1.4%***	0.3%***	2.4%***
Sub													5.5%*	2.2%*	5.5%*	9.37%	5.63%	11.61%			
Service																					
Air Force	3.5%***	3.3%***	2.4%***				18.7%***	5.0%***	34.0%***	8.3%***	4.2%***	8.1%***	3.7%***	1.4%***	4.3%***	6.6%***	2.8%***	11.0%***	1.0%***	0.2%***	1.6%***
Navy										2.2%*	0.8%*	2.7%*	0.42%	0.06%	0.63%	5.79%	0.81%	13.13%			
Army																23.12%	1.34%	73.89%			
Joint																					

Spares	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft	8.9%***	10.1%***	3.1%***							7.2%***	4.1%***	7.8%***	3.1%***	0.7%***	4.6%***	3.0%***	2.0%***	3.0%***			
Electronic/Automated Software																			1.55%	1.02%	1.57%
Engine																					
Missile																					
Rotary Wing																2.69%	0.41%	4.21%			
Space																					
UAV																24.43%	7.44%	40.89%			
Contract Type																					
Cost Plus													2.0%***	0.9%***	2.2%***	6.8%***	1.0%***	22.4%***			
Fixed										6.52%	3.40%	7.65%				5.33%	2.51%	5.26%			
Contractor Type																					
Prime	8.9%***	10.1%***	3.1%***							5.4%***	1.5%***	7.3%***	6.7%***	1.1%***	10.0%***	9.4%***	1.0%***	28.5%***			
Sub																4.05%	3.03%	4.14%			
Service																					
Air Force	8.6%***	9.3%***	3.3%***										8.1%***	1.5%***	11.8%***	2.2%***	0.2%***	3.6%***			
Navy										0.69%	0.14%	1.22%				3.40%	2.05%	3.80%	1.85%	1.56%	1.55%
Army																					
Joint																					

G&A	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
Decade	1950			1960			1970			1980			1990			2000			2010		
Commodity Type																					
Aircraft							20.8%***	18.3%***	8.7%***	15.9%***	17.1%***	8.6%***	20.3%***	17.2%***	29.5%***	24.2%***	23.2%***	11.1%***	37.9%***	16.5%***	48.7%***
Electronic/Automated Software													30.18%	29.94%	14.84%	28.0%**	24.0%**	19.1%**	32.89%	26.12%	38.69%
Engine							20.94%	21.56%	4.70%												
Missile																					
Rotary Wing										22.74%	25.66%	9.98%	33.10%	28.91%	9.97%	26.18%	22.39%	22.11%			
Space																22.23%	19.20%	14.04%			
UAV																30.88%	25.47%	10.81%			
Contract Type																					
Cost Plus				9.9%***	10.1%***	0.7%***	20.9%***	19.4%***	7.7%***	20.0%***	25.7%***	10.6%***	21.2%***	17.3%***	26.4%***	27.9%***	25.0%***	19.1%***	39.9%***	24.8%***	49.1%***
Fixed							24.17%	23.59%	9.10%	17.69%	18.60%	8.48%				21.72%	19.06%	17.52%	24.75%	26.73%	12.57%
Contractor Type																					
Prime				10.3%***	10.0%***	2.9%***	22.3%***	21.6%***	8.2%***	16.6%***	17.2%***	9.1%***	23.2%***	21.4%***	27.4%***	24.5%***	21.4%***	16.4%***	35.6%***	26.1%***	39.7%***
Sub													21.14%	17.20%	13.94%	27.30%	24.21%	19.28%	17.9%***	15.0%***	14.2%***
Service																					
Air Force							20.6%***	20.6%***	8.2%***	18.2%***	19.3%***	9.7%***	19.2%***	17.1%***	29.7%***	25.1%***	21.5%***	17.0%***	26.9%***	24.9%***	11.4%***
Navy				9.16%	9.39%	1.31%				14.71%	14.99%	6.69%	25.24%	18.11%	16.67%	26.55%	22.88%	20.06%	37.93%	24.58%	50.99%
Army													30.25%	29.42%	12.00%	27.14%	24.12%	15.99%	27.70%	25.97%	7.92%
Joint																21.52%	20.58%	7.64%			

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14. ABSTRACT
This research involves the analysis of standard parametric factors by decade within the development stage of acquisitions. Analysts use factors to develop budgets, create a baseline for measuring project progress, or as a crosscheck to the other estimating techniques. This research analyzed data from 408 1921s across seven decades and eight work breakdown structure (WBS) elements. It further analyzed these decades by commodity type, contract and contractor type, and service branch. The statistical tests used in this research determined which decades within our categories were dissimilar and drew conclusions about the impact of those differences. These tests determined that factors have either increased, decreased, or had spikes in many WBS elements, indicating that not all decades represent the overall WBS element or subcategory. The outcome of this research is that cost estimators must take into consideration the decade from which to calculate factors. Analysts will have a reference of which WBS elements, subcategories, and decades to use to develop factors.

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