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The Benefits and Drawback of Standardization of Cost Estimation in Naval Surface Warfare Centers

June 2024

Daniel Moran, CIV

Thesis Advisors: Dr. Robert F. Mortlock, Professor
Dr. Simona L. Tick, Senior Lecturer

Department of Defense Management

Naval Postgraduate School

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ABSTRACT

Work supported by Naval Surface Warfare Centers (NSWCs) enlists the assistance of many engineering codes to generate cost estimates for large projects' budgets. One important issue needing attention is to better understand how to manage estimated costs and planned budgets against the reality of typically higher actual costs. In this project, I examine the benefits and drawbacks of using a standard method for cost estimations at a NSWC for engineering codes for their cost estimations as a way to improve the accuracy of estimations and minimize the margin between estimated and actual project costs. This study draws from prior studies on methods of cost estimation and from reviewing NSWC cost estimate approaches in support of Full Ship Shock Trials (FSST). My examination found that other factors, difficult to anticipate, impact the accuracy of large project budgets to a greater degree than the methods used by engineering codes for cost estimation. The recommendation is to focus on better understanding and defining these other factors to improve the mitigation of large project challenges.

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ABOUT THE AUTHOR

Daniel E. Moran Sr. holds a Bachelor's of Engineering degree from Stevens Institute of Technology in Hoboken, NJ. He supported the US Navy, specializing in Shock for more than 20 years working at Shock Tech, 901D, Gibbs & Cox, and currently at the Naval Surface Warfare Center, Philadelphia Division. He supported Full Ship Shock Trials performed on LPD-19, LCS-5, LCS-6, and CVN-78. He holds a Professional Engineer's License, P.E. in New Jersey and a Project Management Professionals, PMP Certificate from the Project Management Institute.

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LIST OF ACRONYMS AND ABBREVIATIONS

AA	Air-to-Air
AC	Air Conditioner
ACE	Aircraft Elevator
ADCS	Advanced Damage Control System
ADS	Advanced Degaussing System
AED	Aircraft Elevators & Doors
AESS	Aircraft Electrical Servicing System
AFD	Arc Fault Detector
AFFF	Aqueous Fire Fighting Foam
ASD	Anti-Slack Device
ASG	Active Shaft Grounding
AWE	Advanced Weapons Elevators
BDS	Battle Dressing Station
CBR-D	Chemical, Biological and Radiological Defense
CG	Guided Missile Cruiser
CHW	Chilled Water
CO2	Carbon Dioxide
CP	Collection Point
CS	Control System
CTF	Compatibility Test Facility
CTM	Continuous Thermal Monitoring
CVN	Carrier, Fixed Wing Aircraft, Nuclear
CMWD	Countermeasure Washdown
DC	Damage Control
DDG	Guided Missile Destroyer
DLC	Data Link Connector
DMS	Data Multiplex System
DOD	Department of Defense
ECWS	Electronic Cooling Water System

ESG	Expeditionary Strike Group
ETFS	EMALS Trough Fire Suppression System
FAS	Fueling-At-Sea
FCCS	Flooding Casualty Control Software
FDS	Fire Detection System
FFD	Flood and Fire Detection
FSST	Full Ship Shock Trials
E-SPE	E-Stream Sliding Padey
ECDIS	Electronic Chart Display and Information System
EP	Electronic Protection
EPF	Expeditionary Fast Transport
ESB	Environmental Services Branch
GW	Gray Water
H2S	Hydrogen Sulfide
HBFPS	Hangar Bay Fire Protection System
HDD	Head-Down Display
HFP	HeptaFluoroPropane
HM&E	Hull, Mechanical, and Electrical
I&EW	Information & Electronic Warfare
ICCP	Computer Controlled Cathodic Protection, Impressed Current
INLS	Improved Navy Lighterage System
IPDS-LR	Improved (Chemical Agent) Point Detection System Life cycle Replacement
IPE	Industrial Plant Equipment
ISE	Ion Selective Electrode
ISEA	In-Service Engineering Agent
JETS	Jet Engine Test Stand
JP-5	Jet Propellant 5
LBES	Land Base Engineering Site
LCS	Littoral Combat Ship
LHA	Amphibious Assault Ship

LHD	Amphibious Assault Ship
LLMS	Liquid Load Management System
LPD	Amphibious Transport Dock
LS	Lower Stage
LSD	Dock Landing Ship
LXR	Amphibious Assault Ship
MAIS	Major Automated Information System
MBA	Master of Business Administration
MBT	Manual Bus Transfer
MCS	Machinery Control System
MCMS	Machinery Control Monitoring System
MDS	Main Drainage System
MOD	Modernization
MRC	Maintenance Requirement Card
MRG	Main Reduction Gear
MRS	Maintenance Repair & Service
MSC	Military Sealift Command
N2	Nitrogen
NAVSEA	Naval Sea Systems Command
NDE	Nondestructive Examination
NPS	Naval Postgraduate School
NSWC	Naval Surface Warfare Center
NSWCPD	Naval Surface Warfare Center Philadelphia
NWA	Network Activity
NWCF	Navy Working Capital Fund
O2	Oxygen
O&S	Operations and Sustainment
OPA	Oil Pollution Abatement
OWS	Operational Work Station
PD	Philadelphia Division
PMEMA	Permanent Magnet Electromechanical Actuator

PW	Potable Water
PWEDG	Potable Water Electrolytic Disinfectant Generator
R&D	Research and Development
RAND	Research and Development (Corporation)
RAS	Refueling-At-Sea
RHIB	Rigid Hull Inflatable Boat
RLM	Reverse Link Model
ROM	Restriction of Movement
SE	Stores Elevators
SISCAL	Shipboard Instrumentation & System Calibration
SO2	Sulfur Dioxide
SOT	Systems Operation Test
SOW	Statement of Work
SSC	Ship-to-Shore Connector
SSVFC	Solid State Voltage Frequency Converter
SW	Sea Water
TP	Test Procedure
UMM	Universal Modular Mast
UPS	Uninterruptable Power Supply
USCG	United States Coast Guard
VCHT	Vacuum Collection Holding and Transfer
WBS	Work Breakdown Structure
WDCM	Washdown Countermeasures
WSS	Water and Sanitation Services

I. INTRODUCTION

This chapter provides a problem statement, research questions, methodology, limitations and scope, and a description of the organization of the project.

A. PROBLEM STATEMENT

Navy warfare centers support large-scale projects that require engineering services from many of their engineering codes. One issue currently faced is that there is no standard cost estimation method to be used by engineering codes to calculate the costs of their services. This capstone addresses the issue by focusing on identifying and evaluating the merits of a standard, one size fits all method to improve the accuracy of cost estimates to be used to create budgets for those large-scale projects. This study evaluates the pros and cons of whether implementation of a standard cost estimation method would improve the accuracy of the budget for large-scale projects.

Cost estimates used by Naval Surface Warfare Centers' (NSWCs) engineering codes to help create a budget for execution of a recent full ship shock trials (FSST) demonstrated various degrees of accuracy. In the view of the author, the lead of NSWC support of the FSST, some cost estimates appeared to be low by tens of thousands of dollars, while others appeared to be high by hundreds of thousands of dollars. Cost estimates are created independently by each engineering code. There is no standard method put in place by the NSWC. The accuracy of cost estimates is essential, especially when allocating a budget for a large project such as an FSST that calls upon the support of multiple engineering codes. Accurate cost estimating ensures funding is appropriated adequately. Determining cost estimates using various methods can cause three significant problems: (a) funding requests may be made below the required budget, (b) funding requests may be made above the required budget, and (c) sponsors who recognize the estimate inconsistencies may reduce funding regardless of the overall accuracy of the budget request.

Cost estimates for services are provided to customers who are considering purchasing those services; therefore, cost estimates need to be accurate. Customers' budgets are under tight constraints, and customers often have little to no room in their budgets to provide additional funding if cost estimates are too low. If cost estimates are too high, funding may expire and need to be returned, projecting an image of poor planning. Within NSWC, no standardized method of producing cost estimates exists. Each engineering code provides its cost estimates using a methodology of its choice. The estimates have varying levels of accuracy, as outlined during planning a recent FSST that required support from many NSWC engineering codes.

Program offices funding large-scale projects seek objective quality evidence to ensure accurate funding requirements. When responding to the program office's inquiries about how costs were estimated, providing information showing codes employed various methods to estimate costs can give the sponsor pause. A lack of transparency can also cause the program office to reevaluate its confidence in the accuracy of the budget. In either case, should the program office lose confidence in the numbers, a typical reaction may be to request inadequate project funding.

This study focuses on increasing the accuracy of cost estimations created by engineering codes intended to formulate accurate budgets for large-scale projects. Budgets of large-scale projects are made up of more than just a summary of support requirements, but those additional aspects stretch beyond the limits of this investigation. In addition, there are many external forces that impact budgets of large-scale projects, but those forces were not explored in this study.

Large-scale projects combining many cost calculations with varying accuracy can combine to create project funding requirements that are far from the actual budget requirement. For example, for the FSST support, some engineering code estimates added 40% to the cost estimate of the engineering code as slack (D. Moran, personal communication, 2020). This was not disclosed initially when the cost estimate was first submitted. If each engineer code adds 40% slack unbeknownst to those responsible for creating a large project budget, the budget may deviate from the actual need by 40%. Relatively small inaccuracies of individual costs can add up to form project funding requirements that are too high or low. Overfunded projects are problematic because they needlessly tie up funding, which could be put to better use elsewhere. Underfunded projects can cause projects to fall short of completion because only projects for which adequate funding has been appropriated can be executed to completion.

B. RESEARCH QUESTIONS

This research seeks to address the following questions:

- What are the main advantages and disadvantages of using a standard cost-estimating process to support Navy warfare centers' technical codes in estimating costs for special projects?
- In what conditions can a standard cost estimating process across many engineering codes improve the accuracy of the total project cost for large-scale efforts such as an FSST?
- What other factors impact the accuracy of cost estimates used to create budgets for large-scale projects such as FSSTs?

C. METHODOLOGY

This capstone uses a qualitative comparison of advantages and drawbacks of cost-estimation methods used by Navy warfare center engineering codes with the aim to support improving the accuracy of FSST cost estimates to actual spending. This capstone examines prior research on cost estimation and notes the degrees of accuracy of the various methods and estimated labor hours to create the estimates. Further, this capstone draws evidence-based conclusions based on whether one cost estimation method stands out from the others as the best-value option. The capstone reviews prior studies on the standardization of cost estimation methods from the literature that documents the positive and negative effects organizations face when implementing standard cost calculation methods across all groups. Moreover, this capstone study analyzes whether across-the-board standardization of cost estimation can have an overall positive effect, increasing accuracy while maintaining acceptable levels of labor costs to produce the calculations to make a recommendation for use by NSWCs for large-scale projects such as an FSST.

Accurate and consistent cost estimates will improve the efficiency of NSWC services by helping projects remain within budget, ensuring that adequate funding is allocated to efforts, and verifying that funding does not go unused, necessitating its return. The research determines if standardizing cost estimation across engineering codes adds value to NSWC. The research uncovers the benefits and drawbacks of several cost estimation options and the nuances of each NSWC engineering code.

D. LIMITATIONS AND SCOPE

The research provides a discussion of the advantages and disadvantages of different cost-estimating methods, built largely on reviewing prior studies that leverage subject matter experts from the literature to access project cost estimates. However, no surveys or formal interviews are performed. This would be a recommended next step in this vein of research. Moreover, a significant limitation of this capstone is the limited access to actual project cost estimates, actual approved project funding levels, and funding execution data, making verification and validation difficult.

E. ORGANIZATION OF PROJECT

This capstone analyzes cost-estimation methods used by NSWC engineering codes to compare and contrast the impact on the accuracy of various methods by comparing FSST estimates to actual spending. Chapter I provides a problem statement, research questions, methodology, limitations and scope, and a description of the organization of the project. Chapter II covers the context, theoretical framework, conceptual framework, and a description of previous research performed on the project. Chapter III provides research themes, a synthesis process, a description of gaps in the literature, and a revisit of the project's theoretical framework. Chapter IV covers an overview of the methodology, data, and project analysis. Chapter V is the summary. It presents the outcomes of the research, additional discoveries, and recommendations.

II. BACKGROUND

This chapter provides the context, theoretical framework, conceptual framework, and a description of previous research performed on the project.

A. CONTEXT

NSWCs are Naval Sea Systems Command (NAVSEA) warfare centers. NAVSEA's website offers the following description of the functions within the Navy organization:

> Warfare centers supply the technical operations, people, technology, engineering services and products needed to equip and support the fleet and meet the warfighter's needs. In addition, the warfare centers are the Navy's principal research, development, test and evaluation (RDT&E), analysis and assessment activities for ship and submarine platform and machinery technology for surface combat systems, ordnance, mines, and strategic systems products and support. (NAVSEA, n.d., para. 13)

NSWCs are Navy Working Capital Fund (NWCF) funded organizations. A NWCF funded organization aims to cover operating costs through revenue from the sales of services. The goal is to operate on a break-even basis, neither turning a profit nor operating at a loss. Cost estimation for engineering code support aims to be as accurate as possible using the least possible amount of labor. Providing accurate service cost estimates to customers facilitates their choice to purchase the services. Cost estimates must be accurate, as customers' budgets are tight. Often, there is little or no slack to provide additional funding later if cost estimates are too low. If cost estimates are too high, funding may expire and need to be returned. This funding could have provided a benefit elsewhere, and returning funding indicates poor planning.

There is not a standardized method of producing cost estimates at NSWC. Each engineering code creates its cost estimates using a methodology of its choice. The estimates have varying levels of accuracy. Evidence of inconsistencies was discovered when planning a recent FSST that required similar support from many NSWC engineering codes. For example, one estimator added 40% to the cost estimate of the engineering code as slack to account for unforeseen problems (D. Moran, personal communication, 2020). In another example, an engineering code provided an unaffordable funding requirement (D. Moran, personal communication, 2020). In response, the project manager reduced the required level of effort by 50% and requested a new quote (D. Moran, personal communication, 2020). The price quote for half the level of effort was the same as the first quote, remaining unaffordable to the program. When questioned, the engineering code stated that the miscalculation when developing the original quote was to blame for the failure to reduce required costs by 50% in proportion to the reduced level of effort (D. Moran, personal communication, 2020). The cost-calculation method implemented by that engineering code remains undisclosed.

Examples of engineering codes of NSWCs are found in Appendix A. Estimates from many of these engineering codes are typically needed to estimate larger project costs like FSSTs.

Engineering codes like those shown in Appendix A are needed to support FSSTs. The following excerpt provides information describing FSSTs and their goals. It also informs readers about some of the high-level stakeholders involved with FSST execution:

> Shock Trials validate a ship's shock hardness and ability to sustain operations in a simulated combat environment using live ordnance. During the four-month testing evolution, the first-in-class aircraft carrier withstood the impact of three 40,000-pound underwater blasts, released at distances progressively closer to the ship. (Program Executive Office Aircraft Carriers Public Affairs, 2021)
>
> Figure 1 shows the effects of the detonation of a 40,000-pound charge exploding next to CVN 78.

Figure 1. CVN 78 FSST. Source: Program Executive Office Aircraft Carriers Public Affairs (2021, p. 1).

> "The Navy designed the Ford-class carrier using advanced computer modeling methods, testing, and analysis to ensure the ships are hardened to withstand harsh battle conditions," said Capt. Brian Metcalf, manager for the Navy's future aircraft carrier program office, PMS 378.
>
> "These shock trials have tested the resiliency of Ford and her crew and provided extensive data used in the process of validating the shock hardness of the ship."
>
> Metcalf said that the goal of the tests is to ensure that Ford's integrated combat systems perform as designed and added "the tests demonstrated—and proved to the crew, fairly dramatically—that the ship will be able to withstand formidable shocks and continue to operate under extreme conditions."
>
> Rear Adm. James P. Downey, program executive officer for aircraft carriers, rode the ship during the first and third shock evolutions, and observed the historic trials, first-hand. "FSST has proven a critical investment in the Ford-class development," said Downey. "The ship and crew performed exceptionally in these very strenuous conditions and continued their operations throughout the shock events, demonstrating the ship's 'fight-through' capability."

> "We're designing and building these aircraft carriers to sail in some of the world's most contested security environments. So when you think about the threats to warships posed by non-contact blasts and the number of sea mines in the inventories of navies around the world, the gravity and consequence of these shock trials really come into focus. The Navy's ongoing investment in the design, including this modeling, will help ensure the resiliency of Ford's integrated, mission critical systems in underway threat environments."
>
> "So many pieces had to fall into place to execute Ford's FSSTs within the testing window," said Capt. Lanzilotta. "Success required equal measures of technical expertise, trust, and courage—traits you'll find in great supply on Warship 78 and throughout the entire Ford Shock Trial Team. These shots have only strengthened my confidence in the durability of this ship, and the excellence of the crew who came out here to own it, and absolutely crushed it."
>
> The U.S. Navy has conducted FSSTs over several decades, most recently for the Littoral Combat Ships USS Jackson (LCS 6) and USS Milwaukee (LCS 5) in 2016; as well as on the San Antonio-class amphibious transport dock USS Mesa Verde (LPD 19) in 2008, the amphibious assault ship USS Wasp (LHD 1) in 1990, and the guided missile cruiser USS Mobile Bay (CG 53) in 1987. The last aircraft carrier to execute FSST was USS Theodore Roosevelt (CVN 71) in 1987.
>
> The Navy conducted the Gerald R. Ford shock trial testing in accordance with Office of the Chief of Naval Operations Instruction 9072.2, and as mandated by the National Defense Authorization Act of 2016. The first two shots of the FSST sequence occurred on June 18 and July 16. (Program Executive Office Aircraft Carriers Public Affairs (2021, p. 1)

The preceding excerpt described FSSTs and detailed some of their goals. It is important to understand that to achieve those goals, an assessment of the state of every system on the ship must be made before and after FSST. Some systems require continuous monitoring and documentation. Engineering codes are needed for this support because they include experts who are highly familiar with the optimal performance of the ship systems.

The recent FSST examined in this capstone research project was performed on the first ship of a new class and was fresh from the shipyard when it began FSST. Systems remained in development while others were experiencing problems that had not yet been worked out. The FSST required the establishment of a pre-test baseline that could be used to measure performance during and after the FSST. Then, equipment evaluation would be needed during execution and after completion of FSST. The Hull, Mechanical, Electrical, and Damage Control System Director for the FSST was responsible for the baseline, execution, and post-FSST system evaluations. To perform the task, the system director relied on subject matter experts from the various engineering codes within the NSWCs. System experts were called upon to provide evaluation procedures, create plans for monitoring equipment, and document the results of the FSST. Approximately 85 ship systems required support from 67 NSWC engineering codes (Rutgerson, 2017).

B. COST ESTIMATING METHODS USED

The accuracy of engineering code funding requirements is critical, especially when justifying a budget for a large project such as an FSST. Accurate cost calculations ensure that sponsors, such as program offices, have the information to allocate funding appropriately. This capstone is framed around the avoidance of problems caused by inaccurate large project budgets. Funding requests may be made below or above the required budget. Also, sponsors that recognize the estimate inconsistencies may react by reducing funding regardless of the overall accuracy of the budget. The aim is to avoid these issues and the framework focuses efforts on reducing inaccurate budgets.

Program offices that fund large-scale projects require evidence to document the accuracy of funding requirements. Formulating a large project funding requirement requires combining many requirements from various engineering codes. Presenting evidence to the sponsor indicating that many different cost calculation methods were implemented to estimate costs reduces the program offices' confidence in the accuracy of the budget. The use of inconsistent methods does not convey that funding requirements have been calculated in a methodical manner that makes sense and produces an accurate estimate. A typical program office reaction to inaccurate funding requirements is a reduction of project funding.

A common method of building out large-scale project budgets is through the combination of all funding requirements of engineering codes that will support the project. Doing so poses the risk that inaccuracies of each estimate can build into significantly inaccurate project budgets. Overfunded projects are problematic because they needlessly tie up funding, which could be put to better use elsewhere. Underfunded projects can cause projects to halt short of completion because only projects for which adequate funding has been appropriated can be executed to completion. Accurate and consistent cost estimates improve the efficiency of NSWC services by helping projects remain within budget, ensuring adequate funding is provided where most needed and efforts are executed as planned.

This chapter presented information about Navy warfare centers and the importance of calculating costs for the projects they support. FSSTs were described and the various options available for cost estimation were highlighted. The next chapter discusses research into cost estimation methods and their benefits and drawbacks.

III. LITERATURE REVIEW

This chapter provides an overview of cost-estimating research themes and a description of gaps in the literature.

A. RESEARCH THEMES

The literature review for this study focuses on standardizing cost estimation methods. Previous research has revealed that the most important factor in developing accurate budgets is not the method of cost estimation used but the competence of the government personnel tasked with creating the cost estimates.

Prior studies discussed alternative views on cost estimation methods. The Government Accountability Office (2007) offered guidance in the creation of budgets and specified the use of a standard work breakdown structure to perform cost calculations:

> A standard work breakdown structure (WBS), as detailed as possible, should be used, refining it as the cost estimate matures and the system becomes more defined. A Major Automated Information System (MAIS) program may have only a cost estimate structure. The WBS ensures that no portions of the estimate are omitted and makes it easier to make comparisons to similar systems and programs. (p. 6)

Searches were performed looking for capstones, Research and Development Corporation (RAND) reports, theses, Government Accountability Office reports, and any other literature having to do with cost estimation for military and government projects. The documents were scanned in search of standard cost estimation methods.

The research theme for this capstone research includes cost estimation methods used by defense organizations. A Naval Postgraduate School (NPS) Master of Business Administration (MBA) professional project by Juelson (2020) provides insight into the various methods and is considered among other papers fitting the theme of cost estimation methods used by defense organizations:

> There are four methods that the DOD uses to develop cost estimates: analogy (top down), parametric (statistical), engineering (bottom up), and actual (extrapolation). Sometimes, due to lack of data or experience,

> expert opinion is also used as a method for cost estimating. It is important to note that most CEs are a composition of more than one method. (Department of Defense [DOD], 2018)

Another research theme presented in various papers is how organizations can improve their cost estimation practices. Research into this theme is critical to build upon work uncovering positive changes that can be implemented to yield better funding requirement calculations. For example, McClary (2021) discussed the outcome of utilizing a cash reserve: "The result is a quantifiable recommended cash reserve that supports the decision maker's desired confidence level for maintaining cost and schedule objectives without sacrificing technical performance or operational effectiveness" (p. xi). Additional research may prove cash reserves to be a valuable recommendation for NSWC. McBride and Paret (2010) discussed other organizational improvements. Among their many ideas for improvement, the one offering the greatest benefit is ensuring that qualified government employees perform the funding requirement calculations. Before the start of this capstone research, it was not apparent to the researcher that simply ensuring that the employees calculating costs have the required skills and qualifications would offer such a great benefit. However, the literature explaining the benefits of utilizing skilled workers may be included among recommendations to Navy warfare centers. This improvement recommendation is significant not just for this capstone research project but for cost estimation in general:

> In examining the process of building a reliable cost estimate, the difference between the theoretical aspects of cost estimating compared to what happens in the day-to-day working world demonstrates that there is room for and a need for improvement and change…. A buy-in from all stakeholders in the acquisition process is needed to effectively change the problems that we are seeing in the area of cost estimation…. The most significant recommendation that is talked about by most everyone who was interviewed at Aberdeen Proving Ground is the lack of qualified government employees. (McBride & Paret, 2010, p. 72)

Cost estimates can be created through a summary of all required aspects of a project. If all small elements of the effort are known, their costs can be estimated and added together to form the project budget. This is called "bottom-up" or "engineering" cost estimations. The smallest pieces of a project are found in a work breakdown structure or WBS. The excerpt provides an idea about the role of WBS in estimating.

> The WBS is the heat of the project cost control and estimating system. Its organization is arranged so that the lowest indenture work packages correspond to cost allocation items. Thus, at the beginning of the project, the target cost is distributed among the identified work packages and is partitioned downward as lower-level packages are defined. (Kossiakoff et al., 2011, p. 107)

An excerpt from an example of a detailed examination of cost estimation methods follows:

> This thesis has outlined some of the better-known methods that are used to develop cost equations. These estimating techniques range in difficulty from the simple (Simple regression) to the more difficult (Multiple regression). The latter may require the combined talents of a statistician, engineer and accountant. Statistical techniques are generally justified when the estimates are to be used in recurring decisions. The expense involved in gathering and analyzing the data for multiple regression is not usually justified if the estimate of the cost, equation is to be used for only a single decision. However the missile budgeted data are available so that CERs for this are practical. (Choo, 1982)

Papers on cost estimation were explored, such as this example by Doyle. While it appears to be similar in theme to this capstone research, it was found to be specifically related to the Army survey performed by the author and discusses little about the benefits and drawbacks of standard cost estimations.

> This thesis was designed to be an assessment of the current state of Department of Army cost estimating, analysis, and management capabilities. Specifically, it evaluated the extent to which the cost estimating and analysis and cost management communities are meeting Army leadership's current and projected needs. In particular, it supported the Deputy Assistant Secretary of the Army-Cost & Economics' (DASA-CE) mission to provide DA with cost, performance and economic analysis in the form of expertise, models, data, estimates and analysis at all levels; and it will produce opportunities for improvement in the way cost estimating and analysis and cost management communities can better serve the DA. (Doyle, 2005)

Many papers that address cost estimation methods have been published. For example, McBride and Paret (2010) focused on the need for improvement in cost estimation: "In examining the process of building a reliable cost estimate, the difference between the theoretical aspects of cost estimating compared to what happens in the day-to-day working world demonstrates that there is room for and a need for improvement and change" (p. 71). In addition, comparisons of actual FSST cost estimation and funding use data show how close cost estimates were to the actual costs. Other studies have demonstrated the impacts of cost estimation on government acquisition and the decision-making process. For example, Sindall (2010) stated,

> The process presented in this thesis complements the management structures within the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L) Life Cycle Management. By employing this process, HSI practitioners and other acquisition professionals will have access to information to support decision-making throughout the life cycle of the system and to reduce total life cycle costs. (p. xix)

Some researchers have examined the effects of cost-estimating tools. For example, Redman (1994) investigated a tool used to calculate funding requirements: "On the basis of the results, the Cost Simulation model provides a useful tool for predicting direct operating costs and supports sensitivity analysis of various ship's operating cost scenarios" (p. xi). This capstone applied project investigates the previous research to conclude whether the benefits of applying a standard cost-estimating process outweigh the costs.

There are many ways costs can be estimated. From Candreva (2017), we find the following:

> There are four main methods of cost estimation used in the military: analogy, parametric, engineering, and actual costs…Briefly, the analogy technique bases an estimate of the cost of the new system by comparing it to a similar prior system and adjusting for technical difference and time value of money.
>
> Parametric cost estimating is a method that uses algorithms and cost estimating relationships to forecast costs based on historical cost drivers. For example, the cost of a submarine is proportional to its volume, the cost of a ship is proportional to its tonnage, and the cost of a rocket engine is proportional to its weight-thrust ratio. Using these cost drivers and known relationships, from previous programs, the cost estimator can compute an estimate for the new program. This technique is also used predominantly during research and development, but can also be used in early production.
>
> Engineering estimates are bottom-up estimates computed by costing the individual elements of the work-breakdown structure. It is the summation of the estimates of discrete tasks and materials. This method is available only when a design and manufacturing process are understood. It

> is time-consuming and complicated, but can be more accurate than the two prior methods.
>
> Finally, cost estimates can be computed by using the actual cost to produce them. Costs will become known as prototypes and test articles are manufactured in research and development. As more units are produced, learning curve theory predicts the unit cost will fall as learning occurs and manufacturing processes become more efficient. Budget estimates are derived by extrapolating from actual costs of units already acquired. By the time the system is in full rate production, actual costs are the most accurate and defensible means of forecasting future costs. (p 271)

Another central theme of the literature is whether implementing a standardized method to calculate funding requirements offers a more significant benefit than maintaining the status quo. The formulation of a parametric cost model is described by Brandt (1999):

> Because there is no standardized method for calculating reliable estimates of O&S costs—the principal component of total ownership costs—this thesis sets out to formulate a parametric cost model that can be used to determine the total annual O&S costs of U.S. Navy (non-nuclear) surface ships based on known (or assumed) physical characteristics and manpower expectations. (p. xv)

Brandt discussed the challenges of assessing weapon system affordability. This research acknowledges there is no standardized method to calculate total ownership costs of weapon systems and proposes using a parametric cost model to calculate operating and support costs. Brandt used standard regression and data analysis to develop cost estimating relationships for ship light displacement, length, and manpower cost drivers.

B. GAPS IN THE LITERATURE

The focus of this capstone research is to determine whether implementing a standard method of cost calculation across Navy warfare centers will benefit the organizations. A search for published research uncovered the results of similar efforts carried out in organizations like Navy warfare centers. The search revealed that there is a lack of literature that compares a one-size-fits-all method, along with the costs and benefits of this standardized approach, to engineering codes providing cost estimates through methods of their choosing, an inconsistent but possibly less costly and more accurate method. This capstone research project seeks to bridge the gaps among the literature to determine the accuracy of various methods, the importance of cost estimation, and the benefits and drawbacks of implementing cost estimation tools applied specifically to engineering code cost estimates within NWSC. This capstone builds evidence about the benefits and disadvantages of the different cost estimation methods and the positive and negative outcomes gained by implementing a standardized cost estimation method across different engineering codes within an organization.

IV. ANALYSIS OF BENEFITS AND DRAWBACKS OF A STANDARDIZED COST ESTIMATION METHOD

This chapter provides an overview of the methodology, data, and analysis of the project.

A. DATA COLLECTED

Various methods were utilized for data collection, corresponding to the specific type of data. In addition, a systematic approach was applied to find relevant literature and search for relationships between previously published work and the goals of this capstone. Figure 2 presents a summary of the data collection process.

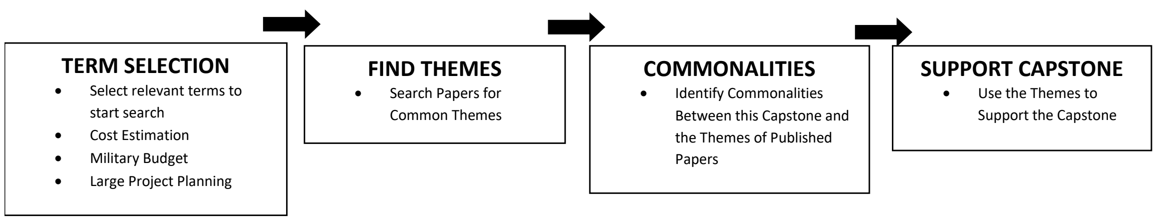

Figure 2. Data Flow Chart

Information about advantages and drawbacks on cost-estimating methods was collected using a literature review. The main points on effectiveness and accuracy of those methods were also identified from the literature review, as was information concerning the burdens created by the methods and their impact on large projects. Data concerning studies on the most effective cost estimation methods was also collected through a literature review.

Initial attempts at analyzing data did not yield usable data. Information from the recently performed FSST was examined, and cost estimates from each of the 67 engineering codes supporting 85 systems involved in the trial were reviewed. Next, the requests made by engineering codes for incremental charge numbers were examined. Unfortunately, though charge numbers are nominally limited, total allowable charges are limited only by the total on the funding document, which in this case was more than the total of all engineering code cost estimates combined. Aggregating the incremental requests of engineering codes could produce flawed results, so this initially planned approach was rejected.

To gather data on an actual large project carried out by a warfare center, data from a recent FSST was documented. During the planning of a large Navy warfare center project, funding requirements provided by 67 engineering codes supporting 85 systems were collected, documented, and reviewed during this capstone effort (Moran, 2021). Then, during the execution phase of the large project, the expenditure of funding by each engineering code was again recorded, documented, and reviewed.

Appendix B shows the example FSST systems and baseline evaluations required. Appendix C presents a report that was run on the charge numbers assigned to engineering codes to support the work performed on each system. Positive numbers indicate unused funding, an indicator that the initial cost estimate was high. Negative numbers indicate overspending and indicate that cost estimates were too low. Zeros indicate full use of funding and accurate cost estimation. The systems associated with each charge number are masked to avoid being able to connect the specific engineering codes with cost estimates that are different from the actuals charged.

In Appendix C, 16 Network Activity (NWA) plans out of this 100 have funding remaining, totaling $131,956. Twenty-seven NWA plans were overcharged, totaling $206,175. Fifty-seven NWA plans were spent down to $0. Almost twice as many NWA plans were overcharged compared to those that were undercharged. Also, the total amount overcharged is nearly double that of the undercharges. This is not surprising due to two events that occurred during FSST execution, both of which caused an unplanned increase in spending, impacting the FSST budget.

NSWC engineering codes are not required to disclose cost calculation methods used to predict funding needed to support large projects. No codes presented calculation methods when they provided their cost estimates. The author requested each engineering code that supported the FSST as part of this capstone project to answer whether the cost estimation method used by their code for FSST support was more of a bottom-up, engineering method or an analogy to similar work. Responses were provided from 10 codes that supported the example FSST. No engineering codes indicated that they developed their estimates purely through analogy. Two codes indicated they used a mix of bottom-up engineering and analogy. Table 1 presents the responses from the engineering codes. "Eng" indicates the use of bottom-up engineering cost estimates, and "Mix" indicates the use of analogy combined with bottom-up engineering cost estimates.

Table 1. Cost Estimation Methods

Code	Cost Est.
1	Eng.
2	Mix
3	Eng.
4	Eng.
5	Eng.
6	Eng.
7	Eng.
8	Eng.
9	Mix
10	Eng.

Finally, Appendix D links the data from the spending report with the cost estimation method used to create the estimate. The author knows the engineering codes associated with the cost estimation method and use of funding, but they have been masked for this research. Unknown indicates that the cost estimation method was not provided.

This data presents the actual charges made by engineering codes to their cost estimates. There is a mix of overcharges, unused funding, and closely matched cost estimates and spending. The next step correlates the various overcharges, unused funding, and accurate cost estimates to the cost estimation methods used to determine if specific methods are more accurate or inaccurate.

After removing information from tasks with unknown cost estimating methods, sorting by method and adding up the over and under charges, Table 2 shows the results of estimating costs through a mix of analogy and bottom-up engineering estimation. Table 3 shows the results of estimating costs through only bottom-up engineering estimation.

Table 2. Mixed Cost Estimation

Assigned Number	NWA Plan Remaining	Cost Estimation Method
1	-$8,769	Mix
2	$0	Mix
3	-$3	Mix
4	$0	Mix
	-$8,772	Total

Table 3. Bottom-up Engineering Cost Estimation

Assigned Number	NWA Plan Remaining	Cost Estimation Method
1	-$4,973	Eng.
2	$3,009	Eng.
3	$2	Eng.
4	-$977	Eng.
5	$0	Eng.
6	$5,582	Eng.
7	$0	Eng.
8	$0	Eng.
9	$120,889	Eng.
10	$0	Eng.
11	-$14,411	Eng.
12	-$10,094	Eng.
13	-$8,046	Eng.
14	-$59,722	Eng.
15	$1,831	Eng.
16	-$5,727	Eng.
17	-$4	Eng.
18	$2	Eng.
19	$0	Eng.
20	$0	Eng.
21	$0	Eng.
22	$3	Eng.
23	$0	Eng.
24	$0	Eng.
25	$0	Eng.
26	$0	Eng.
27	-$7,246	Eng.
28	-$757	Eng.

Assigned Number	NWA Plan Remaining	Cost Estimation Method
29	$0	Eng.
30	$0	Eng.
31	-$8,771	Eng.
32	$0	Eng.
33	-$4	Eng.
34	$0	Eng.
35	$0	Eng.
36	$0	Eng.
37	$0	Eng.
38	$5	Eng.
39	$0	Eng.
40	$0	Eng.
41	$0	Eng.
42	$0	Eng.
43	$0	Eng.
44	$0	Eng.
45	$0	Eng.
	$10,591	Total

Overcharges are nearly double undercharges in both monetary value and the number of NWAs that were overcharged. One NWA with an undercharge has a significantly higher value than all other overcharges and undercharges. That NWA was undercharged by $120,889. If that one NWA were removed, overcharges would be 1,863% higher than the remaining undercharges.

Cost estimates made from a mix of analogy and bottom-up engineering cost estimates produced a total error of $8772 or about $2200 per task within this sample. Cost estimates made from bottom-up engineering calculations produced an error of $10,591 or about $240 error per task. Within this sample, bottom-up engineering calculations perform better on a task-by-task basis than calculating costs using a mix of analogy and bottom-up engineering cost estimates.

Four cost calculations were made via a mix or 4% of the sample. Of those, two were perfectly accurate, and two were overcharged. Forty-five cost calculations were made using bottom-up engineering or 45% of the sample. Of those, eight were undercharged, 25 were perfectly accurate, and 12 were overcharged. Fifty-one cost calculations were made using bottom-up engineering or 51% of the sample. Of those, seven were undercharged, 31 were perfectly accurate, and 13 were overcharged. Many errors for all methods of cost calculations are overcharges.

At the time this work was performed, an hour of labor at the working level was $117.51. If overcharges and undercharges totaling one hour of labor or less are considered to be accurate, bottom-up engineering calculated NWAs were charged accurately 31 of 45 times or with 69% accuracy. NWAs calculated using a mix were charged accurately three of four times or with 75% accuracy. NWAs calculated using an unknown method were charged accurately 39 of 51 times or with 76% accuracy.

Again, considering charges plus or minus one hour of labor or less to be accurate, 10 bottom-up engineering charges were over and four were under. One mix charge was over and none were under. Eleven unknown charges were over and one was under. The majority of errors calculated using all methods were overcharges. The cause for this sample generally overcharging may be because as discussed, all codes and the systems they support incurred additional costs due to COVID-19 and other unforeseen factors.

Costs calculated using a mix of analogy and bottom-up engineering costs were more accurate than those made only through bottom-up engineering cost calculations, 76% and 67%, respectively. The cause of this may be because bottom-up engineering cost calculations consider only the work to be performed while costs calculated through a mix of methods takes the actual costs of previous support into account. Any unforeseen factors that raised the cost of previous work would push mix cost estimates higher than bottom-up engineering methods.

B. DISCUSSION OF ADVANTAGES AND DRAWBACKS ON STANDARDIZATION OF COST-ESTIMATION

FSST data was not without flaws, and it could not be used as initially planned to present conclusively the most accurate cost estimation methods for that case. However, evidence demonstrating the use of various cost estimation methods causes inaccuracies that balance each other out and can be structured to back the conclusion that benefits are gained from allowing codes to select their own cost estimation methods.

All cost estimation methods inherently include some level of inaccuracy. Some cost estimation methods produce higher estimates, while others produce lower ones. Permitting engineering codes across a Navy warfare center to use cost estimation methods of their own selection is likely to result in engineering codes opting for various methods. The results of these estimates can potentially balance one another. Alternatively, implementing a standard cost estimation method across all engineering codes of a Navy warfare center will essentially lock in that cost estimation method's inaccuracies, and a trend of high or low will be compounded when compiling the results of many engineering codes' cost estimates to formulate a budget for a large-scale project.

If one specific calculation method is implemented, inaccuracies inherent to the calculation methods will compound across all engineering codes. Standard cost-estimating methods do not produce more accurate large project budgets. In fact, the larger the project, the more significant the inaccuracy of the overall budget due to the compounding of inaccuracies.

The research was performed to determine if standardizing cost estimation methods justified any cost increases associated with additional labor burdens needed to standardize methods. Findings show that cost estimation will come with inaccuracies. Some cost estimates were accurate. Others were inaccurate, shown either by the codes having spent more than their cost estimates or not having spent all their estimated costs. Standardizing methods across the board, across large organizations, may standardize the inaccuracies. The more groups that are included in a large project, the more the inaccuracies may compound into an inaccurate project budget. Like a quartz watch, which contains a highly accurate movement, there will be some level of consistent inaccuracy, but for a properly performing quartz movement, that inaccuracy is typically no more than one second per day. Over time, the small inaccuracies add up. After a year, the watch could have drifted more than five minutes from an accurate time reading.

On the other hand, allowing engineering codes to create cost estimations in a manner of their choosing runs the risk of groups choosing methods that produce more results containing more significant inaccuracies. The inconsistency of the cost estimation methods chosen by the various codes means the results are also likely to show a lack of consistency. This is like wearing a mechanical watch, which has a movement that is relatively inaccurate when compared with a quartz movement. However, a mechanical movement is inconsistent in its inaccuracy. This is due to the different values of friction forces imparted by gravity on the internal components of the movement, depending on the position in which the watch is placed. Depending on the hours a mechanical watch is worn versus stored and the position it is stored in, a well-functioning mechanical watch could lose or gain as much as 30 seconds each day. Over time, the inconsistent inaccuracies tend to balance out. After a year, a mechanical watch could display perfectly accurate time.

A one-size-fits-all cost estimation method does not show the potential to work adequately for large-scale Navy warfare center projects. When studying the cost estimations for the FSST used as an example for this capstone research, the required engineering code support appeared straightforward: provide procedures to evaluate the performance of equipment and perform the evaluations. Once codes begin planning, however, several unique situations become apparent. In some cases, codes had not received the normal increments of funding needed to become familiar with a new system. In those cases, additional cost estimates were necessary to account for the groundwork needed before developing procedures. Other systems had evaluation procedures readily available and did not require estimates to develop protocol. Still other engineering codes did not have government support available and would have to rely on contractors to perform the work. Contractors have their own cost estimation methods and provide estimates in accordance with the contract that they are supporting. In the case of the FSST, many different contracts were used to fund contractors across many of the 67 engineering codes supporting the 85 systems evaluated throughout the project.

Through discussions with members of the engineering codes supporting the FSST, it became apparent that a common method of cost estimation was based on the amount of time engineers would need to remain onsite in support of the project. The FSST support revolves around the underway schedule of the ship, and flights on and off were not offered as a cost savings option. Engineering codes assumed the work would grow to fill the time onsite and estimated their costs based on estimated days underway and time waiting onsite to sail. The notion that "work expands to fill the time available for its completion" (Parkinson, 1986, p. 2) was applied by the engineering codes when estimating their costs. Engineers stuck on the ship for lengthy underway periods offered their time and support to the Hull, Mechanical, and Electrical (HM&E) team for any FSST needs. Their services were used and much appreciated, and their work onboard the ship grew to fill every available moment of time. Cost estimates made through estimates of underway time for the example FSST proved accurate except for the impacts of COVID-19 restrictions.

A significant factor impacting the accuracy of engineering code cost estimates is having qualified government personnel perform them. Noting the importance of cost estimation, McBride and Paret (2010) recommended improvements to cost estimation processes: "The most significant recommendation that is talked about by most everyone who was interviewed at Aberdeen Proving Ground is the lack of qualified government employees" (p. 72).

Another important aspect to be aware of when budgeting for large-scale projects such as FSSTs is that they almost always run over budget. Careful accounting and the creation of accurate funding requirements for dozens or hundreds of engineering codes lose their value once unforeseen factors impact the project and cause immense changes to the budget needs. Large projects tend to run into unforeseen, unpredictable problems that impact budgets. Because these factors are unpredictable, creating a budget by compiling incremental costs may lead to inaccurate results and should be avoided.

Flyvbjerg and Gardner (2023) found many large-scale projects run over budget:

> The pattern was so clear that I started calling it the "Iron Law of Megaprojects" over budget, over time, under benefits, over and over again.
>
> The Iron Law is not a "law" like in Newtonian physics, meaning something that invariably produces the same outcome. I study people. In the social sciences, "laws" are probabilistic (they are in natural science, too, but Isaac Newton didn't pay much attention to that). And the probability that any big project will blow its budget and schedule and deliver disappointing benefits is very high and very reliable.
>
> The database that started with 258 projects now contains more than 16,000 projects from 20-plus different fields in 136 countries on all

> continents except Antarctica, and it continues to grow. There are some recent and important wrinkles in the numbers, which I'll discuss later, but the general story remains the same: In total, only 8.5 percent of projects hit the mark on both cost and time. And a miniscule 0.5 percent nail cost, time, and benefits. Or to put that another way, 91.5 percent of projects go over budget, over schedule, or both. And 99.5 percent of projects go over budget, over schedule, under benefits, or some combination of these. Doing what you said you would do should be routine, or at least common. But it almost never happens. (pp. 7–8)

The example FSST examined through this capstone research was no exception. Careful planning went into the cost estimations made by each of the 67 engineering codes supporting 85 systems, and those costs were rolled into a project cost estimate and submitted to the program office. During the execution phase of the project, there were two major impacts on costs. The first was caused by restrictions placed on the FSST team in an effort to reduce the spread of the COVID-19 pandemic. The second was due to an event that cannot be discussed in detail in this unclassified format but was unpredictable and caused a significant impact on the project budget.

The COVID-19 pandemic broke out toward the end of the planning of the example FSST and prior to the execution phase of the project. COVID-19 restrictions in place during the execution of the example FSST required engineers supporting the project to follow restriction of movement (ROM) policies. These policies required engineers who traveled under certain conditions to remain in isolation for 14 days (S. Harris, email to author, July 8, 2020). This significantly impacted cost estimates (D. Moran, personal communication, 2020). FSST engineering code cost estimates were provided prior to the COVID-19 pandemic. Many of those estimates planned to support the FSST through engineers going to the work site, performing work for only a day or two, and then returning to the engineer's duty station (D. Moran, personal communication, 2020). These efforts were planned to occur once before the FSST and again after each of the three shots of the FSST, for a total of four trips and a total of four or eight days of work (D. Moran, personal communication, 2020). The COVID-19 requirements meant an additional 14 days of ROM prior to each trip, or an additional 56 days of ROM for each engineer to support four or eight days of work (D. Moran, personal communication, 2020). The COVID-19 pandemic was unforeseen and significantly impacted the cost of the example FSST.

Large project budgets must be able to accommodate the impacts of unforeseen events that significantly impact cost. It is best to seek out examples of projects with fundamental similarities to the large project for which a budget is being developed and examine that budget, the problems encountered, and the impacts the problems made to the budget. It is also vital to implement various methods to scale the budget of the example project to fit the current project. This will provide a much more realistic funding plan than simply tallying up funding requirements from all required engineering codes.

Data collected while planning and executing a large-scale Navy warfare center project shows the large-scale project did not use one consistent cost-estimating method, and therefore, the accuracy of the cost estimations varied. Overall, because the project involved such many engineering codes, with 67 unique codes supporting 85 systems evaluated throughout the project and each one choosing its own cost estimation method, the inaccuracies tended to balance each other out.

C. ANALYSIS SUMMARY

Many engineering codes' use of funds remained closely in step with their funding requirements. Other codes proved to be wildly inaccurate, with both high and low estimates. This served to balance out the equation.

While cost estimations were shown to be more inaccurate when made using a mix of bottom-up engineering and analogy compared to cost estimations made using only bottom-up engineering, the sample size was small; only three NWA charges were created based on the mixed method. When considering only cost estimations made using bottom-up engineering methods, overcharges are more frequent than undercharges by nearly 2 to 1.

If the budget-increasing factors that occurred during FSST execution had not occurred, the NWAs would have had fewer overcharges, and more undercharges. However, large projects almost always face budget-increasing events, and therefore, precise bottom-up engineering cost estimations are not recommended to create an accurate large-project budget.

Using the data sample analyzed by this capstone, it was determined that many costs calculated were accurate. Of the three variants studied, costs estimated by bottom-up engineering, a mix of bottom-up engineering and analogy, and unknown methods, all errors tended toward overcharges. Costs calculated through a mix were more accurate than those calculated through bottom-up engineering, 76% and 69% accuracy, respectively. This may be due to the tendency of analogy to predict higher costs due to considering the actual costs of previous work, which can include unforeseen cost increases. Using a mix of analogy and engineering costs could bring about improvement over calculating costs only using bottom-up engineering. When communicating with the codes about their cost calculation methods, some codes volunteered that they could not use analogy to calculate costs because FSST support was different than other work they support and they either did not have access to previous FSST support costs or their system was unique to the FSST ship and had never been supported (D. Moran, personal communication, 2024).

Ensuring that qualified government personnel perform cost estimates has proven to increase the accuracy of the results, reducing the number of outliers at either the extreme high or low end of the curve. Large projects usually drift far over budget time and time again. A focus on large cost overruns and planning mitigation would serve a project manager well. Accurate costs are important, but project managers would be best served by taking a comprehensive view and maintaining an awareness of the tendency for large projects to exceed expected costs.

The key finding of this study is that when planning large-scale projects at Navy warfare centers, allowing engineering codes to develop cost estimations using methods of their own selection will result in inconsistencies and inaccuracies. However, the inconsistencies will allow the inaccuracies to balance out, with some estimates wildly high or low but others off target only by a small amount. The balance allows for the development of reasonable budgets.

More important than keeping cost estimating methods consistent is ensuring that qualified government personnel develop the cost estimates. This will increase overall accuracy and the likelihood of an on-target budget.

Large-scale projects almost always run over budget due to factors that are impossible to predict. Therefore, the cost estimation process should be revised to include a comparison to similar large-scale projects, using scaling factors to account for variations.

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V. CONCLUSION

A. SUMMARY

This capstone aimed to answer the following questions:

- What are the main advantages and disadvantages of using a standard cost-estimating process to support Navy warfare centers' technical codes in estimating costs for special projects?
- In what conditions can a standard cost estimating process across many engineering codes improve the accuracy of the total project cost for large-scale efforts such as an FSST?
- What other factors impact the accuracy of cost estimates used to create budgets for large-scale projects such as FSSTs?

This capstone examines FSST data and shows that standardizing the use of cost estimation using a mix of analogy and bottom-up engineering cost estimates engineering codes can improve accuracy and provide some benefits. However, analogy is not always possible because large project work can be unique and include support of new systems (D. Moran, personal communication, 2024).

Research has shown that cost-increasing events similar to those that occurred during the execution of the FSST and impacted costs can be expected when executing any large projects. It is not anticipated that those specific events will occur, but other, significant, impactful events can be expected, and planning must include probable, unforeseen events. A mix of analogy and bottom-up engineering cost calculations are useful to scope individual engineering code support, but alternate methods are needed for large-scale project cost calculations.

In perfect conditions, without the impact of external events, standard cost estimating process across many engineering codes improve the precision of the total project cost for large-scale efforts such as a FSST.

Generally speaking, the author has found that pouring into minute details and implementing complicated calculations may create accurate cost predictions of specific aspects of project cost, but when dealing with large-scale projects, it is more effective to remain at a higher level. Costs can be roughly estimated initially and then monitored and modified as projects progress.

When executing a large-scale project, especially one with lengthy durations, external factors are likely to impact the execution and, in turn, the costs. These external events could be anything from COVID-19 to the unplanned early ordinance detonation, an earthquake, a terrible flood, or locusts. Cost estimation for projects such as FSSTs must be able to absorb costs for unforeseen events to execute the project successfully.

This research focused on the potential value of implementing a standard cost estimation method across all engineering codes of a Navy warfare center supporting large-scale projects. All cost estimation methods come with some level of inaccuracy. Implementation of one method will cause the duplication of the same inaccuracy. These inaccuracies, whether high or low, compile into an inaccurate budget and negatively affect a large-scale project. Permitting engineering codes to create their own cost estimations allows for possible inaccuracies. However, due to the likelihood that various methods will be selected by engineering codes, inconsistent inaccuracies can be expected. Inaccuracies of cost estimation will balance when budgeting large projects involving dozens or hundreds of engineering codes.

The capstone finds that two factors stand out, with a greater impact on large-scale project budgets than cost estimation methods currently used by engineering codes. The first factor is the use of qualified government personnel to create cost estimations. The second is knowing that with great certainty, large-scale projects will be impacted by previously unpredictable external factors, which may increase costs. Project leaders should be aware of this, and further research is recommended to uncover methods to persevere through budget-impacting external factors.

Large-scale projects tend to go over budget. Often, uncontrollable and unforeseeable outside factors cause large projects to go over budget. The effects of the outside factors tend to outweigh the impacts of engineering codes' selected cost estimation methods. Thus, it has been discovered that to improve the performance of large projects, stakeholders must acknowledge that outside factors often impact the budgets of large projects and implement mitigations to overcome the negative effects of those factors on project budgets.

Finally, it has been found that to most effectively support large-scale projects, one must focus on the big picture and shift focus away from minute details, such as the implementation of standard cost estimation methods. Due to the high likelihood and severe impact of external factors on the budgets of large projects, building up budgets from the estimates of many supporting engineering codes is not recommended. Instead, use an alternate method: research similar projects to learn what factors affected those projects and their budgets. Anchor the budget around the average budget of similar projects and scale the total up or down, considering the significant aspects that set the current project apart.

B. CONTRIBUTIONS TO THE FIELD

This study focused on the impacts of standardizing cost estimation methods for large-scale projects supported by Navy warfare centers. The capstone built upon research aimed at cost estimation and budgeting. It bridged the gap between cost estimation-focused research and studies of large-scale project execution.

This capstone applied project focused on improving the accuracy of budgets in an FSST project and offered guidance for future researchers to direct efforts to improve large project budgets toward areas with more room for improvement and greater potential benefits.

The capstone found that costs calculated through a mix were more accurate than those calculated through bottom-up engineering, 76% and 69% accuracy, respectively.

C. IMPLICATIONS FOR PRACTICE

The biggest takeaway from this capstone for those conducting large-scale projects is to deemphasize minute details and focus on the big picture. Whether engineering codes use a standardized method of their choosing is insignificant compared to unforeseen and unpredictable external factors, which have a far greater impact on a project’s budget. For large projects to succeed, stakeholders must mitigate budget impacts.

D. IMPLICATIONS FOR POLICY

Policy adjustments should be implemented to guide leaders of large-scale projects supported by Navy warfare centers to create budgets through research and comparison to similar projects. An anchor should be set, and the project budget should be scaled up or down based on estimations of the project's unique characteristics. This would be a significant change from budgets built around estimated hours and tracked closely by program offices to ensure spend plans are being followed. When dealing with large-scale projects, external factors most likely impact the project execution and cause significant variations to the planned budget. A new policy to anticipate and mitigate impacts would create more realistic budgets and seamless project executions.

E. RECOMMENDATIONS AND FUTURE RESEARCH

Future research should be focused on the big-picture aspects of large projects supported by Navy warfare centers. Development of budgets for future projects should begin with research of the costs of similar projects. Then, the budgets should be scaled up or down based on evidence of the current project's unique factors estimated to impact costs. Future research is needed to understand effective ways to find similar projects and to define what makes projects seem unique from and similar to other projects. Work is needed to recognize and interpret evidence that indicates if costs will be higher or lower than similar projects.

This study focused on increasing the accuracy of cost estimations created by engineering codes. With the belief that accurate parts create an accurate project budget, those cost estimates will be compiled into a comprehensive project cost. However, an accurate budget does not guarantee that a project will stay on budget.

Further research is recommended to explore the external factors that cause large-scale projects to go over budget. This research may help create comprehensive budgets for large-scale projects that factor in more than just support requirements. The budgets should include mitigating factors put in place in anticipation of external factors that tend to drive projects over budget.

VI. APPENDIX A. EXAMPLES OF NSWC DIVISIONS AND ENGINEERING CODES

Example of NSWC Divisions and Engineering Codes
Life Cycle Logistics & Readiness Division
Logistic Product Support Management Code
Logistics Data Management Code
Operational Procedures Code
Technical Manual Readiness Code
Provisioning & Supply Support Code
PMS & Maintenance Readiness Code
Logistics Product Readiness Code
Machinery Research & Silencing Division
Automation & Controls R&D Code
Electric Power R&D Code
Machinery Technology R&D Code
Machinery Silencing R&D Code
Energy Conversion R&D Code
Advanced Machinery Systems Integration Code
Research Programs Code
Materials, Structures, Environmental & Protection Division
Petrofluids & Material Performance Code
Corrosion Engineering Code
Ship Systems Hardening Code
Wastewater ISE Code
Solid Waste & HAZMAT ISE Code
Damage Control, Recoverability & Chem Bio Defense Code
Structural Integrity, Welding & NDE Code
Auxiliary Machinery Systems Division
Air Conditioning & Refrigeration Code
Steam Systems Code
Auxiliary Systems Code
Combat Support Systems Code
Life Support & Ventilation Systems Code
Compressed Air Systems Code
Propulsion Systems Division
Amphibious Ship Diesels Code
Combatant & Nuclear Ship Diesels Code
2S Cog/Gas Turbines Life Cycle Support Code

Example of NSWC Divisions and Engineering Codes
Surface Combatant/Gas Turbine Engineering Code
Auxiliary Ships/Acquisition Support Code
MRG & Propulsors Code
Shafting, Surface Ship Propellers & Waterjets Code
Sail, Hull & Deck Machinery Systems Division
Aircraft, Vehicle, Ship & Material Handling Code
Cargo/Weapons Handling & Stowage Systems Code
Launch, Recovery and Hydraulics Systems Code
Hull Outfitting & Shipboard Habitability Code
Sail Systems, I&EW, Radar, UMM & Modeling & Metrology HM&E Code
Antenna Engineering Code
Sail ISEA Field Services & Modernization Code
Weapons Handling & Stowage Systems Amphib/MSC/USCG Code
Power Systems Division
DDG 51 Power Systems Code
LSD, LHD 1, LPD 17 Power Systems EP SW Based Control Code
Power Conversion & Aircraft Support Power Systems Code
Surface IPS & Advanced Power Systems Code
CVN & Submarine Power Systems Code
LCS, LHA 6 & LHD 8 Power & Protection Systems Code
CG 47, Energy Storage, USCCG & Auxiliary Power Systems Code
HM&E Control Systems Division
MCS (LPD, LXR, OBT, New System Development) Code
MCS (LCS, SSC, INLS, CTF, EPF/ESB) Code
MCS (DDG 51 New Ship Construction & LBES Integration Code
MCS (DDG MOD & In-Service Engineering) Code
MCS (LHD/A, CG 47, AA, ESG) Code
MCS (DDG 1000, LSD, MCM) & Advanced Damage Control Systems Code
MCS (Fluid Systems Automation) Code
MCS (Auxiliary Machinery Automation) Code
MCS (CVN, USCG) Code
HM&E Ship Control, Navigation, and Networks Systems Division
Ship Controls & Navigation: CVN and New Development Code
Ship Controls: Amphibs Code
Ship Navigation Systems and Navy ECDIS Controls Code
HM&E/Navigation Networks: DDG 51 Class xDMS Code
HM&E/Navigation Networks: Surface Ships (non-DDG 51) Code
HM&E Cybersecurity, Monitoring & Information Systems Division
HM&E Cybersecurity Systems Code

Example of NSWC Divisions and Engineering Codes
Remote Monitoring & Condition Based Maintenance Systems Code
HM&E Data Acquisition & Information Systems Code
Shipboard Instrumentation & System Calibration (SISCAL) Code

Adapted from NAVSEA Warfare Centers (2021).

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APPENDIX B. SYSTEMS AND BASELINE EVALUATIONS

	System	Procedure Name
Damage Control	ADCS	Advanced Damage Control System (ADCS) Functional Test for FSST
	CBR-D	Conduct Confidence Test for Improved (Chemical Agent) Point Detection System Life cycle Replacement (IPDS-LR)
		CVN 78 FSST Structural Inspection Procedure (CBR-D IPE Kit Bag, CP Mask and Stowage Checklist)
		Inspect and Operate Decontamination Station Equipment and Showers
	FFD	CVN 78 FSST Fire Detection System (FDS) Test Procedure
		CVN 78 FSST Flood Detectors Test Procedure
	ETFS	EMALS Trough Fire Suppression (ETFS) System FSST Test Procedure
	HBFPS	Hangar Bay Fire Protection System (HBFPS) Test Procedure
	LLMS	Flooding Casualty Control Software (FCCS) Functionality Test
	Mag Sprinkling	Test Magazine Sprinkler System (Dry Type)
	Misc Sprinkling	Inspect Sprinkling System Piping and Components
		Flush Sprinkling System Supply Piping; Flush Sprinkling System Distribution Piping/Test Flow Switch Alarm
		Inspect Break Glass Bulb Type Sprinklers
	AFFF	AFFF Non-Standard Procedure
		Demonstrate Hangar Bay Sprinkling System
		Demonstrate HCFF Stations AFFF Unobstructed Flow for Proportioning Pump Outlets
		Demonstrate Flight Deck AFFF System At Sea
	WDCM	Demonstrate Flight Deck CMWD – (Pre-Op Check)
		Demonstrate Flight Deck CMWD System
	HFP/WSS	Inspect HeptaFluoroPropane (HFP) Fire Extinguishing System
		Weigh Installed and Spare Carbon Dioxide (CO2) Actuation Cylinder; Inspect Installed and Spare CO2 Actuation Cylinders
		Inspect Replacement and Spare HeptaFluoroPropane (HFP) Cylinders
		Inspect 1–1/2" Halon/HeptaFluoroPropane (HFP) Discharge Flexible Hose
		Test Operate Halon/HeptaFluoroPropane (HFP) Actuation System
		Weigh Installed HeptaFluoroPropane (HFP) Cylinder(s), and Replacement and Spare HFP Cylinder(s)
	JETS CO_2	CO2 Fire Extinguishing System
	DC Facilities/ BDS/Medical	CVN 78 FSST Structural Inspection Procedure

	System	Procedure Name
Hull	Aircraft Elevators & Doors	53711-523-8875889 CVN 78 ACE Equip Inspection and Op Test
		53711-523-8875890 CVN 78 AED HDD Equip Inspection and Op Test
	Structural Inspection	CVN 78 FSST Structural Inspection Procedure
	Anchor Windlass	CVN-78 FSST Electric Anchor Windlass FSST Procedure
	Weapons Handling	Bridge Crane SOT III_CVN78
		Manual Trolley Hoist SOT III_CVN78
		Pneumatic Trolley Hoist SOT III_CVN78
	Stores Elevators	Accomplish System Operability Test (SOT), Level 2 (SE1 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE2 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE3 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE4 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE5 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE6 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE7 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE8 SOT II W/ Elevator Assessor)
		Accomplish System Operability Test (SOT), Level 2 (SE9 SOT II W/ Elevator Assessor)

System	Procedure Name
	Accomplish System Operability Test (SOT), Level 2 (SE10 SOT II W/ Elevator Assessor)
AWE	CVN-78 US1 SOTIII FSST Copy (Original SOT III weighted test result and an 18 month assessment)
	CVN-78 US2 SOTIII FSST Copy (Original SOT III weighted test result and an 18 month assessment)
	CVN-78 US3 SOTIII FSST Copy (Original SOT III weighted test result and an 18 month assessment)
	CVN-78 UE SOTIII FSST Copy (Original SOT III weighted test result and an 18 month assessment)
	CVN-78 LS5 SOTIII FSST Copy (Original SOT III data)
	CVN-78 LS7 SOTIII Developed for FSST (Original SOT III data)
	CVN-78 LS1 SOTIII FSST Copy (Original SOT III data)
	CVN-78 LS3 SOTIII FSST Copy (Original SOT III data)
	CVN-78 LS2 SOTIII FSST Copy (Original SOT III data)
Boat Handling	Open and Inspect Electrical Panel, and Clean Air Filters
	Clean, Inspect, and Lubricate Winch Safety Switches
	Clean, Inspect, and Lubricate Main (Cradle) Winch Shock Absorber Sheaves
	Clean, Inspect, and Lubricate Traversing Winch Turning Handle Safety Switch
	Clean, Inspect, and Lubricate Traversing Winch Sheaves
	Test Operate 7M RHIB Boat Davit
	Check Transverse Brake Electric-Magnetic Brake Air Gap
	Check Main Gearbox Oil Level
	Check Planetary Reduction Gearbox Oil Level
	Check Traversing Winch Gearbox Oil Level
	Test Operate 7M RHIB Boat Davit Emergency Operation

System	Procedure Name
	Test Safety Switches
	Clean, Inspect, and Lubricate Main Winch Wire Ropes
	Open, Clean, and Inspect Control Station
	Clean, Inspect, and Lubricate Shock Absorber Sheaves
	Inspect Centrifugal Brake
	SOW_RHIB_Removal
Replenishment At Sea / Underway Replenishment	Inspect Electric Brake, Stearns 87,600 Series (Gypsy Winch)
	Inspect Oil Level in Messenger/Utility Winch Gearcase, Model SG 20/10 & Test Operate Winch (Gypsy Winch)
	Clean and Inspect Motor Controllers. Measure Insulation Resistance of Motor and Controller (Gypsy Winch)
	Inspect Gearcase Oil Level (Saddle Winch)
	Test Operation of Indicator Lights (Saddle Winch)
	Test Operation of Indicator Lights. Test Operate Manual Brake Release. Inspect Magnetic Brake. Clean and Inspect Controllers (Saddle Winch)
	Clean and Inspect Motor Controllers. Measure Insulation Resistance of Motor and Controller (Saddle Winch)
	Inspect Winch Drum Handwheel Brake (Span-wire Winch)
	Inspect Flexible Coupling Exterior. Inspect Winch Drum Handwheel Brake. Inspect Spanwire/Light Spanwire Winch Hydraulic Brake. Test Operate Winch. Test Torque (Drum Overload) Clutches (Span-wire Winch)
	Clean and Inspect Motor Controllers. Measure Insulation Resistance of Motor and Controller (Span-wire Winch)
	Inspect Anti-Slack Device (ASD) Pressure Rollers
	Inspect Squeeze Mechanism and Clutch Pressures (ASD)
	Clean and Inspect Motor Controllers. Measure Insulation Resistance of Motor and Controller (ASD)
	Clean, Inspect, and Lubricate Portable and Fixed Attached Point Assemblies (FAS #13)
	Clean, Inspect, Lubricate, and Preserve Replenishment and Transfer-at-Sea Hardware. Lubricate Replenishment Rig Blocks, Sheaves, and Trolleys (Including Spares) (FAS #13)

	System	Procedure Name
		Inspect Fuel Delivery and Receiving Hose and Couplings, if applicable (FAS # 13)
		Inspect RAS/FAS Station Fixtures (FAS # 13)
		Inspect and Lubricate Reversible Bolt and Socket (FAS # 13)
		Clean, Inspect, and Lubricate Receiver Housing, Bellmouth, and Probe Seal. Clean, Inspect, and Lubricate Release Mechanism Seals (FAS Fuel Receiving Stations Double Probe Receivers)
		Inspect Fuel Delivery and Receiving Hose and Couplings, if applicable (FAS Fuel Receiving Stations Double Probe Receivers)
		Inspect RAS/FAS Station Fixtures (FAS Fuel Receiving Stations Double Probe Receivers)
		Inspect and Lubricate Reversible Bolt and Socket (FAS Fuel Receiving Stations Double Probe Receivers)
		Test Operate Sliding Padeye, Navy Standard, Model Heavy E-Stream (E-Stream Sliding Padey E-SPE)
		Clean and Inspect Sliding Padeye Variable Speed Drive System Enclosure (E-Stream Sliding Padeye E-SPE)
	Solid Waste Systems	Conduct General and Operational Assessment of the Large Pulper; Conduct Static Leak Test. (CVN 78 Large Small Pulper Test Procedure)
		Conduct General and Operational Assessment of Small Pulper, and Static Leak Test. (CVN 78 Large Small Pulper Test Procedure)
		Conduct General and Operational Assessment of Small Pulper, and Static Leak Test. (CVN 78 Large Small Pulper Test Procedure)
		Conduct General and Operational Assessment of Small Pulper, and Static Leak Test. (CVN 78 Large Small Pulper Test Procedure)
		Conduct General and Operational Assessment of Small Pulper, and Static Leak Test. (CVN 78 Large Small Pulper Test Procedure)
		Conduct General and Operational Assessment of Shredder. (CVN 78 Metal Glass Shredder Test Procedure)
		Perform General and Operational Assessment of the MOD I Plastics Waste Processor. (CVN 78 Mod I Compress Melt Unit Test Procedure)
		Perform General and Operational Assessment of the MOD I Plastics Waste Processor. (CVN 78 Mod I Compress Melt Unit Test Procedure)
		Conduct General and Operational Assessment of Shredder. (CVN 78 Plastics Shredder Test Procedure)

	System	Procedure Name
Mechanical	Chilled Water	CHW FSST Procedures
		ECWS FSST Procedures
	Compressed Air	CVN 78 Compressed Air Shock Test Assessment Plan
	Gas Detection	Sierra Monitor 1400 Sulfur Dioxide (SO2) Gas Detector System Calibration Verification based on Technical Manual S9436-A8-MMC-010, Section 8–10.
		Sierra Monitor 1400 Hydrogen Sulfide (H2S) Gas Detector System Calibration Verification based on Technical Manual S9550-B7-MMA-010, Section 8–10.
	O2N2	CVN -78 VSA Shock Test Assessment Plan
	Main Reduction Gear	Main Reduction Gear CVN 78 FSST Recommendations
	OWS & Environmental Pollution Control	CVN 78 OPA FSST Test Plan
	Propulsion Shaftline	Bulkhead Seal Inspection and Temperature Readings
		Stern Tube Seal Inflatable Leakage Test
		Stern Tube Seal Static and Dynamic Leakage
		Line Shaft Bearing and Auxiliary Thrust Bearing Oil Leakage
		Line Shaft Bearing and Auxiliary Thrust Bearing Temperature
		Waterborne Bearings Shaft to Stave Retainer Measurements
		Shaft Alignment Procedure
	Refrigeration Systems	NSWCPD PROCEDURE 64498-9514-2020-001 FSST AC Plant
		NSWCPD PROCEDURE 64498-9516-2020-002 FSST Procedure for RLM Rev0
		NSWCPD PROCEDURE 64498-9516-2020-004 FSST Procedure MRS
	Potable Water	CVN 78 001 Water Heaters
		CVN 78 002 Reverse Osmosis
		CVN 78 003 Makeup Water Unit
		CVN 78 004 Potable Water Chlorine Analyzer
		CVN 78 005 PWEDG
		CVN 78 006 PW Pumps and Valves

System	Procedure Name
Seawater Systems	List Control System Test Procedure
	Test Fire Pump Control System Interlocks
	Test System High Performance Butterfly Isolation Valves for Leak-By
	Test Firemain Hull Valves
Auxiliary Steam	Steam Kettle Test Procedure
Steering Gear (Machinery)	Full Ship Shock Trial Baseline Assessment Procedure Steering Gear
Ventilation (Mechanical)	CVN78 FSST TP – Consolidated Ventilation Procedure
Ventilation (Controls)	CVN-78_FSST Baseline & Final Shot Testing
Seawater Systems	USS Gerald R. Ford (CVN-78) Main Drainage System (MDS) Full Ship Shock Trials (FSST) Procedure
	MRC J1KV Test Main Drain Eductors
Steering Gear (Controls)	Ship Steering Control Stations Operational Test
JP-5	Component Procedure: Filling Service Tanks
	Component Procedure: Reclamation System
	Component Procedure: Stripping JP-5 Stowage & Contaminated Tanks
	Component Procedure: Stripping JP-5 Service Tanks
	Component Procedure: Service System Pressurizing For Distribution
	Component Procedure: Aircraft Fueling Station
Lube Oil	Lube Oil System Operational Test
VCHT & GW	Inspect Ejector Pump Mechanical Seal Oil Level.
	Test Ejector Pump Operation
	Inspect VCHT Blower Gear Housing Oil.
	Inspect VCHT Blower Pulleys and Belts.
	Test Operation of VCHT Tank Level Switches, Alarms and Transfer Pump Automatic Operation.

	System	Procedure Name
		Test Operation of Graywater Tank Level Switches, Alarms and Graywater Pump Automatic Operation.
		Inspect Sewage and Graywater Transfer Seal Air Pressure and Flow and Adjust if Required; Inspect Low Pressure Air Filter Separator and Drain if Required
		Scan Vacuum Components for Suspected Vacuum Leaks.
	CS	MCMS End to End Test
	PMEMA	PMEMA Valve Test Procedure
Electrical	60Hz Power	Clean and Inspect Load Center (Perform Visual Inspection ONLY, MRC To Only Be Used As Guidance)
		Test Operation of MBT
		Perform Control Unit Status Check on Arc Fault Detector/Continuous Thermal Monitoring (AFD/CTM) System
	Lighting	Test Signal and Navigation Lights
		Test Running Light Telltale Panel
		Demonstrate Hangar Bay Lighting Control Sys. and Interconnected Lighting Systems
		Physical Inspection – Signal Searchlights
		Physical Inspection – Emergency Lighting System
	400Hz Power	400Hz System (SSVFC, AESS, & MBT) Operational Test
	ICCP & ASG	Perform Checks on Computer Controlled Cathodic Protection, Impressed Current (ICCP) System and Related Systems
		Download Performance Data from the DLC Memory
	UPS	MCMS Uninterruptable Power Supply (UPS) Operational Test
	ADS	Demonstrate Degaussing System

Adapted from Sager (2021).

APPENDIX C. POST FSST SPENDING REPORT

Ship System Task	NWA Plan Remaining
1	-$4,973
2	$3,009
3	$2
4	-$977
5	$0
6	$5,582
7	$0
8	$0
9	$120,889
10	$0
11	-$14,411
12	-$10,094
13	-$8,046
14	-$14,427
15	$0
16	$0
17	$0
18	-$8,769
19	$0
20	$6
21	$0
22	$0
23	$0
24	$0
25	-$4,912
26	$0
27	-$3
28	$0
29	$0
30	-$59,722
31	$1,831
32	-$5,727
33	-$4
34	$2
35	$0
36	$0
37	$0

Ship System Task	NWA Plan Remaining
38	$0
39	$0
40	$3
41	-$13,654
42	$0
43	-$18,164
44	-$3,641
45	$0
46	$0
47	$9
48	$0
49	$0
50	$0
51	-$729
52	$0
53	-$7,246
54	-$757
55	-$10,482
56	-$28
57	$0
58	$0
59	$0
60	-$8,771
61	$0
62	$2
63	$0
64	$1
65	$0
66	-$2,462
67	-$143
68	$2
69	$0
70	-$4
71	$0
72	$0
73	$0
74	$0
75	$0
76	$0
77	-$5,164

Ship System Task	NWA Plan Remaining
78	$0
79	$0
80	$0
81	$0
82	$0
83	$5
84	$0
85	$3
86	$0
87	$5
88	$0
89	$0
90	-$2,863
91	$0
92	$0
93	$0
94	$0
95	$0
96	$0
97	$606
98	$0
99	-$4
100	$0

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APPENDIX D. POST-FSST SPENDING REPORT AND ASSOCIATED KNOWN COST ESTIMATION METHODS

Assigned Number	NWA Plan Remaining	Cost Estimation Method
1	-$4,973	Eng.
2	$3,009	Eng.
3	$2	Eng.
4	-$977	Eng.
5	$0	Eng.
6	$5,582	Eng.
7	$0	Eng.
8	$0	Eng.
9	$120,889	Eng.
10	$0	Eng.
11	-$14,411	Eng.
12	-$10,094	Eng.
13	-$8,046	Eng.
14	-$14,427	Unknown
15	$0	Unknown
16	$0	Unknown
17	$0	Unknown
18	-$8,769	Mix
19	$0	Mix
20	$6	Unknown
21	$0	Unknown
22	$0	Unknown
23	$0	Unknown
24	$0	Unknown
25	-$4,912	Unknown
26	$0	Unknown
27	-$3	Mix
28	$0	Unknown
29	$0	Unknown
30	-$59,722	Eng.
31	$1,831	Eng.
32	-$5,727	Eng.
33	-$4	Eng.
34	$2	Eng.
35	$0	Eng.

Assigned Number	NWA Plan Remaining	Cost Estimation Method
36	$0	Eng.
37	$0	Eng.
38	$0	Unknown
39	$0	Unknown
40	$3	Eng.
41	-$13,654	Unknown
42	$0	Unknown
43	-$18,164	Unknown
44	-$3,641	Unknown
45	$0	Eng.
46	$0	Eng.
47	$9	Unknown
48	$0	Unknown
49	$0	Eng.
50	$0	Eng.
51	-$729	Unknown
52	$0	Unknown
53	-$7,246	Eng.
54	-$757	Eng.
55	-$10,482	Unknown
56	-$28	Unknown
57	$0	Mix
58	$0	Eng.
59	$0	Eng.
60	-$8,771	Eng.
61	$0	Eng.
62	$2	Unknown
63	$0	Unknown
64	$1	Unknown
65	$0	Unknown
66	-$2,462	Unknown
67	-$143	Unknown
68	$2	Unknown
69	$0	Unknown
70	-$4	Eng.
71	$0	Eng.
72	$0	Eng.
73	$0	Eng.
74	$0	Eng.
75	$0	Unknown

Assigned Number	NWA Plan Remaining	Cost Estimation Method
76	$0	Unknown
77	-$5,164	Unknown
78	$0	Unknown
79	$0	Unknown
80	$0	Unknown
81	$0	Unknown
82	$0	Unknown
83	$5	Unknown
84	$0	Unknown
85	$3	Unknown
86	$0	Unknown
87	$5	Eng.
88	$0	Unknown
89	$0	Eng.
90	-$2,863	Unknown
91	$0	Eng.
92	$0	Eng.
93	$0	Eng.
94	$0	Unknown
95	$0	Eng.
96	$0	Unknown
97	$606	Unknown
98	$0	Eng.
99	-$4	Unknown
100	$0	Eng.

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Acquisition Research Program
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net