DOD COST ESTIMATING GUIDE

Version 2.0

OFFICE OF THE SECRETARY OF DEFENSE
Cost Assessment and Program Evaluation

January 2022

This page intentionally left blank.

FOREWORD

In an environment of growing threats, competing priorities, and fiscal pressures, the DoD must spend the DoD budget on the right things, in the right amounts, at the right time. DoD cost analysts play a critical role in this by producing cost estimates that support the planning, programming, budgeting, acquisition, and requirements generation processes. The cost estimating community of ~1500 government analysts supports an annual budget of more than $700 billion, with 160 major weapons systems and information systems, multiple smaller acquisition programs, and ongoing generation of requirements for future capabilities. Cost estimating is a unique skill set that combines the best of science and art into a single role. The work relies on sound mathematical and analytical skills, while also requiring critical thinking, communication, and nuance. Cost estimators have a depth and breadth of knowledge that is unrivaled in many other career fields.

Every cost estimate is unique, but the overarching process for producing a credible, high-quality estimate is not. With the help of cost estimating stakeholders from across the national security community, this guide takes the reader through the steps of the cost estimating process and introduces topics and concepts that are important for every DoD cost estimator to understand. Special thanks to all of the organizations that helped CAPE to prepare this guide: DASA-CE, DON estimating community, AFCAA, MDA, NRO, NPS, AFIT, DAU, GAO, and NASA. The input provided by these stakeholders is invaluable to the finished product.

Version 1 of the DoD Cost Estimating Guide provided an overview of important cost estimating topics, and then pointed the reader to other resources for detailed theory and explanation, mathematical mechanics, and training opportunities. All of this content remains in version 2, but it also incorporates several expansions including:

- updating statute and policy references,
- updating DAU references to reflect revised course numbers,
- expanding the discussion of Middle Tier of Acquisition programs,
- providing WBS and CES examples for different commodities,
- adding a recommended reading list on topics across cost estimating and acquisition, and
- adding a case study that exemplifies the cost estimating process.

Version 2 of this DoD Cost Estimating Guide reflects the current policies and practices as of January 1, 2022. CAPE will endeavor to update the guide as necessary to remain current as these policies and practices inevitably will evolve in the future.

“No one can predict the future” is an often-used cliché, and yet this is what the DoD asks its cost estimating community to do every day, albeit in a highly structured and disciplined way. Whether a new cost estimator or seasoned analyst, this guide will assist with projects and analyses so that the cost estimating community will continue to provide leaders and decision makers with relevant assessments and sound recommendations.

This page intentionally left blank.

TABLE OF CONTENTS

FIGURES

TABLES

1.0 PURPOSE, POLICY, PROPERTIES, AND DEFINITIONS

1.1 Purpose of the Department of Defense (DoD) Cost Estimating Guide

This guide provides consolidated information on the DoD cost estimating process and points the reader to additional references and training for specific estimating topics. It does not replace DoD Component guides and training materials. It does make direct references to existing cost estimating or guidance documents that describe processes, methods, and procedures specific to that environment. This guide:

- applies to all types of cost analyses performed within the DoD,
- bridges the gap between the DoD Directives/Instructions/Manuals (DoDDs/DoDIs/DoDMs) and the Component/ Agency-level guidance/resources,
- focuses on major defense acquisition programs (MDAPs) and Major Capability Acquisitions (MCAs), but also applies to acquisition category (ACAT) II and smaller programs, business system programs, services acquisition programs, Middle Tier of Acquisition (MTA) programs, and other estimates including those for Nunn-McCurdy requirements, and
- provides a starting point for new analysts across DoD and a resource for seasoned analysts.

1.2 Cost Estimating and Analysis Policy

The United States Congress conferred primary DoD acquisition program cost estimation and cost analysis responsibility to the Office of the Secretary of Defense (OSD) Cost Assessment and Program Evaluation (CAPE). This responsibility includes the authority to establish DoD policy through DoDIs. Therefore, the Director of CAPE (DCAPE) has prescribed policies and procedures for the conduct of cost estimation and cost analysis, to include Independent Cost Estimates (ICEs), Analysis of Alternatives (AoAs), multiyear procurements[1] (MYPs), data collection, and other cost-related topics. The following sections discuss the laws and policies that govern cost estimating requirements.

1.2.1 Cost Estimating and Analysis Statutes

The United States Congress passes statutes for cost estimating and analysis and incorporates them into various titles and sections of the United States Code (USC). There are also four fiscal laws that govern how the government spends money and indirectly impact cost estimating. The primary statutes and the associated directives that establish policy relevant to cost estimating are discussed below.

Four primary fiscal laws relevant to cost estimating are:

- **10 USC § 114, "Annual authorization of appropriations"**: Identifies appropriations for military spending. Analysts must understand the military appropriations in order to partition a cost estimate into the proper budget categories.
- **Antideficiency Act**: Creates various laws for expenditures, obligations, and voluntary service, which are necessary for analysts to understand. These laws include:
    - 31 USC § 1341(a)(1)(A) – prohibits authorizing expenditures in excess of the amount appropriated,
    - 31 USC § 1341(a)(1)(B) – prohibits spending of funds prior to funds being appropriated,
    - 31 USC § 1342 – prohibits voluntary service to the government, and
    - 31 USC § 1517(a) – prohibits expenditures in excess of apportionment amounts.
- **31 USC § 1301, "Application"**: Requires that appropriated funds be applied only to the objects for which the appropriations were made. This Appropriations statute, commonly known as the "*Misappropriation Act*", contains language about limitations placed on the

[1] See 10 USC § 3507 "Department of defense contracts: defense acquisitions specifically authorized by law".

use of appropriated funds, which might become an issue during the cost estimating process.

- **31 USC § 1502, "Balances available"**: Requires appropriated funds be used only for goods and services for which a need arises during the period of that appropriation's availability for obligation. Known as the "*Bona Fide Need*" rule, this law contributes to an analyst's understanding of obligation requirements.

Other laws directly applicable to cost estimating and analysis include:

- **10 USC § 139a, "Director of Cost Assessment and Program Evaluation":** Establishes the roles and responsibilities of the DCAPE. Establishes the role of the Deputy Director for Cost Assessment within CAPE.
- **10 USC §§ 3221-3226, multiple titles**: Includes the Weapon Systems Acquisition Reform Act of 2009 (Public Law 111-23) which established the DCAPE statutory authority for independent cost estimation and cost analysis including providing realistic acquisition cost estimates, conducting/approving MDAP cost estimates, assessing and updating cost indices for realistic cost estimation, reviewing Component cost estimates (CCE), analyses and records, and discussing cost estimate risks. Additionally, 10 USC § 3221 provides the authority for DCAPE to issue cost estimating policy, procedures, and guidance. *Prior to January 2022, this was part of 10 USC § 2334, "Independent cost estimation and cost analysis".*
- **10 USC § 3227, "Guidelines and collection method for acquisition of cost data"**: Establishes the policies, procedures, guidance, and a collection method for collection of cost data for acquisition programs over $100 million. *Prior to January 2022, this was part of 10 USC § 2334, "Independent cost estimation and cost analysis".*
- **10 USC § 3507, "Department of defense contracts: defense acquisitions specifically authorized by law":** Establishes the criteria for entering into multiyear contracts. Includes requirements for a preliminary (prior to authorization) and final (prior to contract award) CAPE savings forecast. DoD submits the final savings forecast to Congress, and the contract may not be awarded until 30 days after that submission. *Prior to January 2022, this was part of 10 USC § 2306b, "Multiyear contracts: acquisition of property".*
- **10 USC § 4201, "Major defense acquisition program: definition, exceptions":** Defines an MDAP and designates the Milestone Decision Authority (MDA) for such programs as the relevant Service Acquisition Executive, unless otherwise designated by the Secretary of Defense. This definition and designation has a significant impact on the level of cost estimating detail and documentation required at milestone decision reviews. This law excludes rapid prototyping/rapid fielding programs defined as MTA programs in the 2016 National Defense Authorization Act (NDAA) and some defense business systems (DBS) from the definition of MDAP. *Prior to January 2022, this was part of 10 USC § 2430, "Major defense acquisition program defined".*
- **10 USC § 4251, "Major defense acquisition programs: determination required before Milestone A approval"**: Defines the responsibilities, determination, and submissions required for an MDAP to receive Milestone A approval. As part of the determination prior to granting Milestone A approval, the DCAPE must concur, for the submitted program cost estimate, that the level of resources required to develop, procure, and sustain the program is sufficient for successful program execution. Additionally, within 15 calendar days of granting Milestone A approval, the program MDA is required to submit the program cost and schedule estimates, as well as the ICE, to the congressional defense committees. This

statute also defines a requirement for an AoA. *Prior to January 2022, this was part of 10 USC § 2366a, same title.*

- **10 USC § 4252, "Major defense acquisition programs: certification required before Milestone B approval"**: Defines the certifications, determinations, submissions, and applicable waivers for an MDAP to receive Milestone B approval. As part of the determination prior to granting Milestone B approval, the DCAPE must concur, for the submitted program cost estimate, that reasonable cost and schedule estimates have been developed to execute the program product development and production plan. Additionally, within 15 calendar days of granting Milestone B approval, the program MDA is required to submit the program cost and schedule estimates, as well as the ICE, to the congressional defense committees. This statute also requires the completion of an AoA. *Prior to January 2022, this was part of 10 USC § 2366b, same title.*
- **10 USC § 4253, "Major defense acquisition programs: submissions to Congress on Milestone C"**: Defines the Congressional submissions required after Milestone C approval. Within calendar 15 days of granting Milestone C approval, the program MDA is required to submit a brief summary of the dollar values estimated for the program acquisition unit cost (PAUC), average procurement unit cost (APUC), the total life-cycle cost, the planned dates for initial operational test and evaluation (IOT&E) and initial operational capability (IOC), and the ICE to the congressional defense committees. *Prior to January 2022, this was part of 10 USC § 2366c, same title.*
- **10 USC § 4325, "Major weapon systems: assessment, management, and control of operating and support costs"**: Establishes, the DCAPE authority to collect O&S cost data and gives CAPE the responsibility to establish a database to collect O&S estimates, documentation, and costs. *Prior to January 2022, this was part of 10 USC § 2337a, "Assessment, management, and control of operating and support costs for major weapon systems".*
- **10 USC § 4323, "Sustainment reviews":** Establishes a statutory requirement for ongoing reviews during system sustainment, which includes an ICE and other cost related analyses of major weapon systems. *Prior to January 2022, this was part of 10 USC § 2441, same title.*
- **10 USC §§ 4371-4375, multiple titles**: Establishes the terms procurement program, significant cost growth threshold, and critical cost growth threshold and their relationship to the PAUC and APUC for an MDAP or any designated major subprogram. These relationships form the basis for a Nunn-McCurdy breach that analysts should understand. *Prior to January 2022, this was part of 10 USC § 2433, "Unit Cost Reports".*

1.2.2 DoDDs Relevant to Cost Estimating and Analysis

A DoDD is a broad policy document containing what is required by statute, the President, or the Secretary of Defense to initiate, govern, or regulate actions or conduct by the DoD Components within their specific areas of responsibilities. DoDDs establish or describe policy, programs, and organizations; define missions; provide authority; and assign responsibilities. DoDDs directly applicable to cost estimating and analysis include:

- **DoDD 5000.01, "The Defense Acquisition System" (2020):** Establishes policy and assigns responsibility for managing all acquisition programs. Cost estimating and cost analysis play extremely important roles in acquiring new capabilities for the warfighter.
- **DoDD 5105.84, "Director of Cost Assessment and Program Evaluation (DCAPE)" (2020)**: Assigns the responsibilities, functions, relationships, and authorities of the DCAPE. DCAPE responsibilities include acquisition support, resource planning, analysis and advice, annual reports to Congress, and other duties as assigned by the Secretary or Deputy Secretary of

Defense. Acquisition support contains DCAPE responsibilities for cost analysis, AoAs, and analytic competency.

- **DoDD 5135.02, "Under Secretary of Defense for Acquisition and Sustainment (USD(A&S))" (2020)**: Assigns the responsibilities, functions, relationships, and authorities of the USD(A&S) position.
- **DoDD 5137.02, "Under Secretary of Defense for Research and Engineering (USD(R&E))" (2020):** Assigns the responsibilities, functions, relationships, and authorities of the USD(R&E) position.
- **DoDD 5144.02, "DoD Chief Information Officer (CIO)" (2017)**: Assigns the responsibilities, functions, relationships, and authorities of the DoD CIO. This directive establishes top-level guidance that contributes to information system cost estimating requirements.

The brief summary of these statutes and directives highlight the many requirements placed upon DCAPE in directing and establishing the DoD cost estimating policies and procedures that are further conveyed via DoDIs.

1.2.3 DoDIs Relevant to Cost Estimating and Analysis

DoDIs implement the policy or prescribe the manner for carrying out the policy, operating a program or activity, and assigning responsibilities. DoDIs directly applicable to cost estimating and analysis include:

- **DoDI 5000.02, "Operation of the Adaptive Acquisition Framework" (2020):** Prescribes procedures for managing acquisition programs and assigns program management responsibilities. Describes the purpose and characteristics of six acquisition pathways. Each of the pathways has associated cost estimating requirements. These requirements are further described in the DoDI 5000.73. More information on the acquisition pathways can be found at: https://aaf.dau.edu/aaf/aaf-pathways/.
- **DoDI 5000.73, "Cost Analysis Guidance and Procedures" (2020):** Establishes policy, assigns responsibilities, and provides procedures for the conduct of cost estimation and analysis in the DoD. This is the implementing instruction for DoDD 5105.84. It is the primary instruction on cost estimating and cost analysis across the DoD and its Components. This instruction instantiates cost estimating requirements for many types of cost analysis.
- **DoDI 5000.74, "Defense Acquisition of Services" (2020)**: Establishes policy, assigns responsibilities, and provides direction for the acquisition of contracted services. This is the implementing instruction for DoDD 5134.01. It assigns responsibility to DCAPE for policies and procedures associated with cost estimating and cost analysis for the acquisition of contracted services.
- **DoDI 5000.75, "Business Systems Requirements and Acquisition" (2020)**: Establishes policy for the use of the business capability acquisition cycle (BCAC) for business systems requirements and acquisition. This is the implementing instruction under DoDD 5134.01, DoDD 5000.01, and DoDD 5144.02. It assigns responsibility to DCAPE for policies and procedures associated with data collection, cost estimating, and cost analysis for the acquisition of business systems. The DoDI 5000.75 applies to all business system acquisition programs that are not designated as an MDAP.
- **DoDI 5000.80, "Operation of the Middle Tier of Acquisition (MTA)" (2019)**: Establishes policy, assigns responsibilities, and prescribes procedures for rapid prototyping and rapid fielding as defined in Section 804 of Public Law 114-92. This is the implementing instruction under DoDD 5134.01. It assigns responsibility to DCAPE for advising the USD(A&S) on schedule, resource allocation, affordability, systems analysis, cost estimation, and the performance implications of proposed MTA programs. Additionally, DCAPE is to establish

policies and prescribe procedures for the collection of cost data and cost estimates for MTA programs.

- **DoDI 5000.81, "Urgent Capability Acquisition" (2019)**: Establishes policy, assigns responsibilities, and provides procedures for acquisition programs that fulfill urgent operational needs and quick reaction capabilities. This instruction does not include any specific responsibilities for DCAPE. However, an acquisition program must meet specific cost and schedule criteria in order to utilize the Urgent Capability Acquisition pathway.
- **DoDI 5000.85, "Major Capability Acquisition" (2020):** Establishes policy and prescribes procedures that guide the acquisition of major capability programs and other capabilities developed via the major capability acquisition pathway.
- **DoDI 5000.87, "Operation of the Software Acquisition Pathway" (2020):** Establishes policy, responsibilities, and procedures for the establishment of the software acquisition pathway.
- **DoDI 7041.03, "Economic Analysis for Decision Making" (2017)**: Establishes policy, assigns responsibilities, and provides procedures for conducting cost-effective economic analyses (EA). These analyses evaluate the costs and benefits of any government decision to initiate, renew, or expand program or project alternatives under the Office of Management and Budget (OMB) Circular No A-94, "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs." DoDI 7041.03 is an implementing instruction under DoDD 5105.84. It is applicable to decisions regarding the use of real property, acquisition of information systems, and the acquisition of weapon systems and weapons systems support. With respect to the acquisition of weapons system and weapons systems support, analytic studies and Business Case Analysis (BCA) may also be considered EAs if they deal with cost and effectiveness considerations.

Analysts can find the latest versions of DoDDs/DoDIs under DoD Issuance/Directives and DoD Issuance/ Instructions at: https://www.esd.whs.mil/DD/DoD-Issuances/. These DoDIs are not the end of the policy and guidance chain. DoDMs, specifically the DoDM 5000.04 Cost and Software Data Reporting (CSDR) Manual, and the many guides and manuals referenced throughout this document directly relate to the statutes, directives, and instructions already mentioned. All of these documents work together to address when and how the DoD accomplishes cost estimating.

1.3 Types and Timing of Cost Estimates

The purpose and scope of a cost estimate are a function of program category, events, and type. These program categories, events, and types help define the amount of detail, the timeline, the approval process, and other requirements for the specified cost estimate.

1.3.1 Program Category/Events Requiring a Cost Estimate

While 10 USC § 2430(d)(1) gives MDA authority to the Component Acquisition Executives (CAEs) for most MDAPs, DoDI 5000.85 identifies the USD(A&S) as the Defense Acquisition Executive (DAE) and MDA for the remaining MDAPs. MDAPs at the DAE level are usually very high dollar value or of special interest to the Secretary of Defense. DoDI 5000.85, Appendix 3A, Table 1 identifies the CAE as the MDA for ACAT II and III programs and provides definitions for each ACAT level. In some cases, the CAEs delegate approval authority for lower level ACAT programs to Program Executive Officers (PEOs). Therefore, the analyst should consult Component level guidance for any recent changes to the MDA since the MDA is responsible for approving the cost estimates required for the following:

- **MCA ACAT I – IV programs**: ACAT I – III programs are described in Appendix 3A of DoDI 5000.85, and ACAT IV programs are Component specific (usually limited to the Department of the Navy (DON)). The MDA for ACAT I programs will review an ICE and/or Component Cost Position (CCP) and approve the most appropriate estimate for the program at milestone reviews. The MDA for ACAT II – IV will review a CCE and/or program office estimate (POE) for the specified program at milestone reviews. An ACAT program will have multiple reviews over its life cycle.

- **Business System Categories (BCAT) I – III**: Table 1 of DoDI 5000.75 describes these non-ACAT DBS categories where the associated cost estimates are reviewed/approved by the MDA at authority to proceed (ATP) decision points, which are milestone-like events. A BCAT will have multiple ATP decision points over its life cycle.
- **Service Acquisition Categories (S-CATs) I – IV**: These service acquisitions are described in Table 1 of DoDI 5000.74 where the particular S-CAT level is determined by an independent government cost estimate (IGCE). Following the initial review, there are no milestones or decision points within a service acquisition, but there may be other reviews if contract performance becomes a concern.
- **MTA Program**: The expected costs for these non-ACAT programs, which may surpass MDAP thresholds, determines the type of cost estimate(s) required. The expected five-year or less timeline to finish requires at least one MDA cost estimate review process and possibly more depending on program cost and schedule performance.
- **Software ACAT I-III programs:** Programs using the Software Acquisition Pathway described in DoDI 5000.87 require an initial cost estimate in accordance with DoDI 5000.73 before the program can enter the execution phase and must be updated annually. Cost estimates for programs using the embedded software pathway should coincide with estimates for the overall system.
- **Nunn-McCurdy Breach**: Congress made the Nunn-McCurdy Act permanent in 1983 via 10 USC §2433 (to be renumbered as 10 USC §§ 4371-4375 as of January 1, 2022) by defining significant and critical breaches[2] for MDAPs to curtail growth in weapon systems programs. In addition to several certifications from across the acquisition entities, a Nunn-McCurdy critical breach requires the CAPE to develop an ICE for the revised program on a shorter timeline than for other types of ICEs and present it to the MDA.
- **Sustainment Review**: These reviews are required for covered programs, as defined by 10 USC § 4323, starting five years after the declaration of IOC and continuing every five years until five years prior to disposal. The review requires an ICE of costs for the remainder of the program life and a comparison to prior estimates, in addition to other non-cost factors that assess the health of the program during sustainment. Programs that experience "critical O&S cost growth" must submit remediation plans or a certification from the appropriate Service Secretary that the cost growth is necessary to meet national security requirements. The Fiscal Year (FY) 2021 NDAA § 802 defines critical O&S cost growth as a 25 percent increase in O&S costs from the prior ICE or a 50 percent increase in O&S costs from the original baseline estimate (e.g., the Milestone B Acquisition Program Baseline (APB) for MCA programs). Although the Sustainment Review ICE is focused on future program life cycle costs, the full span of O&S costs must be estimated (or reflect actual costs) in order to facilitate the necessary comparisons to calculate O&S cost growth.

[2] When MDAPs experience cost growth of 15% percent from their current baseline or 30% percent from their original baseline, they are in a "significant" Nunn-McCurdy Unit Cost Breach. Similarly, a 25% current or 50% original baseline growth results in a "critical" Nunn-McCurdy Unit Cost Breach. These breaches are based on growth to the PAUC or the APUC.

1.3.2 Studies

There are acquisition studies containing cost estimates that require approval from a decision authority (possibly the MDA). The program office reviews and approves the cost estimates in these study documents. Depending on the ACAT, BCAT, or S-CAT level, approval by the Component/DoD may also be required. These include:

- **AoA**: A technical and cost assessment to objectively evaluate different potential courses of action. In DoDD 5105.84, DCAPE requires that an AoA consider trade-offs among life-cycle costs. While this is an ACAT I requirement, the Components have implemented similar requirements on lower ACAT programs.
- **EA**: A systematic approach to identifying, analyzing, and comparing costs and benefits of alternative courses of action. In DoDI 7041.03, DCAPE establishes the requirement for cost and benefit analysis to support acquisition decisions. These decisions involve selecting the best alternative from multiple criteria, including life-cycle costs in net present value[3] (NPV) terms. Analytic studies and BCAs including cost and effectiveness considerations for the acquisition of weapons systems and weapons systems support are types of EA.
- **BCA**: A study used to determine whether a new approach should be undertaken. The DoD has issued BCA guidebooks (e.g., Product Support (PS) BCA) and templates (e.g., Information Technology (IT) BCA)). Components have also issued guidance for BCAs. In all cases, the requirement to include cost estimates in the BCA exists. The BCA addresses the question: Should I invest or not? A PS BCA guidebook can be found at: https://www.dau.edu/tools/t/Product-Support-Business-Case-Analysis-(BCA)-Guidebook.
- **Source Selection/Proposal Evaluation**: The source selection criteria issued by the Director of Defense Pricing and Contracting (DPC) requires that the program manager[4] develop an IGCE prior to the release of the final request for proposal (RFP) in order to help evaluate proposal cost reasonableness and realism.

While there are other analytic studies concerning cost and effectiveness considerations that require cost estimates, these are the major types. The Components have issued specific guidance for the types of analysis they require. For example, Air Force Instruction (AFI) 65-501, "Economic Analysis" states that implementing the EA approach is applicable to a variety of comparative analyses including EA, lease vs. buy decisions, BCA, PS BCA, cost benefit analysis, and AoAs and then proceeds to provide guidance on the implementation of these comparative analyses. The DON, alternatively, has separate EA and BCA templates. The analyst must be familiar with the respective Component requirements for cost estimates in these types of studies.

1.3.3 Cost Estimate Type

Regardless of the type of analysis it supports, every estimate should be realistic, defendable, comprehensive, and well documented. The cost estimate type is a function of the program category, events, its purpose, and the organization responsible for its development. The following are broad cost estimate types:

---

[3] NPV analysis account for the time-value of money based on the assertion that dollars received in the future are worth less than dollars in available today. The OMB promulgates Circular-94 "*Guidelines and Discount Rates For Benefit-Cost Analysis Of Federal Programs*" annually.

[4] This guide does not use the acronym PM. Program manager is spelled out to avoid confusion with the term project manager.

- **ICE**: A life-cycle cost estimate[5] is statutorily required for all MDAPs during acquisition and sustainment decision reviews, significant out-of-cycle reviews such as Critical Nunn-McCurdy breaches, and programs (ACAT II and above) acquired through the Software Acquisition pathway. A government organization not directly aligned with the acquisition management of a program should develop the ICE in order to preserve the estimate's independence. For an MDAP in the acquisition process, the CAPE produces an ICE or reviews and approves the ICE if produced by a Component. For non-MDAP programs, the Component Cost Agency performs the ICE for the Army and Air Force, while the System Command cost organization performs this function for the DON. An ICE includes all relevant costs regardless of appropriation limitations or funding sources.
- **DoD CCP**: The CCP is the outcome of the reconciliation between the CCE and the POE. It serves as the program official cost position from that Component. For the DON, the CCE serves as its official cost position, in the absence of a CCP; the POE serves as the official cost position in the absence of both a CCP and a CCE.
- **DoD CCE**: A life-cycle cost estimate developed by one of the Components typically developed by the Component Cost Agency. The System Command cost organization (or Direct Reporting Program Manager cost organization) develops the CCE for the DON.
- **POE**: A cost estimate developed by the program office and used as a tool for life-cycle cost management throughout the life of the program. A program updates its POE as required to capture actual incurred costs to date and refined estimating methods. The program manager uses the POE to inform the acquisition and O&S management processes. The POE is a consideration during the creation of the CCP.
- **Cost Capability Analysis (CCA)**: An estimate typically developed by the program office to support the program manager in the delivery of cost-effective solutions through deliberate trade-off analysis between operational capability and affordability.
- **IGCE**: Pertains mostly to services acquisitions, specifically contracts, as mentioned in DoDI 5000.74. It provides a government developed cost estimate of an individual contract. The analyst conducts an IGCE to check the reasonableness of a contractor's cost proposal and to make sure that the offered prices are within the budget range for a particular program. The IGCE may assist in cost realism analysis[6].
- **Should Cost Estimate[7] (SCE)**: A management tool associated with the OSD Better Buying Power initiative to control and reduce cost throughout the lifecycle, often referred to as a Should Cost Initiative. The objective is to proactively target cost reduction through process and productivity improvements. Over time, the SCE has evolved in intent and purpose and therefore the reader is encouraged to seek out the relevant Component definitions and policies for this type of cost estimate.
- **Sufficiency Review**: A review to ensure a program or cost estimate has sufficient information for a formal milestone review. These reviews are typically component specific. For example, the Air Force Life Cycle Management Center conducts program sufficiency reviews "*culminating in a final outbrief of the results of those assessments to obtain*

[5] A life-cycle cost estimate is the estimated cost of developing, producing, deploying, maintaining, operating, and disposing of a system over its entire lifespan.

[6] The 2018 Independent Government Cost Estimate (IGCE) Handbook for Services Acquisition defines cost reasonableness and cost realism.

[7] "Joint Memorandum on Savings Related to "Should Cost"" signed by Under Secretary of Defense for Acquisition , Technology, and Logistics (USD(AT&L)) and USD Comptroller/Chief Financial Officer (C/CFO) April 22, 2011

approval of a program baseline[8]" and there is a sufficiency review checklist for cost estimates scoring documentation, reasonableness and relevance, completeness and consistency, and risk.

1.4 Properties of a Good Cost Estimate[9]

Regardless of the type of cost estimate produced, the analyst can expect leaders and other analysts to assess it against how well it:

- predicts, analyzes, and evaluates system cost and schedule resources,
- facilitates decision making, and
- assists program managers with program control planning and execution.

Due to the wide variety of cost estimate purposes and types, it is impossible to build a one-size-fits-all cost estimate evaluation metric. However, the following are fundamental characteristics of any good cost estimate:

- It is realistic, comprehensive, believable, and all-inclusive.
- It can be audited via traceability in the work breakdown structure (WBS), source data, and cost model.
- It contains clear and concise definitions.
- It can be replicated by other estimators via well-defined documentation.
- It identifies and substantiates the costs of program resources (e.g., time, materiel, manpower) aligned to the year in which the funding is required.
- It documents all estimating ground rules and assumptions used in the analysis.
- It discloses any excluded costs along with the rationale.
- It results in a specific mathematical answer, but that answer is framed within the context of risks/opportunities and uncertainty.
- It includes comparisons to previous cost estimates and the available (or expected) budget.
- It addresses key stakeholder requirements including tables and charts that support decision-making.
- It is structured to be easily modified to provide answers for unplanned program changes.
- It has been independently reviewed.
- It is completed on time.

These properties are not a complete list, but analysts should consider them individually and in total when developing a cost estimate of any type.

1.5 Definitions

This section provides key definitions that are particularly important to the ensuing content in this guide and discussions with other analysts. A comprehensive list of acronyms used throughout this document

---

[8] 2016 Air Force Life Cycle Management Center (AFLCMC) Internal Process Guide to Conduct Program Sufficiency Reviews (PSR)

[9] Inspired by the Department of the Air Force Cost Analysis Agency (AFCAA), Cost Analysis Handbook, 2008, Chapter 1, "*Properties of a Good Estimate*", pg.1-20 and Government Accountability Office (GAO), Cost Estimating and Assessment Guide, 2020, Chapter 3, "*The Characteristics of Credible Cost Estimates and a Reliable Process for Creating Them*", pg. 5

is found in **Appendix A** Acronyms. The Defense Acquisition University (DAU) maintains a comprehensive glossary of Defense acquisition acronyms and terms (https://www.dau.edu/glossary/Pages/Glossary.aspx).

1.5.1 Cost Analysis vs. Cost Estimating

CAPE policies are consistent in distinguishing between cost analysis and cost estimating. Cost analysis encompasses the entire range of activities in the cost estimating process. Cost analysis includes activities such as sensitivity and what if analysis that are performed on the results of a cost estimate. (See **Sections 7.3.2** for sensitivity and **7.3.3** for what-if analysis.) Cost estimating itself is a blend of art and science to develop a realistic cost forecast of proposed products or services. In this guide, cost analysis refers to any effort performed in the support of generating a cost estimate and its documentation. For example, assessing the benefit of a MYP (rather than annual procurement) is a cost analysis activity with various results, some of which the analyst incorporates into the cost estimate.

1.5.2 Work Breakdown Structure and Estimate Structure

The 2020 military standard Work Breakdown Structures for Defense Materiel Items (Military Standard (MIL-STD)-881E) describes WBS as a consistent and visible framework for product-oriented materiel items and contracts within a defense program. Analysts may use the MIL-STD-881 WBSs as the basis for acquisition cost estimates of they may use a Cost Element Structure (CES) that utilizes the MIL-STD 881 WBS for further decomposition of elements. The 2020 CAPE O&S Cost-Estimating Guide defines an O&S CES that categorizes and defines cost elements covering the full range of O&S costs that could occur in any defense system. This guide uses the following terms:

- **Program WBS**: Refers to a WBS that describes the program and is based on the current version of MIL-STD-881 inclusive of all government costs.
- **Contract WBS**: Refers to the agreed-to contract reporting level and includes any discretionary extensions to lower-levels for reporting. It should be closely aligned with the program WBS.
- **O&S CES**: Refers to the CES as defined in the 2020 CAPE O&S Cost-Estimating Guide.
- **Estimate Structure**: Refers to a program WBS and/or O&S CES that has been expanded and/or rearranged to support the required cost estimate.

See **Section 3.1.2** for a more extensive discussion on the program and contract WBS.

1.5.3 Inflation vs. Escalation

Inflation is the rise in an economy-wide average (general) price level over time; there is only one rate of inflation that applies to all goods and services in the US economy. Escalation is the change in price (to include inflation) of particular goods and services in specific sectors of the economy. Escalation has two components: inflation and real price change (RPC). RPC is the portion of escalation unexplained by inflation such as market-specific supply and demand.[10]

To account for inflation and escalation, cost can be expressed in a number of different ways, each suitable for a specific purpose. **Table 1** displays terms that the cost community uses to characterize or modify cost to the proper context.

[10] See the 2021 Inflation and Escalation Best Practices for Cost Analysis handbook for authoritative details on inflation, escalation, and other terms that characterize cost,

The 2021 CAPE Inflation and Escalation Best Practices For Cost Analysis contains more information on calculations associated with the terms in **Table 1**.

Table 1: Key Inflation/Escalation Terms

Term	Definition
Inflation Index	A series of multipliers that measure the percentage change in the general price level over time, relative to a particular year. Costs normalized using an inflation index are Constant Year (CY) dollars.
Escalation Index	A series of multipliers that measure the percentage change in price for particular goods and services over time, relative to a particular year. Costs normalized using an escalation index are Constant Price (CP) dollars.
CY[11] Dollars	Cost normalized for inflation only (not normalized for RPC) to a specific FY.
CP Dollars	Cost normalized for escalation, including both inflation and RPC.
Base Year (BY)	The year against which costs are measured for comparison, in either CY$ or CP$. For weapon system estimates supporting major decisions such as milestones, the year of the decision is often chosen as the "program base year" in order to have a consistent point of reference.
Outlay Profile	In percentage terms, the rate at which a budget is spent (expended) over time (years).
Then Year (TY) Dollars	Costs that include an outlay profile[12] to cover escalation as obligations are expended over a multiyear period. Primarily used for budgeting purposes (e.g., Total Obligation Authority (TOA)).

1.5.4 Cost vs. Price

Cost is the expense incurred for a product or service. Price represents the amount of money the government intends to pay for that product or service. The difference between cost and price is fee (commonly referred to as profit). Calculating fee is a function of contract type, and there are many variations. A comparison of major contract types is found at:
https://www.acq.osd.mil/dpap/ccap/cc/jcchb/Files/Topical/Contract_Type_Comparison_Table/resources/contract_type_table.docx

[11] CY can also be the acronym for "current year" or "calendar year". CY refers to "constant year" in this guide.

[12] Some appropriations are required to be obligated within one year fully expended by the second year (e.g., Operations and Maintenance (O&M)). Others are spent over a period of up to seven years (e.g., shipbuilding). The outlay profile specifies the percent spent in each year.

1.5.5 Direct vs. Indirect

Direct costs are costs attributable to a single product and generally categorized as labor, material, and other direct cost (ODC). ODC includes items or services, such as tooling or consulting, that are neither material nor direct labor but are attributable to a single product.

Indirect costs are service or expense costs that benefit multiple products such as utilities and facilities and are therefore difficult to allocate to a single effort. Companies typically prorate these costs across multiple contracts. An analyst may allocate indirect costs to different efforts based on relative direct cost.

1.5.6 Cost Model vs. Cost Estimate

The cost model is what the analyst builds and utilizes to characterize the behavior of the program and produce a credible cost estimate. The cost estimate is a product of the cost model and the cost projection of the subject program, given a set of cost model inputs. **Section 2.1.6** describes the basic elements of a cost model.

1.5.7 Cost Contributors vs. Cost Drivers

The question "*What is driving the program cost*?" elicits different answers depending on who is answering the question. For some, the answer is the element(s) of the estimate structure that contribute the most to the total cost of interest. For others it is the programmatic, technical, performance, or schedule element that has the greatest impact on the total cost of interest. These concepts can be summarized as:

- **Program cost contributors**: The element(s) of the estimate structure (generally at a level lower than acquisition or O&S) that contribute the greatest cost to the program. Finding data to support elements of the estimate structure that contribute only a small fraction to the total cost are not as important as those that contribute significantly more to the total cost interest. For example, CAPE O&S CES 2.1 Energy may be a high cost contributor to the overall O&S estimate.
- **Program cost drivers:** The inputs (hours, labor rates, quantities, weight, power, etc.) to cost estimate methods that have the most influence on the total cost of interest. Using the same 2.1 Energy example, either the price of a gallon of fuel or the fuel consumption rate of the system is likely to drive the total fuel cost.

The notion of contributors and drivers applies to not only their influence on the point estimate[13] but also their influence on cost or schedule risk/opportunity and uncertainty. A review of similar programs and the benefit of subject matter expert (SME) guidance helps to identify potential program cost contributors and drivers and, in turn, may influence the data collection focus.

1.5.8 Risk/Opportunity, and Uncertainty

A risk is a potential future event or condition that may have a negative effect on cost, schedule, and/or performance. An opportunity is a potential future event or condition that may have a positive effect on cost, schedule, and/or performance[14]. Risk/opportunities have three characteristics: a triggering event

[13] This guide does not use the acronym PE. Point estimate is spelled out to avoid confusion with the budgeting term program element.

[14] DoD, Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs, 2017, para. 1.1, "*Purpose*", pg. 3

or condition, the probability that event or condition will occur, and the consequence of the event or condition should it occur.

Analysts often use the terms risk and uncertainty interchangeably. In fact, they are distinct from one another. Uncertainty is the indefiniteness of the outcome of a situation[15]. Uncertainty captures the entire range of possible positive and negative outcomes associated with a given value or calculated result. In a cost estimating model, an analyst generally addresses uncertainty first. The analyst then addresses risks/opportunities if and only if the uncertainty assessment has not already captured them.

1.6 Cost Estimating and Analysis Policy References

- AFCAA, AFI 65-508, 2018, Chapter 1 "*Overview, Roles, And Responsibilities*"
- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 2, "*Overview of Life-Cycle Costs*"
- Department of the Army, Cost Analysis Manual, 2020, Chap 2 "*Cost Analysis References*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 1 "*Why Government Programs Need Cost Estimates and the Challenges in Developing Them*"
- Missile Defense Agency[16], Cost Estimating and Analysis Handbook, 2021, Section 1.4 *"Cost Estimating Policy"*
- National Aeronautics and Space Administration (NASA), Cost Estimating Handbook, 2015, para. 1.2 "*The NASA Acquisition and Management Processes*"
- Naval Center for Cost Analysis (NCCA)/ AFCAA, Software Development Cost Estimating Handbook, 2008, Chapter 2.1 "*The Defense Acquisition System*"

1.7 Cost Estimating and Analysis Policy Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to cost estimating policy. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- Business Cost Estimating (BCE) 1000 Fundamentals of Cost Estimating
- Business, Cost Estimating, Financial Management (BCF) 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000Advanced Cost Estimating
- Business, Financial Management (BFM) 0050 Planning, Programming, Budgeting, and Execution
- BFM 0040 Budget Policy
- Continuous Learning, Business (CLB) 014 Acquisition Reporting Concepts and Policy Requirements
- CLB 039 Cost Estimation Terminology

The International Cost Estimating and Analysis Association (ICEAA) publishes the Cost Estimating Body of Knowledge (CEBoK). The follow modules are relevant to cost estimating policy:

- CEBoK v1.2, 2013, Module 1 "*Cost Estimating Basics*"
- CEBoK v1.2, 2013, Module 2 "*Cost Estimating Techniques*"

---

[15] NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook (JA CSRUH), 2014, para. 1.2.2 "*The Difference Between Risk, Opportunity, and Uncertainty*", pg. 2

[16] Missile Defense Agency is spelled out to avoid confusion with Milestone Decision Authority (MDA).

- CEBoK v1.2, 2013, Module 4 "*Inflation*"
- CEBoK v1.2, 2013, Module 14 "*Contract Pricing*"

The following course numbers starting with FMF refer to the course number assigned by the Financial Management (FM) Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 1546 Business Case Analysis
- FMF 1558 DoD FM 101 - Fiscal Law
- FMF 4069 Budget Concepts, Policies, and Principles
- FMF 6599 DoD Basic Fundamentals and Operations of Budget
- FMF 1559 DoD FM 101 - Acquisition & Contracting
- FMF 1560 DoD FM 101 - Cost Analysis
- FMF 4050 Business Case Analysis - Mini-Course
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

2.0 THE COST ESTIMATING PROCESS

This chapter provides an overview of the cost estimating process, and subsequent chapters provide more detail on each step in the process. The analyst should always tailor the process to his/her specific estimate or project.

2.1 DoD Cost Estimating Process

Analysts can have very different opinions on how best to arrive at a realistic cost estimate because the number of viable paths to get there and the hurdles to surmount can appear endless. Over the course of several years, the GAO worked diligently with dozens of national and international experts, both government and industry, to develop a consensus on a clearly defined cost estimating process and to document the best practices supporting that process. The result was the 2009 GAO Cost Estimating and Assessment Guide. This guide was updated and released again as the 2020 GAO Cost Estimating and Assessment Guide (GAO-20-195G). The GAO guide includes a process of 12 steps, which, if followed correctly, should result in reliable cost estimates. It is common for DoD Components to reference this flow chart directly or to provide a modified version adapted to their environment.

In deference to the many organizations that have developed flow charts to suit their unique requirements (several of them can be found in **Appendix B**), **Figure 1** defines a generalized cost estimating process for DoD. This DoD version captures all of the steps in the GAO process and most of the elements from Component guides, handbooks, and manuals. (See **Appendix B.1** for the GAO process.) The graphic in **Figure 1** provides the framework for the discussions in this guide and gives the reader a comprehensive overview of a DoD-centric process.

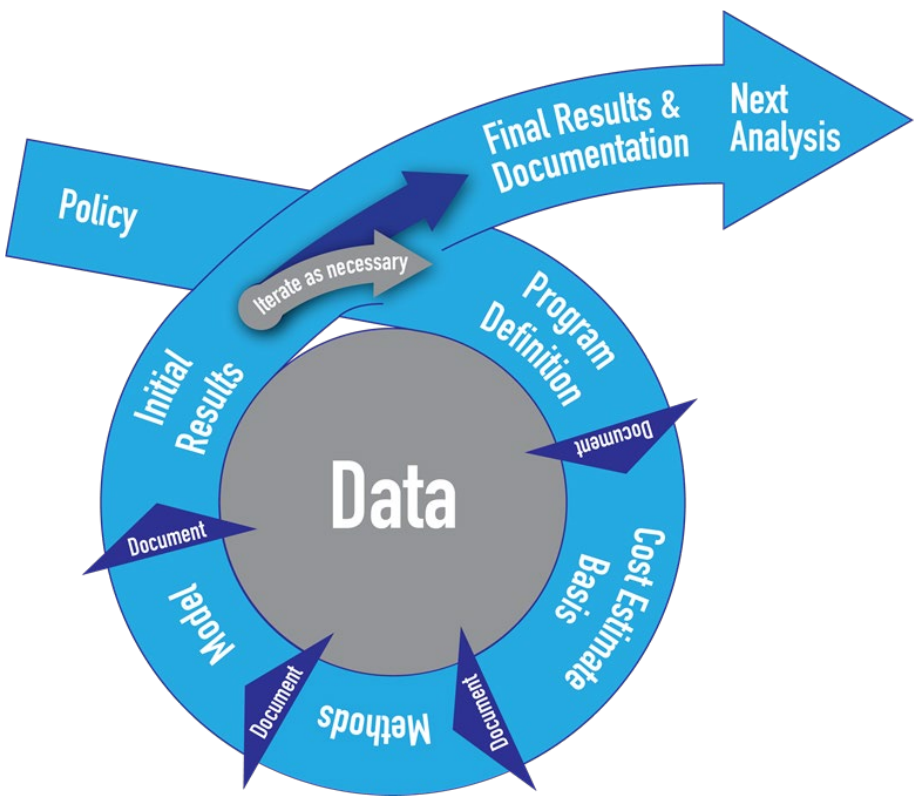


Figure 1: DoD Cost Estimating Process

Key features of **Figure 1** include:

- Policy and the program definition tend to be products produced by authorities other than the analyst, although it is important to have analysts participate in these efforts.
- The process recognizes the effort related to Data as fundamental to the success of any cost estimate and often the most time/effort intensive activity. **Figure 1** emphasizes that data is at the center of the other steps in the process.
- The steps in the process are necessarily overlapping and iterative. It is common to be performing parts of two or more steps simultaneously, and at any point, returning to previous steps. A precise and repeatable serial flow for every cost estimating circumstance simply does not exist.

The remainder of this section introduces the key iterative steps of the DoD cost estimating process.

2.1.1 Policy

The statutes, policies, and guidance summarized in **Chapter 1.0** identify the requirements for various types of cost estimates, cost data collection, and other cost estimating related processes.

2.1.2 Program Definition

The program definition is a detailed description of a DoD program for use in preparing a cost estimate. **Chapter 3.0** examines the primary elements, including the Cost Analysis Requirements Description (CARD), baseline system, and program WBS.

2.1.3 Cost Estimate Basis

The analyst is responsible for clearly documenting the purpose and scope (including level of detail) of the estimate. In particular, this step includes the framing assumptions, ground rules, and assumptions (e.g., CY to express costs, life-cycle phases to be estimated, level of detail, need for what-if analysis, and anything else that influences how the estimate is performed), as well as the schedule for the completion of the cost estimate. (See **Chapter 4.0** for more detail**.)**

2.1.4 Data

Data is the heart of the estimate. The identification, collection, validation, normalization, and analysis of quality data influence all of the remaining steps in the cost estimating process. (See **Chapter 5.0** for more detail.)

2.1.5 Methods

An analysis of the collected data leads to the selection of the best cost/schedule estimating method(s) for a specific element of the estimate structure. (See **Section 1.5.2** for a definition of "estimate structure"). The estimating methods address a variety of applicable influences such as the effects of weight, volume, and power; quantities produced (learning curves and rate effects); quantities per year; phasing; and many others. The time and availability of data required to implement the method is a consideration when selecting methods. (See **Chapter 6.0** for more detail.)

2.1.6 Model

An analyst produces a cost estimate from a mathematical model that includes all relevant cost elements. Each lowest level element of the estimate structure has an estimating method. (See **Chapter 6.0** for a discussion of estimating methods). In some cases, the estimating method is a direct function of another cost in the estimate structure. The analyst should design the cost estimate model to assess the impact of a change in quantity, phasing, schedule, labor rates, operating/operational/operations tempo

(OPTEMPO), or anything else that could influence one or more element of the estimate structure. (See **Chapter 7.0** for more detail.)

2.1.7 Initial Results and Iterate as Necessary

Once the analyst builds the cost model (including the impacts of risk/opportunity and uncertainty), then he/she should verify the model serves the intended purpose and validate the model results by performing the following:

- **Crosscheck**: Tests the model's results for accuracy at various levels in the estimate by comparing them to the cost and/or schedule of completed projects, or by comparing against the results of a relevant, alternative cost model that applied different data and/or methods.
- **Sensitivity analysis**: Tests the model's ability to estimate the impact on total cost by changing a specific cost driver.
- **What-if analysis**: Tests the model's ability to estimate the impact of changing a variety of cost drivers that define a specific alternative.

There are many reasons that make it necessary to iterate through the cost estimating process, including unexpected results from the crosschecks, sensitivity analysis, or what-if analysis. (See **Section 7.5** for more detail.)

2.1.8 Final Results and Documentation

The content and format of results with their associated documentation and presentations are a function of the estimate purpose and type. Documentation should start at the outset of the cost estimating process, as shown in **Figure 1**, to capture all the necessary elements from each step, and be continually refined throughout the process. (See **Chapter 8.0** for more detail.)

2.1.9 Next Analysis

The final step in the cost estimating process is to move on to the next analysis. This could be a completely new program, additional investigation on the current program, or any other cost estimating related task. Often, future analysis uses the results of the current analysis.

2.2 Component Guidance Documents

Practices and procedures vary between cost analysis organizations according to mission requirements, workload, staffing, and special circumstances. Components have issued documents that implement DoDIs and represent a consensus of best practices useful to cost analysis practitioners for their organizations and cost estimate stakeholders. This is recognition that cost analysis cannot be reduced to a single linear set of rules to follow. In addition to the DoDD and DoDI documents described in earlier sections, Component-specific guidance exists in:

- **Department of the Army Cost Analysis Manual:** Provides basic frameworks for methodologies and procedures to implement policies for better cost analyses. It is a useful aid in understanding and participating in the Department of the Army cost and EA process. The document may be accessed here: https://www.asafm.army.mil/Portals/72/Documents/Offices/CE/20200330%20CAM.pdf, or through the DASA-CE Cost and Performance portal (https://cpp.army.mil/).
- **AFI 65-508 Cost Analysis Guidance and Procedures**: Establishes timelines, documentation requirements, and review procedures for all Air Force cost estimates, and provides specific

instructions on performing cost analyses. https://static.e-publishing.af.mil/production/1/saf_fm/publication/afi65-508/afi65-508.pdf

- **DON Cost Estimating Guide**: Provides a compendium of best practices for life-cycle cost estimates of weapon system and information systems acquisition programs within the DON. It strives to improve and standardize processes and procedures while recognizing the fluidity inherent in the field of defense cost analysis. This, and a variety of additional relevant references, can be found at: https://www.ncca.navy.mil/references.cfm.
- **Missile Defense Agency Cost Estimating and Analysis Handbook**: Serves as a desk reference for the Missile Defense Agency analysts and anyone who interfaces with the organization analysts or uses its cost estimates. A secondary purpose is to identify and define a set of standard data requirements for Missile Defense Agency cost estimates. The handbook can be found at: https://service.cade.osd.mil/cade-ng/library.

2.3 Cost Estimating Process References

- AFCAA, Cost Analysis Handbook, 2008, Chapter 3 "*Cost Estimating Process and Methods*"
- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7, "*O&S Cost Estimating Process*"
- Department of the Army, Cost Analysis Manual, 2020, Chapter 3 "*Cost Estimating Process*"
- DoD Independent Government Cost Estimate Handbook for Service Acquisition, 2018, "*Cost Estimation*"
- DoDI 5000.73, Cost Analysis Guidance and Procedures, 2020, Section 3, *"Cost Estimation Requirements and Procedures"*
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 3 "*The Characteristics of Credible Cost Estimates and a Reliable Process for Creating Them*"
- Marine Corps Systems Command (MARCORSYSCOM), Cost Analysis Guidebook, 2020, Chapter 3 "*Cost Estimating Process*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Chap 5 "*The Cost Estimate*"
- NASA, Cost Estimating Handbook, 2015, Chapter 2 "*The Cost Estimating Process*"
- NCCA, Cost Estimating Guide, 2010 Chapter 1 "*Overview*"
- NCCA/AFCAA, Software Development Cost Estimating Handbook, 2008, Chapter 3 "*Levels of Detail in Software Estimates*"
- SPAWAR[17], Inst 7110.1 Cost Estimating and Analysis, Encl. 1, 2016, Chapter 2 "*Overview"*

2.4 Cost Estimating Process Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimating process. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000Fundamentals of Cost Estimating
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000 Advanced Cost Estimating
- CLB 007 Cost Analysis (*focuses on the basic cost analysis process*)

[17] Space and Naval Warfare Systems Command (SPAWAR) became the Naval Information Warfare Systems Command (NAVWAR) June 3, 2019.

- CLB 025 Total Ownership Cost (*provides the framework necessary to estimate total ownership cost within the acquisition process*)
- CLB 032 Force Structure Costing (*explains the definition, purpose, and utility of DoD Force Structure Costing techniques*)
- Acquisition Management (ACQ) 0060 Independent Government Cost Estimate (IGCE) for Services
- Program Management (PMT) 0160 Cost Estimating

The ICEAA publishes the CEBoK. The follow modules are relevant to cost estimating policy:

- CEBoK v1.2, 2013, Module 2 "*Cost Estimating Techniques*"

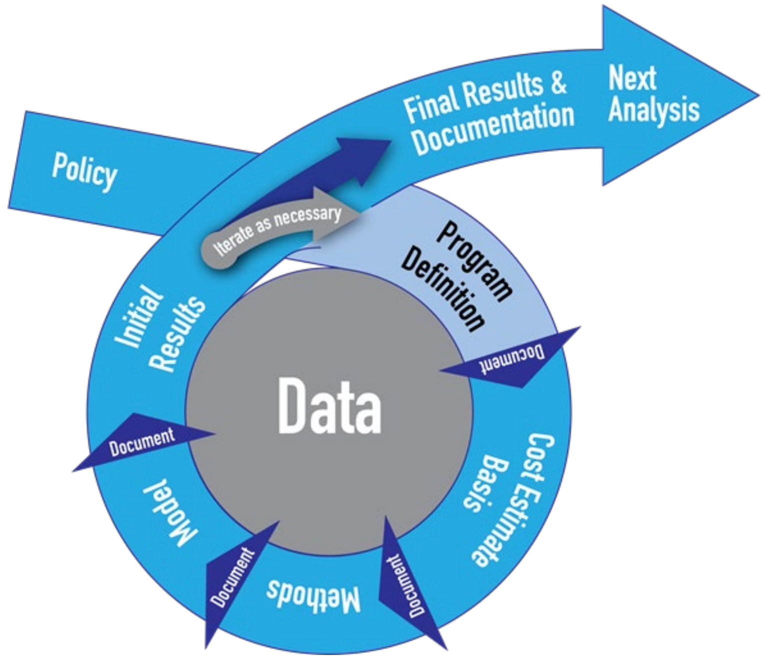
The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 1560 DoD FM 101 - Cost Analysis
- FMF 6175 AFIT Cost 669 - Advanced Cost Analysis
- FMF 1546 Business Case Analysis
- FMF 6016 FMA 301 - Business Case Analysis
- FMF 6320 AFM 301 - Cost Estimating for Major Investment Programs
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

The following cost analysis related degrees and certificates are available:

- A 16-course Distance Learning Masters in Cost Estimating and Analysis offered by the Naval Postgraduate School (NPS) in Monterey, CA
- A four-course Distance Learning Certificate in Cost Estimating and Analysis offered by the NPS in Monterey, CA
- A two year resident Masters in Cost Estimating and Analysis offered by the Air Force Institute of Technology (AFIT) in Dayton, OH
- The Defense Acquisition Workforce Improvement Act (DAWIA) Cost Estimating career field level certifications. Requirements can be found at: https://icatalog.dau.edu/onlinecatalog/CareerLvl.aspx#
- A Certified Cost Professional (CCP) administered by the Association for the Advancement of Cost Engineering International (AACEI)
- Certified Estimating Professional (CEP) administered by the AACEI
- An apprentice-level certification for practitioners with at least two years' experience, university degree and ICEAA administered Professional Cost Estimator/Analyst Certification (PCEA®) exam
- A professional certification for practitioners with at least five years' experience, university degree and ICEAA administered Certified Cost Estimator/Analyst (CCEA®) exam

3.0 PROGRAM DEFINITION



A key contributor to a sound cost estimate is an accurate and detailed program definition. Many formal program documents address the goals and content of the envisioned program (in varying levels of detail depending on the maturity of the program). Even so, the analyst requires a complete and detailed description of the programmatic, performance, technical, and schedule aspects of the program, which should be suitable for any type of cost estimate. (See **Section 1.3.3** for a discussion on cost estimate types.) From the analyst's perspective, the program definition contains many pieces of information that are essential. However, just knowing the essentials is insufficient. Understanding the purpose(s) behind the basis for the estimate structure and its tailoring, estimating method development, time-phasing, normalization, and development and maintenance costs are just as important.

This chapter and **Chapter 4.0** examine additional details behind selecting the necessary essentials for the type of estimate as well as the purpose for selecting those essentials.

3.1 Establish a Program Definition

The program manager and experts throughout the program office are responsible for defining the program. As such, the program definition is likely not a single document but a synthesis of many documents and sources. In many settings, this starts with a CARD or a CARD-like document. (See **Section 3.1.1** for a discussion on CARDs.) Ideally, the CARD tables and narrative are a complete, detailed description of the program. Analysts, however, should not blindly use this information, but take time to review, understand, and where necessary, question the information to build a full understanding of the program. The best CARDs unambiguously address all of the analyst's questions sufficiently so that no other source of program definition information is required. In situations where the CARD does not exist or is not sufficient for some reason and the program manager cannot improve it, the analyst can use other acquisition documents like those listed in **Table 6**, **Table 7** and **Table 8** (introduced in **Section 5.4.2**) to bridge the gap. The analyst can glean necessary program information from those documents and assemble them into the program definition. This includes general system knowledge and programmatic information such as:

- an overarching understanding of the program, to guide the development of the estimate structure and to start thinking about estimating methods,
- program systems engineering/program management (SEPM) personnel by grade and FY,
- contractor, subcontractor, and major vendor roles and related information from which to calculate contract loads by vendor tier, and

- items furnished by the government and other information necessary to identify items that will not be part of the prime contractor's cost.

The information assembled from source documents includes technical and performance parameters such as:

- programmatic, performance, technical, and design heritage parameters for use as variables for cost estimating relationships (CERs), schedule estimating relationships (SERs), scaling, or analogy selection,
- metrics and cost drivers to enable direct estimation of common elements of the estimate structure in lieu of estimating them by using a factor of the Prime Mission Product (PMP),
- software parameters necessary for estimating software development cost and software maintenance cost,
- facility construction and facility conversion data,
- parameters by part for performing commercial-off-the-shelf (COTS)-heavy bottom-up estimating, or component analysis, and
- end item composition (both uniqueness and commonality), for multiple end-item configurations.

From the source documents, it is also necessary to assemble schedule and quantity information such as:

- dates for milestone decisions, engineering gates (e.g., Critical Design Review), and other key program events from which to time-phase and inflate/escalate the cost estimate, and
- phase and contract (annual production lots) quantities and begin/end dates needed to estimate time-sensitive costs (those elements that vary by duration) and to compute learning and rate of production methods.

For estimating sustainment, the program's documentation provides relevant information, including:

- cumulative fielding quantities and expected service life for O&S cost calculations,
- OPTEMPO as a measure of the pace of an operation or operations in terms of equipment usage (e.g., aircraft flying hours, ship steaming days, or tank driving miles),
- metrics and cost drivers to estimate the cost of maintenance and other O&S costs,
- operators, maintainers, and support personnel by grade and by fiscal year, and
- logistics parameters regarding parts removed for repair/replacement.

The program office is essential to building the program definition, but it is not unusual for the analyst to spend extensive time and effort reviewing, contributing necessary information, and making recommendations for improvements. Analysts should work with program/system SMEs and managers to locate and evaluate program definition information. **Appendix C** contains a sample SME interview questionnaire from the Missile Defense Agency. This format can assist with both conducting the interview itself and serving as documentation of the event. Analysts should understand and evaluate framing assumptions that have been central in shaping program expectations. **Section 4.2.1** further discusses framing assumptions. No matter how complete the CARD and other key program documents may be, the analyst preparing the estimate must attain a solid understanding of the system being estimated. Key personnel within the program office can assist with the analyst's understanding. These include the Program Manager, Deputy Program Manager, Acquisition Manager, Contracting Officer, Business Financial Manager, Chief Engineer, Chief Tester, and Product Support Manager. **Appendix D** provides a list of sample questions suitable for a kick-off meeting and developing an understanding of the program definition.

3.1.1 Cost Analysis Requirements Description (CARD)

The CARD provides a complete, detailed description of the program baseline prepared by the program office. If the program has a CARD, or a CARD-like document, it is an important source for most of the program definition information the analyst requires.

The CARD represents a snapshot of that program. DoDI 5000.73 requires a CARD for all major capability acquisition programs. The CARD thoroughly describes the programmatic, performance, technical, operational, sustainment, and schedule characteristics of a program, along with some initial supporting data sources, and provides program information necessary to develop a cost estimate.

The CARD enables different organizations preparing cost estimates to develop their estimates based on the same understanding of program requirements. The CARD can serve as a management tool within the program office and as a common, agreed-upon baseline for all the stakeholders. Therefore, the program office developing the CARD should include only that information pertinent to the cost estimate. That is, if the cost estimate focuses on Increment I of a system, then information on Increment II should not be included in the CARD unless it specifically impacts a cost element in Increment I.

As a program evolves and analysis refines its costs and funding needs, the CARD, as a living document, evolves with it. The Cost Assessment Data Enterprise (CADE) website (https://cade.osd.mil/policy/card) provides guidance and instructions for the preparation and maintenance of the CARD. The CAPE establishes CARD requirements for ACAT I programs, and the Components establish CARD requirements for non-ACAT I programs.

For the portions of CARD content that are contextual and descriptive, a CARD narrative is used. Additionally, recognizing that cost analysis is a quantitative endeavor, the CAPE prescribes that certain CARD content be in tabular form. In the event that the program does not have a CARD or CARD-like document (e.g., an MTA program), the CARD tables can nonetheless be a data organization convenience for the analyst who must assemble the information to compile a program definition. The CAPE-designed CARD tables are commodity specific and address the following three objectives.

- The tables contain key programmatic and technical data required to estimate costs at a sufficient level of detail to support program acquisition reviews (e.g. Milestone Reviews) or PPBE process reviews (e.g., Program Objective Memorandum (POM) submission reviews).
- Over time, the completed tables serve as a record of program evolution.
- The tables support future automation via a database that analysts use for cost estimating, analysis, and research.

The CARD is an acquisition document written for the cost analysts. It should never be the responsibility of the cost analyst (at any level) to create the CARD. A common pitfall within program offices is to ask the program cost estimating team to develop the content of the CARD. Since the CARD contains the programmatic and technical data of the program, the acquisition and technical professionals in the program office should develop the content. Program cost analysts can review the CARD to assess if the content is detailed enough to support the cost analysts at the Service and OSD levels.

3.1.2 Contractor Proposals During Source Selection

While the CARD is an excellent resource to understand the program's requirements, the program office develops it to reflect generalized inputs, especially when the system vendor has not yet been determined. More specific data may be available in the system proposals during source selection (or proposal evaluation for sole source contracting situations). For example, the government may require that a system can travel at least two hours without requiring refueling; the program would reflect this requirement in the CARD. Contractors may propose a system that can exceed this requirement. This is likely an improvement appreciated by the end user and technical community, but it could have cost ramifications that the estimators should include in all program cost estimates. Estimators can only gain access to this more specific data by reviewing the proposals submitted by the contractors.

In the past, contractor proposals were not readily available to cost estimators outside of the cost proposal evaluation team. This often created a disconnect between the cost estimates developed by those who could see the proposals and the analysts performing POEs, CCEs, or ICEs. The proposal evaluation team had access to the more detailed information coming directly from the contractor, reflecting in detail how the contractor expected to meet the government's requirements. Meanwhile, the life cycle cost estimators relied on parameter estimates or thresholds from the CARD and other historical data. Leaders have recognized this disconnect in recent years and taken steps to allow sharing of the proposals with cost estimators. However, this is still done on a case-by-case basis and personnel must agree to strict rules about sharing or discussing the information. Cost estimators should work closely with the program office, evaluation team, and organizational lawyers to access this potentially rich data source.

3.1.3 Understanding the Program and Contract WBS

The primary objective of a program WBS is to achieve a consistent framework for all programmatic needs, including performance, schedule, risk/opportunity, budget, and contracts. It is also the basis for an estimate structure across programs and life-cycle phases. The program WBS also facilitates comparison of estimates performed by different estimators (e.g., ICE vs. CCP).

The contract WBS encompasses only the program WBS elements related to a contract deliverable, but extended to the agreed-to contract reporting level and any lower level for items considered high-cost, high-risk, high technical, and/or special interest. While the contract WBS must be closely aligned to the program WBS, the two are not identical. The program WBS will have elements for Government and other contractors not contained in the contract WBS. The program WBS serves as a consolidation mechanism for multiple subordinate contracts and Government elements.

The CADE website (http://cade.osd.mil/policy/csdr-plan) is a source of extended WBS product-oriented structures. MIL-STD-881 references this site as a source of extensions to each commodity-specific appendix. These extensions serve to increase the consistency of the data collection at lower levels of a contract WBS. In addition to the MIL-STD-881 commodities, this resource has product-oriented structures for a few additional commodities (e.g., training systems) as well as for sustainment-phase contracts. The sustainment structure is an extension of the CAPE O&S CES. MIL-STD-881E Appendix L provides further guidance on how the sustainment cost reporting structure is related to the defense materiel systems WBS.

DoDI 5000.85 cites Disposal as one of two major efforts within the O&S program phase. Though neither the MIL-STD-881 nor the CAPE O&S CES explicitly address disposal, a program's estimate structure should accommodate eventual disposition of the material items. Considerations include demilitarization, detoxification, long-term waste storage, environmental restoration, and related elements of transportation and program management.

3.1.4 Program WBS, Contract WBS, O&S CES and the Estimate Structure

A logical, hierarchical structure is necessary to organize the program objectives and the cost estimate by breaking them both down into manageable elements. Analysts sometimes use the terms WBS and CES interchangeably. Strictly speaking, they are different but related concepts. This guide introduced the terms: program WBS, contract WBS, O&S CES, and estimate structure in **Section 1.5.2** to help clarify the use of WBS and CES in this document.

A program office develops a WBS to serve as the framework for specifying objectives. MIL-STD-881 states that this WBS is a hierarchy of product-oriented elements, such as hardware, software, data, and services that collectively comprise the system. The CAPE requires a program WBS be included in the CARD as part of the program definition.

Acquisition professionals describe a WBS as either a program WBS or a contract WBS. The program WBS contains all program acquisition content, but generally not the O&S content. A contract WBS contains only a portion of the program WBS, and it usually contains a more extensive, lower level breakout of this program WBS portion. It relates specific program WBS elements to the elements of a contract statement of work in order to manage the contractor's work. It may also serve as a contract cost reporting structure. The program WBS provides the initial structure for the cost estimate.

An estimate structure defines and groups all of the costs of the program in a disciplined hierarchy whose structure is largely determined by its suitability for cost estimation, i.e., by the availability of data and the need to perform specific what-if drills. The analyst bases the estimate structure on selected program WBS elements (e.g., airframe) and may further break it down into functional categories (e.g., engineering and manufacturing labor; overhead). Since the program WBS is usually a product-oriented structure, it may not be sufficiently decomposed to adequately capture all the cost. In these scenarios, the estimate structure is an extension, or further breakdown, of selected program WBS elements in order to adequately capture costs and provide a foundation for investigating what-ifs. It is important to understand that acquisition elements of the estimate structure must roll up into the higher-level program WBS elements. In some cases, the program WBS is sufficient for the cost estimate and O&S CES elements are not necessary. In this particular case, the program WBS may be identical to the estimate structure.

Since many cost estimates cover the entire life cycle, the estimate structure is more expansive than the program or contract WBS. On occasion, multiple estimate structures are required to estimate a program. For example, in a large program it may be necessary to develop specific estimate structures separately (e.g., airframe, avionics, propulsion, everything else) and have another estimate structure to combine them. Additionally, since the cost estimate model will likely be used to explore variations on the proposed technical solution, the estimate structure is often more granular than either the program WBS or contract WBS which are based upon the guidance in MIL-STD-881. This could mean more elements at a particular level and/or more levels of indenture. An O&S WBS does not exist in MIL-STD-881 because the O&S phase is not product-oriented. Therefore, the 2020 CAPE O&S Cost-Estimating Guide provides the cost structure for this phase via an O&S CES. **Appendix E** provides examples of Program WBS, Contract WBS, and O&S CES to illustrate the similarities and differences. The Cost Estimate Basis, **Chapter 4.0,** further develops the purpose and utility of an estimate structure.

3.2 Start Building a Cost Model

As the program definition begins to take shape, the analyst should start thinking about how to structure the cost model, the implications for data gathering, and the estimating methods likely to be employed. **Chapter 5.0** describes a data collection process primarily focused on the collection of data from analogous historical programs similar to the program definition to serve as the basis for estimating the program costs. Building a simplified cost model at this point can help identify holes in the program definition and help formulate the data collection plan.

3.3 Program Definition References

- AFCAA, AFI 65-508, 2018, Chapter 5 "*Cost Analysis Requirements Description (CARD)*"
- AFCAA, Cost Analysis Handbook, 2008, para. 5-2 "*Develop a Technical Baseline*"
- AFCAA, Tabular CARD Sufficiency Review Handbook, 2017
- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7.2, "*Program Definition*"
- Department of the Army, Cost Analysis Manual, 2020, Chap 3 "*Cost Estimating Process*"
- DoDI 5000.73, Cost Analysis Guidance and Procedures, 2020, Section 3 "*Cost Estimation Requirements and Procedures*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 6 "*Step 3: Define the Program – Technical Baseline Description*"
- MARCORSYSCOM, Cost Analysis Guidebook, 2020, para. 3.1 "*Establish A Program Baseline*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Section 5.4 "*Define Program Characteristics*"
- NASA, Cost Estimating Handbook, 2015, para. 2.1 "*Project Definition Tasks*"
- NCCA, Cost Estimating Guide, 2010 para. 2.1 "*Establish a Program Baseline*"
- NCCA/AFCAA, Software Development Cost Estimating Handbook, 2008, Chapter 3 "*Levels of Detail in Software Estimates*"
- Performance Assessments and Root Cause Analyses (PARCA)[18], MIL-STD-881D, Work Breakdown Structures for Defense Materiel Items, 2018
- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, Chapter 4 "*Establish a Program Baseline*"

3.4 Program Definition Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimate program definition. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000 130 Fundamentals of Cost Estimating
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000 Advanced Cost Estimating
- PMT 0130 Work-Breakdown Structure

The ICEAA publishes the CEBoK. The follow modules are relevant to program definition:

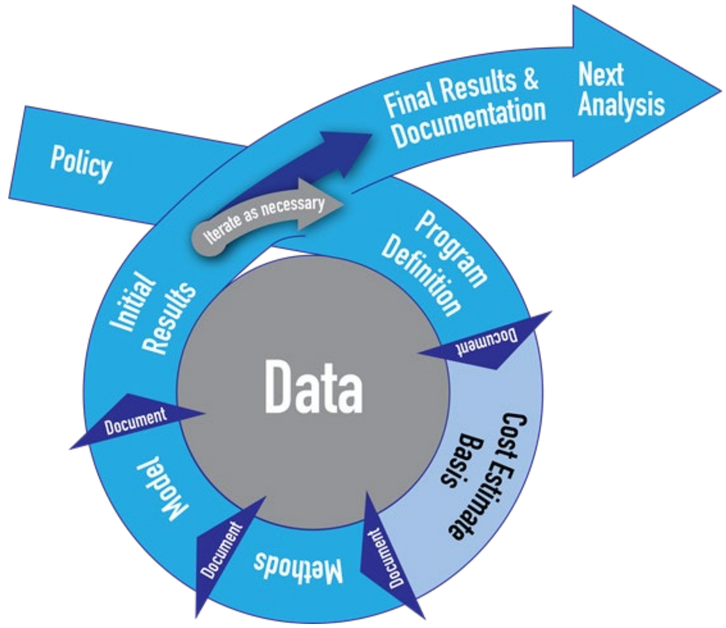
- CEBoK v1.2, 2013, Module 2 "*Cost Estimating Basics*"

The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 4898 ADM 300 - Work Breakdown Structure Review
- FMF 6175 AFIT Cost 669 - Advanced Cost Analysis
- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

[18] PARCA was superseded by Acquisition, Analytics and Policy which is now Acquisition Data and Analytics (ADA)

4.0 COST ESTIMATE BASIS



The cost estimate basis is the estimate purpose, scope, schedule, and the framing assumptions, ground rules, and cost estimating assumptions. This step in the estimating process builds on the program definition and establishes the basis for the data collection, estimating method development, and cost model building. The more thought and planning performed at this stage of the cost estimating process, the more efficient and successful the remaining steps.

Developing a cost estimate can be a major effort, and it demands the attention of experienced, professional analysts. The cost analysis team must cope with a great deal of uncertainty because the products and/or services they are estimating may not be precisely defined. Framing assumptions, ground rules, cost estimate assumptions along with an interpretation of requirements and data bound the estimate. To successfully navigate, define, and apply them, the analyst team must possess a variety of skills. The overarching reality is that a quality cost estimate requires significant time, resources, and planning. The analyst uses the cost estimate basis to substantiate and defend the cost estimate during reviews and reconciliation sessions.

4.1 Cost Estimate Plan

A cost estimate plan organizes the estimators and stakeholders around the purpose, scope, structure, and schedule of the cost estimate. The analyst should focus this plan on a list of scheduled events that he/she needs to accomplish to complete the estimate, along with the anticipated timeline to finalize and deliver the cost estimate. The amount of detail and rigor in these plans varies depending on the number of people, organizations, and stakeholders involved, as well as the size and complexity of the cost estimate scope. For example, an ACAT ID milestone POE will likely require a bigger team and more time than an ACAT III sufficiency review.

The larger the cost estimate team, the more detail the cost estimate plan should include to ensure everyone is working towards common goals. While developing this plan, all organizations that have a vested interest in the cost estimate – the stakeholders – need to be identified with their roles and responsibilities to prevent confusion regarding who is involved and why. For larger programs it is often a good practice to have the cost estimate plan signed by the program manager, and potentially other stakeholders, to validate that the plan has been vetted and accepted by the program office and is being used as the basis for collecting data and developing the cost estimate. CAPE and the Component Cost Agency may build their own plan, but in many cases they will want to review the program cost estimate plan for completeness.

Table 2 provides a summary of the information that should be included in a cost estimate plan.

Table 2: Information to Include in a Cost Estimate Plan

Content	Rationale
Policy and procedures	References the policies and procedures that drive the cost estimate and the process used.
Purpose and Scope	Provides the reader with an understanding of why the cost estimate is required and to whom it will be delivered. The scope defines the boundaries of what is or is not explicitly included in the estimate. This includes identifying the level of detail required to support every element in the program, all anticipated what-if excursions, and all reports.
Define the Estimate Structure	An estimate structure provides context to the cost estimate and supports the variety of cost analysis anticipated to deliver the all the required results. Providing a copy of the estimate structure to Level 2 or Level 3 is helpful. At this level of detail, the estimate structure should match the program WBS.
Process / Approach	Provides a general overview of the process and steps taken to complete the cost estimate. The analyst should have built a rudimentary estimate structure and be considering/documenting estimating methodology options to influence the listing of desired/required data and data collection efforts. It is also important for engineers and other SMEs to gain an understanding of why an analyst is requesting specific data.
Team Members and Assignments	Include the name, organization, phone number, and email address for both the team of analysts and the program office. For larger programs and estimates, it is important to also point out the responsibility of each team member. If team members require Non-Disclosure Agreements (NDAs) to accomplish their assignments, this should be noted.
Travel	Many cost estimates require travel to government or industry sites to collect data and meet with SMEs. This section should detail the travel dates, locations, and purpose of each trip.
Schedule	Defines the timeline for the estimate to be completed, to include important meeting dates (e.g., kickoff meeting), data collection(s), draft version dates, review cycles, final delivery dates, and the dates the documentation will be provided.

Although a cost estimate plan is a living document, the cost estimate team should keep it under configuration control and change it only with agreement from the stakeholders. Appendix 7 of the 2020 Department of the Army Cost Analysis Manual provides an example of the sorts of documentation captured in a cost estimate plan. To establish consistency in content and use, guidance on how formal these plans need to be and their review/approval process should be promulgated by the applicable authority.

4.1.1 Establishing the Purpose and Scope

The purpose of the cost estimate should be a clear and concise statement that defines the intended use of the cost estimate. There are various purposes for a cost estimate, including: developing a budget quality estimate, supporting a POM process, supporting an acquisition milestone decision, performing an AoA, investigating cost vs. capability trades, conducting an NPV analysis, participating in proposal evaluation, and conducting a PS BCA, among others.

The scope of the estimate identifies the level of detail required to support not only all elements in the program, but all anticipated what-if excursions and reports. The scope also defines the boundaries of what is or is not explicitly included in the estimate being performed. For example, the program manager may decide that the program includes the cost of a ship but not any additional craft required for security when that ship is in port. Or, during an AoA, the stakeholders may all agree that cost elements that remain the same between the different alternatives will not be included in the cost estimate. The purpose and scope drives the cost estimate schedule and the resources required to complete the remaining steps of the cost estimating process. The stakeholders who play a role in the development, review, and the ultimate use of the cost estimate should agree with the estimate purpose and scope.

4.1.2 Define the Estimate Structure

The program manager approves a program WBS as part of the program definition. Once the stakeholders approve the purpose and scope of the cost estimate, the analyst modifies and/or expands the program WBS to support the desired cost estimating results. The result is an initial estimate structure. It is an initial estimate structure because additional detail or different structure may become apparent as the estimate progresses. The estimate structure may address a complete and detailed life-cycle cost estimate, e.g., a POE, or be limited to a subset of program scope. For example, a program completing the Technology Maturation and Risk Reduction (TMRR) phase and working towards a Milestone B review requires an estimate structure that covers all program cost. In contrast, a program in the Materiel Solution Analysis (MSA) phase might require an estimate structure that supports an AoA. In this scenario, only the portions of the estimate structure that highlight the differences among alternatives are useful. Scopes of work that are assumed to be common among alternatives are often removed from the AoA study via an agreed upon ground rule and are not included in an MSA cost estimate.

If an element of the estimate structure is not a sub-element to any program WBS element, it should remain closely aligned to the current DoD MIL-STD-881 for acquisition elements and the CAPE O&S CES for O&S elements. Some organizations use Component specific guidance to augment these resources. For example, the Naval Sea Systems Command (NAVSEA) uses the Expanded WBS Weight Classification Guidance[19], which defines the Expanded Ship WBS (ESWBS). The shipbuilding industry uses ESWBS to further delineate the scope of work associated with a shipbuilding program. When shipyards and government program offices use ESWBS as their organizing construct, it improves clarity and facilitates discussions when the ship analyst adopts it as well. As mentioned in **Section 3.1.3**, there is no O&S WBS, but the 2020 CAPE O&S Cost-Estimating Guide provides an O&S CES.

4.1.3 Creating a Cost Estimate Schedule

Once the stakeholders define the purpose and scope of work, the analyst should develop a resource-loaded schedule[20] to provide a plan for completing the work. This plan should consider the timeframe in

[19] https://www.sawe.org/files/SAWE%20ESWBS%20RP%2003042011.pdf

[20] Referred to as a Plan of Actions and Milestones (POAM or POA&M) in some contexts.

which the cost estimate is required[21], the types of results needed, and the format(s) in which the analyst needs to provide them. The cost estimate schedule must plan adequate time to complete all steps of the cost estimating process.

Although it is not necessary to develop a logically linked schedule in a scheduling tool (such as Microsoft Project or Primavera®), the schedule should provide a sequential set of steps that need to be completed, many of them iteratively, and identify the resources required. It should include key meetings, dates when key deliverables are provided (with adequate time for draft reviews), and define the timeline for completion of the cost estimate. The analyst may “reverse engineer” the schedule dates based on the desired end state (e.g., the date a program must submit documents to a Milestone C review panel). The schedule should be vetted with stakeholders for adequacy and availability of resources (both government and industry) to support it. Once finalized, the schedule is an important component of a cost estimate plan.

4.2 Framing Assumptions, Ground Rules, and Cost Estimate Assumptions

The second part of the cost estimate basis is the framing assumptions, ground rules, and cost estimate assumptions. The analyst needs to have a clear understanding of each of these and ensure he/she captures them in the cost estimate documentation. The remainder of this section discusses the differences among them and importance of each towards the goal of developing a credible and defendable cost estimate.

4.2.1 Framing Assumptions

A framing assumption is any supposition (explicit or implicit) that could significantly shape cost, schedule, or performance expectations of the program. The program manager is responsible for developing the framing assumptions. The concept was introduced by PARCA (now named Acquisition Data and Analytics (ADA)) in 2012, when analyzing root causes of Nunn-McCurdy program breaches. PARCA identified false assumptions as a cause of significant cost growth in some programs, which led to the definition of framing assumptions.

DoDI 5000.85 mentions framing assumptions in the context of acquisition and states that the program manager is required to present them at Milestone A, Development RFP Release Decision, Milestone B, and in acquisition strategies. The principles of framing assumptions are applicable to any cost estimate.

In general, there should be a small number (optimally 3-5, but circumstance dependent) of framing assumptions with the following attributes:

- **Critical**: Significantly affects program expectations for cost, schedule, or performance.
- **No work-arounds**: Consequences cannot be easily mitigated.
- **Foundational**: Not derivative of other assumptions.
- **Program specific**: Not generically applicable to all programs.

Some sources of framing assumptions include:

- technological and engineering challenges,
- cost, schedule, and requirements trade-offs,
- effectiveness of program-specific managerial or organizational structures (particularly for joint or combined programs),

[21] DoDI 5000.73 outlines the timelines for the preparation of an ACAT ID ICE, ACAT IC cost estimate review, MYP contract cost analysis, cost analysis of Critical Nunn-McCurdy Breach, and others.

- suitability of contractual terms and incentives to deliver specific expected outcomes,
- interdependencies with other programs, and/or
- industrial base, market, or political considerations.

Framing assumption examples include:
- legacy performance requirements are adequate for this system,
- threat levels will not significantly change in the next *X* years,
- requirements will be relaxed as necessary to achieve cost and schedule goals,
- development of *X* technology will achieve required performance levels, or
- COTS items can be easily integrated and significantly reduce cost.

Framing assumptions are typically a part of program documentation and contained within the program definition. (See the 2013 PARCA Information Paper on Framing Assumptions at: https://www.acq.osd.mil/asda/ae/ada/docs/2013-09-13-information-paper-framing-assumptions.pdf, and DAU, Developing Framing Assumptions (FAs) Job Support Tools (JST) at: https://www.dau.edu/tools/Lists/DAUTools/Attachments/160/JST_FAs.pdf for more detail.)

4.2.2 Ground Rules

Ground rules represent a common understanding regarding the program that the analyst should not question or change unless the program office makes formal changes to the program. Ground rules are different from framing assumptions (**Section 4.2.1**) in that ground rules characterize the program while framing assumptions describe an environment within which the program must perform or face significant problems. The CARD should document the ground rules that are important to the program office and stakeholders. Ground rules provide a common understanding for activities, constraints, events, or other concerns that have a major influence on program cost, schedule, and performance. They may include scheduled events, budget constraints, involve Government Furnished Equipment (GFE) / Government Furnished Information (GFI), or anything else that may have a major influence but is open to interpretation. Information commonly addressed in ground rules include:
- boundaries of the program/estimate,
- a production profile for the system,
- the CY for which the cost estimate will be reported,
- how recurring and nonrecurring effort is segregated,
- the expected age or life cycle of an individual platform,
- the year in which a program completes IOC and transitions into sustainment,
- the maintenance approach to maintaining a platform,
- scopes of work that are not included in an estimate (used in AoAs and similar studies),
- how to report sunk cost in a life-cycle cost estimate, and/or
- the discount rate used to conduct NPV / Return on Investment (ROI) calculations (provided in OMB Circular A-94).

It is important for the analyst to remember that the program manager and his/her technical experts create the program's ground rules, not the analyst.

4.2.3 Cost Estimate Assumptions

Separate and distinct from the program definition and framing assumptions developed by the program manager and ground rules approved by all stakeholders, the analyst develops assumptions to bridge any gaps resulting from incomplete information. Cost estimate assumptions are never arbitrary, and all stakeholders should review and understand them. The most important assumptions are often the ones the analyst makes when there is no ground rule. For example, in the early stages of a program, decisions regarding the service life of a platform may be unknown. If not provided as a ground rule, an assumption is required to establish the number of years the platform will be in service, and that is used as a basis for estimating O&S and disposal cost. Examples of topics often requiring an assumption include:

- the degree of overlap between the Research and Development (R&D), Production, O&S, and Disposal phases,
- inflation and escalation rates used to normalize the cost estimate (if not a ground rule),
- where the production units are manufactured or if a production line is shared,
- process/plan disruptions,
- the amount of existing software that will be reused for a new application or purpose,
- the expectation of facility upgrades,
- operating hours per system,
- how a contractor's accounting cost is allocated across elements of the estimate structure, or
- the cost and schedule impacts of Foreign Military Sales (FMS).

The analyst must carefully think through assumptions, as they have a significant impact on the steps that follow, particularly how to build the cost model and address risk/opportunity and uncertainty.

4.3 Documentation of the Cost Estimate Basis

A completed cost estimate includes documentation of its results as well as the process followed to achieve those results. At this point in the process, the cost estimate basis needs to be clearly defined and documented. The complete estimate documentation is easier to build when the cost team starts constructing it upfront and keeps it updated throughout the cost estimating process. As with all the estimate documentation, the cost estimate basis should be constantly updated, but under a reasonable level of configuration management.

4.4 Cost Estimate Basis References

- AFCAA, AFI 65-508, 2018, para. 2.1 "*Cost Estimate Types and Expectations*"
- AFCAA, Cost Analysis Handbook, 2008, para. 5-1 "*Understand the Purpose of the Estimate*"
- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7.3.2, "*Ground Rules and Assumptions*"
- Department of the Army Cost Analysis Manual, 2020, Chap 3 "*Cost Estimating Process*", pg. 9 and Appendix 7 *"Example Documentation*"
- DoDI 5000.73, Cost Analysis Guidance and Procedures, 2020, Section 3 "*Cost Estimate Requirements and Procedures*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 4 "*Step 1: Define the Estimate's Purpose*" and Chapter 5 *"Step 2: Developing the Estimating Plan"*
- MARCORSYSCOM, Cost Analysis Guidebook, 2020, para. 3.0 "*Establish Needs with Stakeholders*", and para. 3.1 "*Establish a Program Baseline*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Chapter 2 "*Define the Purpose*"
- NASA, Cost Estimating Handbook, 2015, Chapter 2 "*The Cost Estimating Process*"
- NCCA, Cost Estimating Guide, 2010, para. 1.1 "*Establish Needs with Stakeholders*"
- NCCA, Joint Agency Cost Estimating Relationship (CER) Development Handbook (JA CER Handbook), 2018, para. 1.3 "*Cost Estimate Purpose and Scope*"

- NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014, para. 2.1, "*Strategic Approach*"
- NCCA/AFCAA, Software Development Cost Estimating Handbook, 2008, para. 3.4 "*Estimating Process*"
- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, para. 3 "*Establish Needs with the Customer*"

4.5 Cost Estimate Basis Training

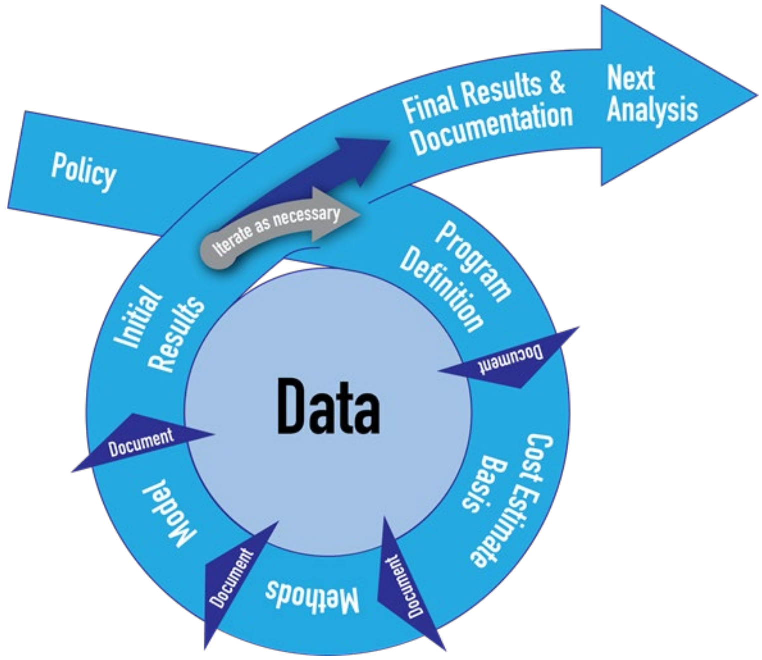
The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimate basis. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000 Fundamentals of Cost Estimating
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- Continuous Learning, Engineering (CLE) 021 Technology Readiness Assessments

The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 1560 DoD FM 101 - Cost Analysis
- FMF 6175 AFIT Cost 669 - Advanced Cost Analysis
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

5.0 IDENTIFY, COLLECT, VALIDATE, NORMALIZE, AND ANALYZE DATA



The core of a quality cost estimate is defendable, credible, and relevant data. The best cost estimating methods are those that rely on credible and reliable data. For each cost element within the estimate, the analyst must identify and use the best data available. Data needs are not always clear at the assignment's beginning, and data requirements often evolve during an estimate's development. This makes data collection one of the most difficult, time-consuming, and costly activities in cost estimating.

The relevance, currency, and quality of the data defines its usefulness to the cost estimate. A small mistake in the interpretation, analysis, and application of imprecise or irrelevant data can lead to a large error in the estimate results. Data collection is a top priority for analysts.

The DoD cost estimating process graphic highlights the importance of data by placing it in the center, influencing and being influenced by every step in the process. The availability and usefulness of data has a significant influence on the remaining cost estimating steps. The data step in the cost estimating process includes collection, validation, and normalization processes, which all rely on a strong foundation built by the program definition and cost estimate basis. The program definition and cost estimate basis drive the data source identification and collection process. The focus of finding and collecting data should target the greatest program cost contributors and the cost drivers that have the most influence on total cost.

This chapter provides guidance on the types of data, where to find that data, how to collect it, and how to validate it. This chapter also introduces the data normalization process and data analysis techniques that support the cost estimating process.

5.1 Characterizing Data

Data is either quantitative or qualitative. Both quantitative and qualitative data is also either objective or subjective. Relevant, accurate, and objective quantitative data is the most useful, but subjective, qualitative data may also provide valuable context for the cost estimate.

- **Quantitative data** are measures of values or counts and are expressed as numbers. Weight, power, labor rates, quantities, and rate of production are all examples of quantitative data.
- **Qualitative data** approximates and characterizes the item(s) of interest. SMEs illuminate essential details not immediately apparent in the objective quantitative data. Analysts collect qualitative data through one-to-one interviews, focus group meetings, and similar methods. An example of qualitative data are descriptions of how the program of interest

compares to others by describing relative measures of complexity, production efficiencies, differences in resource capabilities, and identifying programs that are "similar".

- **Objective data** is an observable or measurable fact and comes with a pedigree, a well-documented source. Facts are without bias and rely on relevant, accurate, and actual historical data. Cost analyses become meaningless if the data behind them are incomplete, irrelevant, or simply wrong. An analyst should invest time to find objective data sources. When an analyst learns near the end of the cost estimating process that a source of objective data was in fact available, but missed, it can impede a good estimating outcome and the approval process. An example of objective, quantitative data is the weight of an existing item. A description of implemented production line improvements is objective, qualitative data.
- **Subjective data** originates from sound judgment and expert opinion. While objective data is preferred, subjective data is often necessary. This speaks to the art of cost analysis being every bit as important as the science. Acknowledging that the available objective data is not useful or misleading might lead the analyst to rely upon subjective data to fill a void. A SME opinion that the new product will be half the cost of the previous one is subjective, quantitative data. A production manager predicting that planned upgrades to the facility will deliver a moderate improvement in efficiency is an example of subjective, qualitative data. Analysts should understand that subjective data has the potential for many forms of bias. The 2014 JA CSRUH para. 2.5.2 "*Elicitation of Subjective Bounds from Subject Matter Experts*" provides an overview of the most common biases and techniques to mitigate them.

There is a distinction between primary and secondary data as shown in Table 7 of the 2020 GAO Cost Estimating and Assessment Guide. Primary data is generally of higher pedigree than the secondary data, as follows:

- **Primary**: Data collected from the original source such as the contractor accounting system.
- **Secondary**: Data derived, and possibly computed, from primary data e.g., $/lb.

Primary data is preferred during data collection so that the analyst does not inherit unknown derivations or biases of a secondary data set. If only secondary data is available, then the analyst should ensure that the cost team understands any derivations to the greatest extent possible.

5.2 Data Types

There is a variety of data types available to produce a quality cost estimate. Cost is just one type of data the analyst must collect for a complete dataset. As with the program system description, the analyst should obtain programmatic, performance, technical, and schedule data from the historical programs on which many cost estimating methodologies are based. The remainder of this section describes the types of data to be collected.

5.2.1 Cost Data

Cost data reflects monetary expenditures incurred on past or present systems. Cost data is best explained in the context of life-cycle cost that includes the top level cost categories, or phases of the system life cycle: R&D, Production, O&S, and Disposal. Each of these categories can be further categorized as[22]:

[22] For more detail, see DoDM 5000.04 CSDR Manual https://cade.osd.mil/content/cade/files/csdr/guidance/DoDM%205000.04-M-1%20CSDR%20Manual.pdf

- **Recurring**: Repetitive elements of R&D, Production, O&S, or Disposal that generally vary with the quantity being produced or maintained. Examples: fabrication, assembly, touch labor, installation, check out, and preventative maintenance.
- **Non-recurring**: Non-repetitive elements of R&D, Production, O&S, or Disposal that do not vary with the quantity being produced or maintained. Examples: definition, design, acceptance testing, and establishing a facility.

Analysts further subdivide recurring and non-recurring costs into subcategories such as labor, material, overhead, and fee. These subcategories are where the analyst is likely to find cost data.

It is also important to subdivide cost into time-sensitive and not-time-sensitive categories. Depending on when the analysts performs the cost estimate, the estimate may include both the cost incurred to date on the program and future costs. Costs incurred to date on the program are sunk cost and should be part of the data collection effort.

5.2.2 Programmatic Data

Programmatic data describes overarching characteristics of the program. Examples of programmatic data include: program WBS and/or O&S CES allocations (accounting), requirements growth, delay and disruptions, accounting system changes (prior to or concurrent with production), different production rates, and inflation/escalation. Each Component has developed cost guides that provide examples of programmatic characteristics unique to their environment that an analyst should capture during data collection to provide context and influence how to interpret the cost data. Programmatic data can have a direct and significant influence on the recorded cost data.

Programmatic data can be quantitative or qualitative. Analysts, or more likely automated systems, measure and record quantitative programmatic data (e.g., timekeeping systems, production line instrumentation, integrated accounting systems, onboard measuring instruments) as numeric values such as hours by labor category, quantities, production rates, purchasing, or fuel consumption. Qualitative programmatic data is descriptive rather than numeric (e.g., contract type, competition approach, heritage[23], and maintenance concept). Though direct use of qualitative programmatic data in a cost estimating model may not be immediately obvious, the context in which past costs have been incurred is an essential part of the full picture.

5.2.3 Performance and Technical Data

Performance data describes what the systems can/must do. Technical data describes physical and functional characteristics of the system. Speed, range, depth, survivability, and noise reduction are examples of performance characteristic data. Size, weight, and power (SWaP) are examples of technical characteristic data. Source lines of code (SLOC), function points, and story points are examples of software technical data.

5.2.4 Schedule Data

Schedule data describes activities and activity interdependencies that control or influence the progress on a program. Schedule dependencies and interactions between development, production, and software modifications/upgrades are just a few of the issues that could significantly influence a system schedule and therefore, the cost estimate. A well-developed schedule helps identify important handoffs between participants in a program. It also provides a frame of reference for the analyst to work with the scheduler to build resource loaded schedule. (See the 2015 GAO Schedule Assessment Guide, best

[23] Examples of heritage data are percent new design, number of new or modified drawings, and Technology Readiness Level (TRL).

practice 3 "*Assigning Resources to Activities*" for guidance on how to assign resources to a schedule.) Durations of key processes (e.g., development, final design, production, trials) help add context to the cost collected from the program. The top levels in the schedule should always be consistent with the program WBS and the O&S CES to facilitate mapping schedule data to the cost model.

5.3 Data Sensitive to Duration or Quantity

An important distinction to understand when collecting data is if the data are sensitive to time or quantity. This differs from the recurring and non-recurring data distinctions described in **Section 5.2.1**. Cost can be sensitive to:

- **Quantity**: Where cost is a function of how many items are produced annually and in some cases the rate at which they need to be produced.
- **Duration**: Where cost is a function of calendar or workdays, weeks, months, years or some other measure of time. For example, level-of-effort activity is sensitive to the number of workweeks a given team is required to be on the program.
- **Neither Duration nor Quantity**: Where cost is influenced by neither duration nor quantity. For example, the price of a facility may be the same regardless when the sale occurs.

Duration is a useful parameter to obtain in any data collection. Even if duration is not used directly in the estimating method knowing that the estimating method was based on programs with an average duration of *X* months and is to be applied to a program anticipated to run *Y* months provides a basis to reconsider adjusting the estimating method for duration. (See **Chapter 6.0** for estimating methods.)

5.4 Identify Data

There are a variety of sources that provide quality data on historical and current programs. **Table 3** provides a generic summary of potential data sources.

Table 3: Data Types and Generic Sources (not exhaustive)

Data Type	Data Elements	Potential Sources
Cost	Historical Costs Labor Costs Material Costs Fee, Overhead Pricing Costs	Basic Accounting Records Cost Reports CADE EVM Central Repository (EVM-CR) Contracts and Proposals
Programmatic	Development and Production Schedules Quantities Produced Production Rates, Breaks in Production Significant Design Changes	CARD Program Database Functional Organizations Program Management Plan Major Subcontractors
Performance/ Technical	Physical Characteristics Performance Characteristics Performance Metrics Technology Descriptors Major Design Changes Operational Environment	CARD Technical Databases Engineering Specifications/Drawings Performance/Functional Specifications Functional Specialist End User and Operators Master Equipment Lists
Schedule	Start/End Dates Schedule Dependencies	Integrated Master Schedule CADE and EVM-CR

The remainder of this section discusses more specific data sources available to the analyst.

5.4.1 Data Repositories

DoD and the Components have established useful collections and databases where analysts can obtain authoritative and curated data. These collections of documents and databases provide tremendous potential for an analyst to identify the data required for a cost estimate. Many of these sources have limited access in order to protect sensitive data. Analysts may need to apply for accounts to these systems and declare their need for access to the data. Non-government personnel may need to go one step further and prove they are supporting a government effort.

One of the largest data repositories in the DoD is CADE. CADE is a DoD initiative for collecting, organizing, and displaying data in an integrated web-based application. CADE supports the search for authoritative data by providing DoD employees access to a large amount of raw component/agency acquisition and O&S data. This expanding compendium of data includes historical cost, technical, programmatic, and contractual data across numerous ACAT I and II programs, information systems, and some BCATs. Government analysts across the DoD are encouraged to take advantage of CADE by obtaining accounts and accessing the system regularly to determine if data sources exist within CADE that improve their cost estimates. Two of the primary data sources within CADE are:

- **Contractor Cost Data Reporting (CCDR)**: Used by contractors to report all costs associated with the contract. (See https://cade.osd.mil/content/cade/files/csdr/guidance/DoDM%205000.04-M-1%20CSDR%20Manual.pdf for more detail.)
- **Software Resources Data Report (SRDR)**: Used by contractors and government entities that develop or maintain software to report all technical and cost data on software development, software maintenance, and Enterprise Resource Planning (ERP) development efforts. (See the SRDR Implementation Guidance https://cade.osd.mil/content/cade/files/csdr/guidance/SRDR%20Implementation%20Guide_2019.02.01.pdf for more detail.)

The CCDRs and SRDRs are the primary means by which the DoD collects data on the costs that contractors incur on DoD programs. Policies including DoDI 5000.73 and DoDM 5000.04 establish the requirements for these two specific reports. The CADE website (https://cade.osd.mil/about/cade) provides more information. The FlexFile report and Quantity Data Report[24] are the default cost reporting requirements for new programs. The core of the FlexFile delivers time-phased dollars and hours at the account level in contractor native categories. The Quantity Data Report ties the necessary quantity information to the FlexFile. These files can be very large. (See https://cade.osd.mil/policy/flexfile-quantity for more detail.) **Table 4** lists additional data sets and analysis options within CADE.

Another example of a collection of identified data sources is the EVM-CR, which the Integrated Program Management (IPM) division of ADA manages. The EVM-CR establishes a source of authoritative EVM data for the DoD. Programs with contractual EVM reporting requirements submit their EVM data in the form of Integrated Program Management Data and Analysis Reports (IPMDARs) to the EVM-CR. (See https://www.acq.osd.mil/asda/ae/ada/ipm/index.html for more detail.) Contracts that do not meet the EVM reporting thresholds submit EVM data as determined by their CAE, typically reporting only directly to their program office or PEO.

[24] On the legacy CCDR forms, quantity data were reported in tandem with cost data. Quantity data are now reported separately from the cost data (FlexFile) as part of the Quantity Data Report.

Table 4: CADE Data

Name	URL	Synopsis
Defense Automated Cost Information Management System	https://service.cade.osd.mil/dacims35/site/home.aspx	Second source of CSDRs. Contains historical files back to 1966, and various 1921 forms
Data & Analytics Program Search	https://service.cade.osd.mil/cade/Site/SelectFavoritePrograms.aspx	Search by Program, Contract, Plan, or Submission for CSDRs
CSDR Browse	https://service.cade.osd.mil/cade-ng/data-by-program/browse-submissions	Allows search across multiple components (i.e., program, commodity, service etc.) to facilitate export of specific CSDR Data
Contract Database Search	https://service.cade.osd.mil/cade/Site/Tools.aspx	Search by Service, Commodity, Contractor, Plan Number, Program Manager, or Submitter/Reviewer
1921-3 & Forward Pricing Rates (FPR) Browse Submit-Review	https://service.cade.osd.mil/fprsr/	Search by Submission ID, Contractor, Date Range, and Reporting status to review Contractor Business Base Data Reports (1921-3) and Forward Pricing Rate Agreements (FPRA) by Contractor
Enterprise Visibility and Management of Operating and Support Cost (EVAMOSC)	https://evamosc.osd.mil/	EVAMOSC is a data platform for actual O&S cost data of major weapon systems to meet emerging requirements for senior leader decision support and the O&S data community. EVAMOSC will serve as the DoD's authoritative source of O&S cost data for weapon systems.
CADE Cost Community Library	https://service.cade.osd.mil/cade-ng/library	Various supporting documentation for specific programs to include CARDs, ICEs, technical data, etc.

Each Military Department has implemented robust data collection of O&S costs and related operational data under the umbrella of the DoD VAMOSC program. The specific VAMOSC databases are:

- **Department of the Army**: The Operating and Support Management Information System (OSMIS) contains reparable and consumable costs for selected tactical systems by major command. The Army Military-Civilian Cost System (AMCOS) provides personnel cost factors for estimating acquisition, installation operations, and force/unit requirements. AMCOS is particularly useful for the development of the training mission. (See https://www.osmisweb.army.mil/ for more detail.)
- **DON**: The Naval VAMOSC management information system collects and reports US Navy and Marine Corps historical direct O&S costs of weapon systems, some linked indirect costs (e.g., ship depot overhead), flying hour metrics, steaming hours, age of aircraft, etc. The VAMOSC Military Personnel databases contain personnel costs and attribute data. (See https://www.vamosc.navy.mil/)
- **Department of the Air Force**: The Air Force Total Ownership Cost (AFTOC) database serves to acquire, normalize, aggregate, allocate, and organize financial and logistic data. AFTOC satisfies the need to provide a single source of authoritative, processed financial and

logistics data organized by system or infrastructure. (See https://aftoc.hill.af.mil/ for more detail.)

Additional Component-level repositories are available, but details of those repositories are left to Component-level guidance.

A list of data repositories managed at the DoD level is shown in **Table 5.**

Table 5: DoD-level Data Repositories

Name	URL	Synopsis
Advanced Analytics (ADVANA)	https://advana.data.mil	Leverage leading edge analytics to deliver business value
CADE	https://cade.osd.mil	Authoritative source of all programmatic, system, hardware, software, and technical data pertaining to cost
Collaborative Cost Research Library (CCRL) System	https://www.ncca.navy.mil/library/library.cfm	Cost analysis publications including technical documentation, briefings, ICEs, CCEs, CARDs, service cost positions, etc.
Contract Business Analysis Repository (CBAR)	https://www.dcma.mil/aboutetools/	DoD Procurement Contracting Officer (PCO) access to Defense Contract Management Agency (DCMA) contract-related company information
Defense Acquisition Visibility Environment (DAVE)	https://dave.acq.osd.mil/login	Accurate, authoritative, and reliable data supporting acquisition oversight, insight, analysis, and decision-making
Defense Finance and Accounting Service (DFAS) Electronic Document Access (EDA)	https://www.dfas.mil/contractorsvendors/irapt/eda.html	Secure online access, storage, and retrieval of contracts, contract modifications, Government Bills of Lading (GBLs), DFAS Transactions for Others (E110), vouchers, and Contract Deficiency Reports
Defense Technical Information Center (DTIC)	https://discover.dtic.mil/	Science and technology data to support development of the next generation of technologies for our Warfighters
EVM-CR	https://www.acq.osd.mil/asda/ae/ada/ipm/index.html	Authoritative EVM data for DoD
Maintenance and Availability Data Warehouse (MADW)	https://madw.acq.osd.mil	Weapon system and readiness reportable equipment availability, cost, inventory, and transactional maintenance data

Analysts must fully understand the limitations of any data repository, including the intended purpose of the repository and how the data was collected, normalized, and/or presented for user consumption. The repository's data dictionary and/or user guide should provide this type of information. In additional to data repositories, there are various data libraries available to cost estimators.

The Data & Analytics application in CADE contains Cost and Other Libraries. These libraries provide the analyst access to several libraries managed across the DoD or by DoD affiliated research partners, with a wealth of prior estimates, cost research, system specific technical and programmatic information, and the results of cost estimating research projects. These libraries include:

- The CADE library,

- The Air Force library,
- The Cost Research Hub,
- Federally Funded Research and Development Center (FFRDC) libraries,
- The DTIC,
- The Pentagon digital library, and
- The Datasets, Tools, and Models Hub (DTMHub).

The following paragraphs briefly describe each of these resources.

The **CADE library** combines many years of data accumulation on a host of programs to include ICEs, CARDs, program briefings, and a variety of other material deemed relevant by the cost estimator. Currently there are approximately 4,500 documents covering data sets, program briefs, acquisition strategies, Post Award Conference information, collaboration/ conference materials, GAO Reports, contractor information, and analyses for approximately 800 defense programs. The repository is mainly used to store hanging files that are searchable via a variety of fields. It is important to note that the library search does not include a site-wide search of the CSDR or EVM data in DACIMS, the EVM-Central Repository, or CADE at-large. As the library evolves, it will contain older CAPE files, including thousands of older documents dating back as far as the 1950s.

The **Air Force library** allows analyst access to Air Force specific research documents, data sets, program briefs, acquisition strategies, and other authoritative documents. The Air Force Library provides secure access to service-specific, programmatic documents. Designated Air Force librarians manage library content and restrict access to designated user groups. Currently contributing librarians represent Air Force programs from space systems to ground systems and most weapon systems. Analysts interested in restricted documents can request access from the librarian.

The **Cost Research Hub** is an Office of the Deputy Assistant Secretary of the Army for Cost and Economics (ODASA-CE) sponsored platform that allows analysts to search, retrieve, and incorporate official, validated data for cost estimates and models. The application supports Automated Cost Database (ACDB), Selected Acquisition Report (SAR) queries, and houses ACDB cost studies. Using the ACDB Bulk Data Flat Files Library, users can download Excel files containing mapped and normalized CSDR data published to ACDB for all records within each of the four ACDB databases; Aviation, Communications and Electronics, Missiles and Munitions, and Wheel and Tracked Vehicles.

The **FFRDC libraries** include: Aerospace FFRCD, Center for Naval Analysis, Lincoln Laboratories, National Defense Research Institute, National Security Engineering Center, Software Engineering Institute, and the Systems and Analysis Center (Institute for Defense Analysis). These facilities all conducted research and development on behalf of the government and provide written reports of their efforts.

DTIC is the authoritative source for the DoD's scientific and technical information, under the auspices of the USD (R&E). The DTIC mission is to aggregate and fuse science and technology data to rapidly, accurately, and reliably deliver the knowledge needed to develop the next generation of technologies to support the Warfighter and help assure national security. Some information in DTIC is available in a public collection, while other information is limited to government employees.

The **Pentagon library** serves the needs of the offices of the Secretary of Defense, Joint Chiefs of Staff, and the Military Departments. The collection focuses on the topics of military, law and legislation, government, history, international affairs, and management and leadership. The Pentagon Library utilizes both physical and electronic resources, including books, journals, newspapers, and inter-library loan.

While not a library per se, the **DTMHub** is a collection of endorsed datasets, tools, and models to share with the cost community. DTMHub enhances collaboration and provides more data access to government analysts. Organizations that have developed or utilized datasets, tools, and models that may be helpful to the cost community can contact the POCs listed in the DTMHub to have their information placed into the DTMHub.

5.4.2 Deliverables and Reports

DoD programs routinely prepare business and engineering products to organize information and guide staff towards successful project completion. For cost estimating purposes, these artifacts are rich with programmatic, performance, technical, and schedule data. There is a variety of specific government and industry products that analysts can search for during data discovery.

Required acquisition documents can provide a wealth of information for an analyst. A list of all of the statutory and regulatory documents required for an acquisition program, including the timing of the various documents, can be found at: https://www.dau.edu/aafdid/Pages/Milestone-and-Phase-Information-Requirements.aspx. **Table 6** uses that list to highlight possible data sources. These documents may be a data source for both the system being estimated and historical systems. Given the number and variety of reports Program Offices/Industry are required/contracted to produce and deliver, analysts should research to determine whether desired data and information is already available through established sources before initiating requests which duplicate existing requirements.

Table 6: Potential Data Available in Required Acquisition Documents

Acquisition Documents	Cost	Programmatic	Performance	Technical	Schedule
4251 Written Determination (formerly 2366a)	X	X			X
4252 Certification and Determination (formerly 2366b)	X	X			X
Acquisition Decision Memorandum (ADM)	X	X			
Acquisition Program Baseline (APB)	X	X	X		X
Acquisition Plan (AP)/Acquisition Strategy (AS)	X	X	X	X	X
Affordability Analysis	X	X			
AoA	X	X	X	X	X
Bandwidth Requirements Review				X	
Capability Development Document (CDD)	X		X		
Capability Production Document (CPD)	X		X		
CARD	X	X	X	X	X
CCE	X				
CCP	X				
Clinger-Cohen Act Compliance		X			X
Concept of Operations (CONOPS)			X		
Contract Data Requirements List (CDRL)	X	X	X	X	X
Core Logistics Determination/Sustaining Workloads		X		X	X
Cybersecurity Strategy			X	X	X

Table 6: Potential Data Available in Required Acquisition Documents (continued)

Acquisition Documents (continued)	Cost	Programmatic	Performance	Technical	Schedule
Defense Intelligence Threat Library		X		X	
Development RFP Release Cost Estimate	X				
DoD Component Life Fire Test and Evaluation Report			X	X	
Director, Operational Test and Evaluation (DOT&E) Report on IOT&E			X	X	
EA	X	X			X
Executive Order 12114 Compliance Schedule			X	X	X
Exit Criteria			X	X	
Frequency Allocation Application				X	
Full Funding Certification Memorandum[25]	X				
ICE	X				X
Independent Logistics Assessment (ILA)	X		X	X	
Information Support Plan (ISP)			X	X	X
IT and National Security Interoperability Certification				X	
Initial Capabilities Document (ICD)			X		X
Item Unique Identification (IUID) Implementation Plan		X		X	
Life-Cycle Mission Data Plan		X	X	X	X
Life-Cycle Sustainment Plan (LCSP)		X	X	X	X
Live Fire Test and Evaluation (LFT&E) Report			X	X	
Low-Rate Initial Production (LRIP) Quantity		X			X
Operational Test Agency (OTA) Report of Operational Test and Evaluation (OT&E) Results			X	X	
Operational Test Plan (OTP)			X	X	
Post Implementation Review (PIR)		X	X	X	
Preservation and Storage of Unique Tooling Plan		X		X	X
Program Protection Plan (PPP)		X	X	X	
Replaced System Sustainment Plan		X			X
RFP	X	X	X	X	X
Should Cost Target	X				
Spectrum Supportability Risk Assessment			X	X	
Systems Engineering Plan (SEP)			X	X	
Technology Readiness Assessment (TRA)			X	X	
Technology Targeting Risk Assessment				X	
Test & Evaluation Master Plan (TEMP)		X	X	X	X
Validated On-line Lifecycle Threat (VOLT) Report				X	
Waveform Assessment Application				X	

[25] More recently, full funding is documented through an ADM signed by the MDA. However, bespoke full funding memos are likely available for older programs and may provide information.

Table 7 lists additional government documents/reports that may provide data appropriate for estimating. These are not required acquisition documents, but may support required acquisition documents. They may be available for both the program being estimated and any identified analogous systems.

Table 7: Potential Data Available in Identified Government Data Sources[26]

Government Source	Cost	Programmatic	Performance	Technical	Schedule
Contract Funds Status Report (CFSR)	X	X			
Contracts	X	X	X	X	X
Contract History/Data (detailed)	X	X	X	X	
CCDR	X	X	X	X	X
Defense Acquisition Executive Summary (DAES)	X	X	X	X	X
Deployment Plan/Beddown Plan		X			X
Depot Source of Repair (DSOR)		X		X	X
Detailed Test Execution Plans			X	X	X
EVM Reports	X		X		X
Failure Mode Effects and Criticality Analysis (FMECA)			X	X	
Failure Reporting, Analysis, and Corrective Action System (FRACAS)			X	X	
FPRAs	X				
Integrated Logistics Support Plan (ILSP)		X	X	X	X
IPMR	X		X		X
Life-Cycle Management Plan (LCMP)		X	X	X	X
Manpower Estimates/Actuals		X		X	
Performance Work Statement (PWS)			X	X	X
President's Budget (PB)/Budget Estimate Submission (BES)	X				
Previous Cost Estimates	X	X	X	X	X
Resource Data Table (RDT) - Gov information	X	X		X	X
Risk Management Plan	X		X	X	X
SAR	X	X	X	X	X
Software Quality Report			X	X	X
SRDR	X		X	X	
Spares Provisioning Report				X	X
Statement of Objectives/Work (SOO/SOW)		X	X	X	X
Store Technical and Mass Property Sheet (STAMP)				X	
Technical Requirements Description (TRD)			X	X	

Table 8 lists documents/reports available from industry that may provide information relevant for an analyst.

[26] DON 2010 Cost Estimating Guide, para. 1.3.2.1; 2018 JA CER Handbook, para. 1.4; AFCAA Tabular Cost Analysis Requirements Description (CARD) Sufficiency Review Handbook

Table 8: Industry Data Sources to Consider[27]

Industry Source	Cost	Programmatic	Performance	Technical	Schedule
Bill of Materials (BOM)/Parts List	X	X			
Business Plans		X		X	X
Catalog Prices	X				
Configuration Audit		X		X	
Configuration Drawings			X	X	
CCDR	X		X	X	X
Contract WBS (CWBS)		X			
CSDR Technical Data Reports			X	X	
Integrated Master Plan/Schedule (IMP/IMS)					X
Mass Properties (detailed)				X	
Power Allocation Summary				X	
Preliminary and Critical Design Review Reports			X	X	X
Proposals	X	X	X	X	X
RDT - contractor information	X	X		X	X
SWaP Reports			X	X	
SRDR	X		X	X	
Software Development/Sustainment Plan				X	X
Vendor Lists	X		X	X	

The potential data sources listed and discussed in **Section 5.4** are not an exhaustive list. Analysts should always pursue additional sources appropriate for the specific subject matter being estimated.

5.5 Collect, Validate, Normalize, and Analyze Data

Although described as a logical sequence, an analyst is rarely able to perform the data collection, validation, normalization, and analysis in a single pass. The process is typically ongoing and repeated within the iterative estimating process. At any point, it can become apparent that the analyst needs to revisit work performed in the previous step, or it could become clear that the data collected is unusable. Consequently, it is common for an analyst to return to refine the cost estimate basis (**Chapter 4.0**) and then search for other data sources. Sequential or not, the following sections describe the work to be done to conduct this step of the estimating process.

5.5.1 Data Collection Plan

A data collection plan establishes the time and resources required specifically for data collection, validation, normalization, and initial analysis. Analysts should recognize that the data collected provides a primary source for modeling and/or analyses. Historical cost, technical, schedule, and other programmatic data can/should be used to establish statistical parameters (e.g., measures of central tendency, anticipated range of outcomes, parameter distribution, etc.) for modeling. The entire data collection effort is a potentially difficult and time-consuming process. The analyst can make it more efficient by thinking through and documenting a deliberate, systematic, and succinct plan to accomplish the data collection goals. The analyst must adhere to the defined purpose of the collection effort and exercise continuous discernment regarding data usefulness or it can quickly become unmanageable. For

[27] DON 2010 CEG 1.3.2.1; 2018 JA CER Handbook, para. 1.4; AFCAA Tabular Cost Analysis Requirements Description (CARD) Sufficiency Review Handbook

large programs with numerous cost elements and cost drivers, the amount of data to collect is significant. Ensuring the data collected also supports the eventual estimate risk/opportunity and uncertainty analysis adds to the complexity, effort, and amount of data to be collected. This leads back to the importance of developing a data collection plan that maintains a focus on the largest cost contributors and cost drivers. The plan should include alternative actions or paths for when data collection and/or validation encounters dead-ends or useless data.

A data collection plan can treat these four levels of data collection sources sequentially: DoD level (e.g., CADE, EVM-CR), Component level (e.g., VAMOSC), program office, and industry. After each successive data collection step, analysts are able to focus more narrowly on filling the holes. Therefore, an analyst should start with CADE-housed and Component level data prior to approaching a program office. Subsequently, the analyst should exhaust program office-housed data before approaching industry partners. A clear and focused data request is extremely important because each party is busy fulfilling their primary missions. At a minimum, a data collection plan:

- identifies the data required and where the focus should be, consistent with the purpose and scope of the estimate,
- ensures that every cost element is covered,
- plans to capture time-phased data (e.g., monthly, quarterly), rather than just the total-at-completion. Doing so will allow for more accurate inflation/escalation calculations and analysis of the phasing profile,
- identifies the actions required to capture cost, programmatic, performance, technical, and schedule data,
- recognizes that the types and quantity of data available evolve as a system progresses through its life cycle,
- projects a data collection timeline to keep the estimating effort on track, and
- allows time for the inevitable need to iterate between the collection and validation phases.

5.5.2 Collecting Data

With a Data Collection Plan in place, an analyst can begin collecting the required data. Analysts handle objective and subjective data collection in different ways, and analysts may need to conduct the collection efforts more than once.

5.5.2.1 Objective Data Collection Activities

At a minimum, objective data collection activities include:

- **Identify**: Offices, organization, and points of contact.
- **Collect Cost Data**: Obtain costs (including labor hours), by cost account and accounting period.
- **Characterize Data**: Identify which elements of the estimate structure are quantity and/or time sensitive and which elements of the estimate structure are driven by one or more other element(s). Characterization can also be related to situation (peacetime vs. wartime) or other attributes that influence cost.
- **Document the Phase and Recurring/Non-recurring**: Identify the collected cost by life-cycle phase and also as recurring or non-recurring.
- **Allocate**: For accounts that contribute to multiple products, allocate their costs to the individual products. The program WBS and O&S CES dictionaries are key sources for explanations of what is included and excluded. The 2020 MIL-STD-881E and the 2020 CAPE O&S Cost-Estimating Guide provide definitions for individual elements. The program office typically defines any elements in the dictionaries not included in these documents.

- **Collect Cost Driver Data**: Collect performance parameters (such as speed, range, depth, stealth, and noise), technical parameters (such as size, weight, power, SLOC, frequency, duration, quantities, production rates), and schedule parameters (such as start/finish dates for phases and milestones), for each element of the estimate structure.

5.5.2.2 Subjective Data Collection

As mentioned in **Section 5.1,** the analyst may have to collect expert judgment from engineers, managers, and other SMEs. Called elicitation, numerous biases influence this process. For instance, an analyst may trace over-optimism both to cognitive biases, which are errors in the way the mind processes information, and to organizational (motivational) pressures. SMEs base their predictions on an assessment of their own capabilities, experiences, and expectations. The analyst can temper the elicitation process by having a statistical analysis of relevant historical data on hand. Such data provides a reality check that should have a positive influence on the SME's intuitive view of the situation. An analyst can often gauge SME input by asking for a range of answers vice a specific value. **Section 5.6** recommends additional reading on elicitation and subjective biases. **Appendix C** is a sample form for documenting SME information.

5.5.2.3 Data Collection Execution

Prior to any data collection, the analyst should understand and consider the proprietary, and possibly classified, nature of the data to be collected. While individual data elements may themselves be unclassified, at some level of aggregation they may become classified. It must be a priority to protect the data and to handle it appropriately.

With data protection in mind, the analyst's first round of data collection is the non-intrusive searching of existing data housed within government repositories. These resources are preferred because the analyst can query or browse them without imposing on others. Purposeful, efficient, and complete use of these resources not only satisfies many of the data collection needs but also allows the analyst to better focus on subsequent steps. While program office data is necessary and critical to the cost estimate, the time required to respond to data requests can become burdensome.

Government analysts visiting program office sites should request and expect to obtain access to relevant data. If the office internally manages execution data on shared drives or something similar with little to no outside connectivity, it is important for the analyst to work closely with the program to gain access to that data. As the program office delivers and/or the analyst retrieves necessary data, it may become quickly apparent that certain pieces of data are not available from the program office. This leads the analyst to propose discussions with the prime contractor, subcontractors, or other government offices.

Given that the defense industry manufacturers are a primary source of much of the data related to the program of interest, the analyst should make an effort to arrange site visits to enhance the understanding of the program and any relevant data. These site visits may involve participants from the program office, the appropriate Component Cost Agency, and/or the CAPE to provide for simultaneous participation rather than several individual visits. Analysts' requests for program office and/or contractor information and visits should include a list of data collection priorities well in advance. Many times, analysts can combine their required visits with other programmatic meetings.

5.5.2.4 Data Collection is an Iterative Process

Once the analyst has completed an initial round of searching government and contractor sources, the data collection picture is clearer. All expected cost elements and potential cost drivers should have an initial data capture that at least partially, preferably mostly, addresses them. The analyst should schedule repeat visits only after he/she has exhausted all other sources and clearly identified the remaining data requirements.

Gaps in clean, objective data might still exist after the analyst collects data from the sources mentioned in this chapter. If this happens, then the analyst should consider SME level guidance from other analysts and literature. Subjective data and SME guidance is often necessary.

In the context of the cost estimating process, data collection is not finished until the cost estimate is complete and approved. It begins again with the next estimate task. For data owners, data collection is an ongoing process, which could cause a change in cost estimate results. Data updates can establish trends and support key, fundamental findings within a cost estimate. Consequently, it is a good practice to query data sources more than once over the course of the cost estimate development.

5.5.3 Validate Data

Closely following the collection of data is the validation of the data. The analyst should not confuse this with validating the cost model or any other portion of the cost estimating process. Each of the Component handbooks and guides provide some guidance for data validation. The 2010 DON Cost Estimating Guide provides a good description of and basis for validating data. It explains the important distinction between verification and validation in the context of a cost estimate when it states "*validation ensures 'doing the right estimate' while verification ensures 'doing the estimate right'.*" In the context of data validation, one can restate this as: collecting the right data. Typical validation checks include:

- **Currency:** Identify the most recent, up-to-date data on analogous programs.
- **Applicability**: The most useful data originates from sources consistent with the program mission, operating environment, and platform type. As the analyst seeks analogous or related data, he/she must take specific care to ensure the analogy or related data appropriately represents the system being estimated.
- **Accuracy**: Import processes, manual entry, and interpretation of units are some of the issues that need careful attention to ensure accuracy of the data. Accuracy is established from evidence the data is correct, complete, and current for the item measured. Precision is not a measure of accuracy. For example, capturing a data element value to 10 decimal places is a measure of precision, but does not guarantee that the value is correct.
- **Veracity:** Try to obtain corroborating pieces of information from various sources. Concurrence or divergence sheds important light on the quality of the data.

5.5.4 Normalize Data

The purpose of data normalization is to convert the collected data into a form consistent with and comparable to other data used for the estimate. Normalization of data to support a particular estimate requires attentiveness to anything that influences how the analyst interprets and reduces the data to a form consistent with the cost estimate purpose. It is not just the cost data itself that requires attention. The following is a summary view of data normalization:

- **Cost Data**: An analyst must address many influences on cost to render the data in a consistent form. Contract WBS arrangements/changes/revised definitions, requirements creep, program durations, accounting system changes, prior or in-parallel quantities, production rates, labor rates (hours vs. days), and escalation/inflation are all examples of program characteristics that influence how to interpret the state of the cost data. The 2021 DoD Inflation and Escalation Best Practices for Cost Analysis includes details on how to address inflation/escalation normalization (https://cade.osd.mil/policy/inflationandescalation/).

The 2018 JA CER Handbook provides guidance on how to address many cost data normalization procedures beyond inflation/escalation (https://www.ncca.navy.mil/references/CER_Dev_Handbook_Feb2018_Final.pdf).

- **Programmatic Data**: An analyst uses programmatic data to adjust cost data for the quantitative and qualitative program characteristics introduced in **Section 5.2.2**. For example, the analyst can calculate the per unit cost for use in comparing costs to a budget or to other programs. Unit costs must be characterized by their lot or unit of production (e.g., the unit cost of the 100^{th} item (UC100)). It is equally important to account for the production rate (e.g., UC100 at a production rate of 10 per month), otherwise the analyst may reach misleading conclusions in comparing programs with dissimilar rates of production. Adjusting for quantity and production rate effects is called adjusting for learning effects, a topic covered extensively in the 2018 JA CER Handbook. The normalization process may not address some qualitative programmatic features of the data. Rather, these considerations may influence the cost method functional form selection.
- **Performance and Technical Data**: An analyst uses normalization of performance and technical data to convert data to a common set of units. Also, the values must be mapped to an element of the estimate structure or prorated across several elements based on either accounting or SME guidance. For instance, the analyst may have to prorate the total weight of an item across two or more elements of the estimate structure.
- **Schedule Data**: Schedule data includes milestone dates, activity durations, and activity dependencies (schedule impacts of one or more tasks on one or more others). Reducing costs to a cost per unit of time (e.g., cost per hour, week, month, or year) is a useful way to compare costs across or within programs. It provides a means to build cost models that are realistically sensitive to time. The analyst must confirm definitions of schedule terminology such as: FY, labor year, and holiday/vacation/sick leave adjustments. The federal FY starts on October 1 and runs through September 30 but this is typically not the same throughout industry. Similarly, time allowed for holidays, leave, and sick time is not consistent. However, each company has a standard definition for a labor year that they use for planning purposes.

5.5.5 Analyze Data

While collecting, validating, and normalizing data, it is appropriate to begin performing exploratory data analysis (detailed statistical analysis to support methodology selections comes later). The primary benefit of doing exploratory data analysis early is to discover patterns in data, holes in the data, potential outliers, and to narrow the gap between the collection of data and the understanding of it. This understanding, in turn, helps to:

- identify outliers (an observation that lies outside the overall pattern of the data)
- suggest hypotheses regarding the initial specification of regression equations for explaining changes in dependent variables such as cost or person hours of effort,
- support the selection of appropriate statistical tools and techniques, and/or
- provide a basis for further data collection.

Outliers can become apparent by simply graphing the data. Analysts should study these observations should to ensure the data is captured correctly and that the observation is relevant to the program. A more detailed look for outliers, and how to address them, happens in the estimating methods step of the cost estimating process. (See **Section 6.3.4** for a discussion on outliers.)

A wide range of statistical techniques is available to execute exploratory data analysis. These include:

- visuals (e.g., scatter plots, influence diagrams, and classification trees),
- traditional statistics (e.g., univariate, regression, and outlier considerations), and
- modern techniques (e.g., data-mining algorithms and machine learning).

DAU course BCF 130 "*Fundamentals of Cost Analysis"* introduces some of these techniques. Additionally, the commercial market has many software packages and visualization tools that are specifically oriented towards exploratory data analysis. The introduction of FlexFiles for collecting contractor data further motivates the desire to consider powerful data analysis tools, as the amount of data in a FlexFile can strain the limitations of more traditional tools like Microsoft Excel. (See **Section 5.4.2** for a discussion on government and contractor sources of data.) Free open-source programming languages are becoming popular alternatives to perform statistical analysis (e.g., R) and data science[28] (e.g., Python®) of large data sets. The data collected via FlexFiles will provide new opportunities for more detailed investigations into the way contractors perform their work.

5.6 Data References

- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 6, "*Sources of O&S Cost Data*"
- Department of the Army, Cost Analysis Manual, 2020, Chap 3 "*Cost-Estimating Process*"
- DoDI 5000.73, Cost Analysis Guidance and Procedures, 2020, Section 4, "*Data Collection*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 9, "*Step 6: Obtain the Data*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Section 5.7 "*Obtain Data*"
- NASA, Cost Estimating Handbook, 2015, para. 2.2.4 "*Task 7: Gather and Normalize Data*"
- NCCA, Cost Estimating Guide, 2010, para. 1.3.2 "*Collect, Validate, Normalize, and Analyze Data*"
- NCCA, Joint Agency Cost Estimating Relationship (CER) Development Handbook, 2018, para. 1.4 "*Sources of Data*" and para. 1.5 "*Collect and Validate the Raw Data*"
- NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014, para. 2.5.2, "*Elicitation of Subjective Bounds from Subject Matter Experts (SMEs)"*
- RAND, Improving the Cost Estimation of Space Systems, 2008, Chapter 3, "*Data Availability and Quality Issues*"
- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, para. 5.a(2) "*Collect, Validate, Normalize, and Analyze Data*"

5.7 Data Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimate data. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000 Fundamentals of Cost Estimating
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000 Advanced Cost Estimating
- BCE 1700 CADE 101

[28] Data science involves developing methods of recording, storing, and analyzing data.

- BCE 1710 FlexFiles 101
- BCE 2500 CADE 201
- CLB 030 Data Collection and Sources (*introduces the basics of data sources and collection as it relates to cost estimating*)
- CLB 033 Databases for the Cost Estimate (*introduces a cross section of DoD databases*[29])
- CLE 035 Introduction to Probability and Statistics (*basic introduction and understanding of probability and statistics)*

The ICEAA publishes the CEBoK. The follow modules are relevant to data:

- CEBoK v1.2, 2013, Module 4 "*Data Collection*"
- CEBoK v1.2, 2013, Module 5 "*Inflation*"
- CEBoK v1.2, 2013, Module 6 "*Data Analysis*"
- CEBoK v1.2, 2013, Module 10 "*Probability and Statistics*"

The following course numbers starting with FMF or FML refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

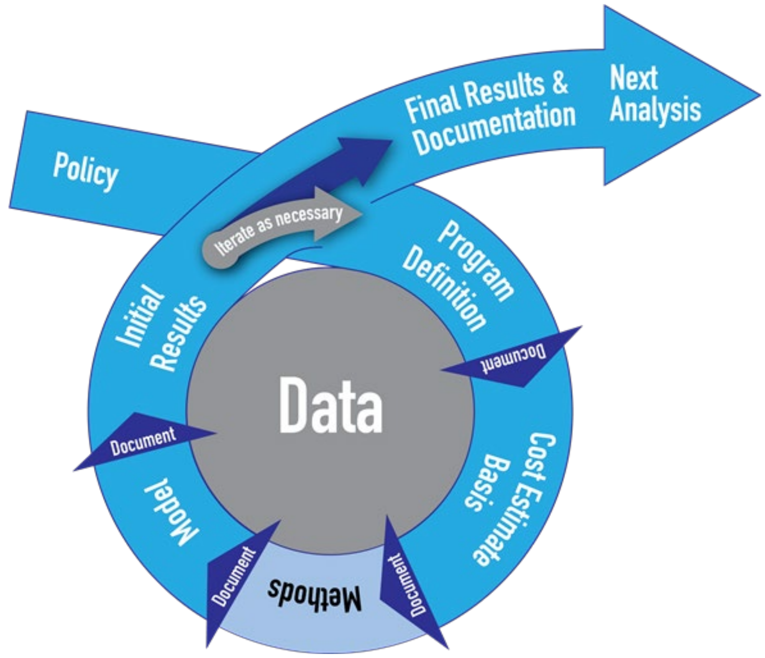
- FMF 1253 FMA 202 - Financial Management Concepts Course - Descriptive Statistics
- FMF 1124 FMA 204 - Financial Management Concepts Course - Trend Analysis
- FML 4110 Building Business Acumen
- FMF 4439 Air Force Total Ownership Cost (AFTOC) Decision Support System (DSS) 101
- FMF 4440 AFTOC Decision Support System (DSS) - Data Access Techniques
- FMF 4441 AFTOC Decision Support System (DSS) - Account Tool Basics
- FMF 4442 AFTOC Decision Support System (DSS) - Advanced Data Mining
- FMF 1546 Business Case Analysis
- FMF 6540 Analytic Cost Expert Distance Phase (ACE dL)
- FMF 7815 WKSP 0672 Data Analytics Tools and Techniques
- FMF 7816 WKSP 0673 Applied Concepts of Data Analytics Tools and Techniques
- FMF 7883 Data Analytics
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

Training on specific data sources is available at:

- CADE training videos: designed as a handy reference for the first-time user or seasoned analysts that just need a refresher. Topics include: user guidance for the CADE portal, data and analytics, plus "how to" guidance on CCDR, SRDR and available libraries are available at https://cade.osd.mil/support/videos (public)
- CADE Pivot Tables for Analysts: https://cade.bridgeapp.com/learner/library (requires a CADE login)
- Naval VAMOSC Training Videos: https://www.vamosc.navy.mil/
- Army OSMIS Training Videos: https://www.osmisweb.army.mil/Osmis/Support/SupportVideos and https://www.osmisweb.army.mil/Osmis/Support/Tutorials

[29] Access to most of the DoD databases is controlled and in some cases, is classified; both of these issues limit the databases that can be openly discussed.

6.0 SELECT COST/SCHEDULE ESTIMATING METHODS



Analysts build cost estimates using a combination of the estimating methods introduced in this chapter. The suitability of a specific method largely depends on the maturity of the program, the nature of a particular element of the estimate structure, the usefulness of available data, and the time available to develop the estimate. Like all the steps in the cost estimating process, this one is also iterative. In particular, the estimate basis and data collection steps both influence and are influenced by the progress made in identifying viable estimating methods.

The identification, collection, validation, and normalization of data along with the information from the program definition and cost estimate basis help determine the best cost estimating method for a particular element of the estimate structure. The data analysis described in the previous chapter primarily supports the data validation process, but that analysis may reveal patterns in the data that point to a specific estimating method. Additionally, analysts should review previous, similar estimates to identify estimating methods that worked well in the past.

Many estimating methods apply to estimating cost or schedule durations. For simplicity, this guide refers to both cost and schedule estimating methods as "estimating methods".

The remainder of this chapter introduces the most common DoD cost estimating methods, how to address outliers, and how to determine the estimating method uncertainty.

6.1 Basic Estimating Methods

Common estimating methods used in DoD cost estimates are analogy, build-up, extrapolation of actuals, and parametric.

The methods described below are intentionally presented alphabetically to avoid any perceived preferences. Component guidelines, circumstance, and the analyst's assessment drive the rank order of preference. The following sections introduce each method, and **Table 9** compares the advantages and disadvantages of each.

6.1.1 Analogy Estimating Method

With the analogy estimating method, the analyst bases his/her estimate for the new system or effort upon the known cost of a similar, completed system or effort. In its most basic form, the analogy method states that if a historical system is known to cost *$X*, and the new system is similar to the historical system, then the new system cost estimate is *$X*, subject to adjustments to account for differences between the programs.

Ideally, the analyst will base any analogies on data from completed programs. While an analyst can draw data from systems still under development or in production, it may be less defendable than drawing data from a completed program because significant, unforeseen changes could still occur in unfinished programs.

A primary advantage of using a fully developed and deployed analogous system is the ability to declare that the analyst has captured the impact of risk/opportunity and uncertainty experienced by the analogous program in the reported cost, schedule, and technical characteristics. This may be an over simplification and is discussed further in **Section 6.1.3**. A criticism of cost estimating based on past program(s) is that the risks that impacted the original program(s) will likely be avoided in the new program, but the new cost estimate still reflects these risks if the historical data has not been adjusted. A counter to this argument is that even if previous risks are avoidable, it is likely that new ones that influence the estimate in a similar way exist. The onus is on the analyst to develop a defendable approach.

It is unlikely that the analyst can find a perfect analogy for the system being estimated since technologies and capabilities evolve over time. Even if the new system is a direct replacement for an existing system, the new system likely has more capability. For example, computers have better processors, engines may have more thrust, or materials may weigh less. The analogy method should include adjustments to account for differences between the historical and new system. The analyst develops adjustments as objectively as possible based upon data analysis where feasible. In some cases, the adjustment might add or subtract value to account for differences in the systems. In other cases, the analyst may use factors, sometimes called scaling parameters, to account for differences in size, performance, technology, and/or complexity. The analyst should document how the analogous system relates to the new system, identify the important cost drivers, and decide how each cost driver influences the overall cost in the analogous and new system. The analyst can apply the analogy method to the program overall or to a specific, lower level element of the estimate structure. The selected analogy must have a strong parallel to the item being estimated, and any adjustments should be straightforward and readily understandable.

For this method, it is important for the estimator to research and discuss with program experts the reasonableness of the analogy, its technical program drivers, and any required adjustments for the new system. This discussion should address whether the adjustments are simple additions to or subtractions from the new system or if there is a need to employ scaling factors to the analogy. Scaling factors can be linear, nonlinear, or some other form. Linear adjustments are the most common and easiest to apply. Examples of nonlinear adjustments include using the cost improvement curve formula (**Section 6.3.2**) to adjust the analogy directly or to estimate the reference cost. The analyst should consider previously developed estimating methods for potential scaling approaches. The analogy method is a useful crosscheck when a different primary method is used.

6.1.2 Build-up Estimating Method

The build-up cost estimating method assembles the overall cost estimate by summing or rolling-up detailed estimates created at the lower levels of elements of the estimate structure. Because the lower-level approach associated with the build-up method uses industrial engineering principles, it is also referred to as an engineering build-up or a bottom-up estimating method. When extensive high-quality data exists from closely related systems and/or from limited-rate or prior production, the build-up method becomes a viable candidate methodology.

A build-up estimate is a detailed treatment of direct/indirect labor hours, direct/indirect labor rates, materials, facilities, travel, and all other costs for each element of the estimate structure. The analyst assigns costs at the lowest level elements of the estimate structure according to how the worker accomplishes the task(s). Typically, analysts work with manufacturing or maintenance engineers to develop the detailed estimates. The analyst's focus is to obtain detailed information from the engineers in a way that is reasonable, complete, and consistent with the program definition and its ground rules and assumptions.

When an analyst uses a build-up method for a production estimate, he/she normally applies it when the system's configuration is stable and the required details are available. The high level of detail requires the manufacturer to identify, measure, and track each step of the workflow so that the analyst can use the results to refine the estimate. When used as a primary method, the analyst should corroborate the results using one or more of the other methods identified in this chapter.

6.1.3 Extrapolation from Actuals Method

Extrapolation from actuals uses observed costs from earlier stages in the program to project a cost in future stages of the same program. Arithmetic averages, moving averages, burn rates, cost improvement curves, and EVM estimates at completion (EAC) are examples of extrapolating from actual costs. (See **Section 6.3.2** for a discussion on cost improvement curves.) These projections can occur at any level of elements in the estimate structure, depending on the availability of data. An analyst can consider the extrapolation of actuals method once an item's actual production or O&S data become available.

The analyst can generally account for changes in the product design, manufacturing process, or operating and support concept of follow-on items in the same ways discussed under the analogy estimating method. In this case, he/she simply treats the earlier items as the "analogy" instead of using another program. If major changes have occurred, analysts may need to consider a different estimating method since the actuals may not be relevant enough to extrapolate for future costs.

6.1.4 Parametric Estimating Method

The parametric estimating method centers around relating cost or duration to one or more programmatic, performance, or technical characteristics via an algebraic equation. The strength of a parametric estimate lies in the relevance/quality of the data and in the validity of the relationships within that data. Unlike an analogy, parametric estimating relies on data from many programs rather than just one and yields a relationship that is valid over a range of possible solutions. Also, unlike the analogy method, the parametric analysis captures the realities of situations addressed by a number of similar completed programs, rather than realities from just one program. The analyst should consider the number of data points required to form a statistically useful data set. The 2018 JA CER Handbook addresses this topic.

Analysts use parametric cost estimating models throughout the life cycle, but they are particularly useful tools for preparing early conceptual estimates when performance and technical details are not fully developed. They are also useful for quickly establishing cost and/or schedule impacts over a range of alternatives.

Ultimately, the parametric method's objective is to find the best functional form of an equation to fit the available data. While there are many ways to construct the best curve through a series of data points, regression is popular because it provides statistical inference and an assessment of the uncertainty present in a curve. The regression analysis used in this method is a statistical process for estimating the relationship between a dependent variable (the element estimated) and one or more independent variables (variables that influence the estimate). The resulting equation is a parametric CER (to estimate a cost) or a SER (to estimate schedule durations).

An analyst applies parametric regression analysis in an iterative process testing functional forms against the available data sets many times prior to selecting the best equation. The best equation is one that:

- makes sense (i.e., the behavior between the independent and dependent variables is logical),
- is based on data that is relevant to the estimate,
- is populated with independent variables that are within the source data set range,
- passes all the statistical tests for significance,
- generates the least uncertainty, and
- is the simplest of the equally accurate, statistically significant relationships.

The two most common functional forms are:

- **Linear**: $Cost = a + b * Parameter + \mathcal{E}$
- **Nonlinear**[30]: $Cost = a * Parameter^{b} * \mathcal{E}$

The functional forms only show one parameter for simplicity. Parametric equations often have more than one independent variable (parameter). Independent refers to the relationship between multiple parameters used in the same equation. Regression theory requires parameters to be independent of each other.

The error term $\mathcal{E}$ in the functional forms represents the difference between the data and the result predicted by the equation. The objective of regression analysis is to solve for the coefficients (e.g., *a* and *b*) that minimize $\mathcal{E}$. The 2018 JA CER Handbook provides more detail on these and other parametric equations and the available regression techniques used to solve for the coefficient values.

When the analyst uses regression analysis to develop parametric equations, he/she needs to document the conditions under which the relationships were established. This information is necessary to support the validity of the estimate and influence how to address uncertainty. Each equation used in the estimate should be documented with descriptive and regression statistics, assumptions, and data sources.

6.1.5 Comparing Basic Estimating Methods

Table 9 summarizes the advantages and disadvantages of the basic estimating methods.

Figure 2 is an illustration of which cost estimating methods are often most appropriate at different times through the system's life cycle. **Appendix F** contains figures from several guides and handbooks that illustrate where in the major capability acquisition process each of the basic estimating methods may apply. **Figure 2** is a generalized rule-of-thumb for analysts working on MCA programs. However, it is always up to the analyst to decide the most appropriate method for a particular element or phase, usually dependent on the data that is available.

[30] Also known as a "log-linear" equation because it becomes linear when taking the logarithm of both sides. Natural log (LN) is the standard practice.

Table 9: Summary of Advantages and Disadvantages of Basic Estimating Methods

Estimating Method	Advantages	Disadvantages
Analogy	• Applicable before detailed program requirements are known • Can be developed quickly • Completed analogous program inherently includes risk and uncertainty • Based on objective historical data that can be readily communicated and understood	• Relies on a single data source • May require adjustments for risks/opportunities and uncertainties not present in the current program • Technical data required for scaling may be elusive and/or difficult to defend • Subjectivity with technical parameter adjustment factors likely to be introduced • Appropriate analogy may not be available
Build-Up	• Fully documents and addresses exactly what the cost estimate includes • Captures the specific manufacturer's processes and rates • Explicitly reveals the major cost contributors • Provides a basis to check for duplicates and omissions	• May be expensive to implement and time consuming • Less flexible and may not answer many of the what-if questions • New estimates must be built for each alternative • Product specification must be well known and stable • All product and process changes must be reflected in the estimate • Small errors can grow into larger errors through the summation • Elements can easily be omitted or duplicated by accident in large models
Extrapola-tion of Actuals	• Uses the program actual data to develop the estimate	• Access to sufficient and reliable cost data may be challenging • Changes in accounting, engineering, and manufacturing processes have to be identified and addressed
Parametric	• Versatile and can be derived at any level where the data is available • Supports what-if explorations of design alternatives • Supports cost driver sensitivity analysis • Provides objective measures of statistical significance of each coefficient and of the model as a whole • Provides objective measure of uncertainty (standard error) • Objective measure of the result's probability of exceedance • Derived from objective historical data	• Source data must be consistent, accurate, and properly normalized • Often have to rely on a few data points • Cannot use without fully understanding how it was generated • Must be updated to capture the current cost, technical, and program data • Populating with independent variable values outside the range of the source data leads to increased uncertainty and may produce erroneous results • Complicated relationships may be difficult to defend

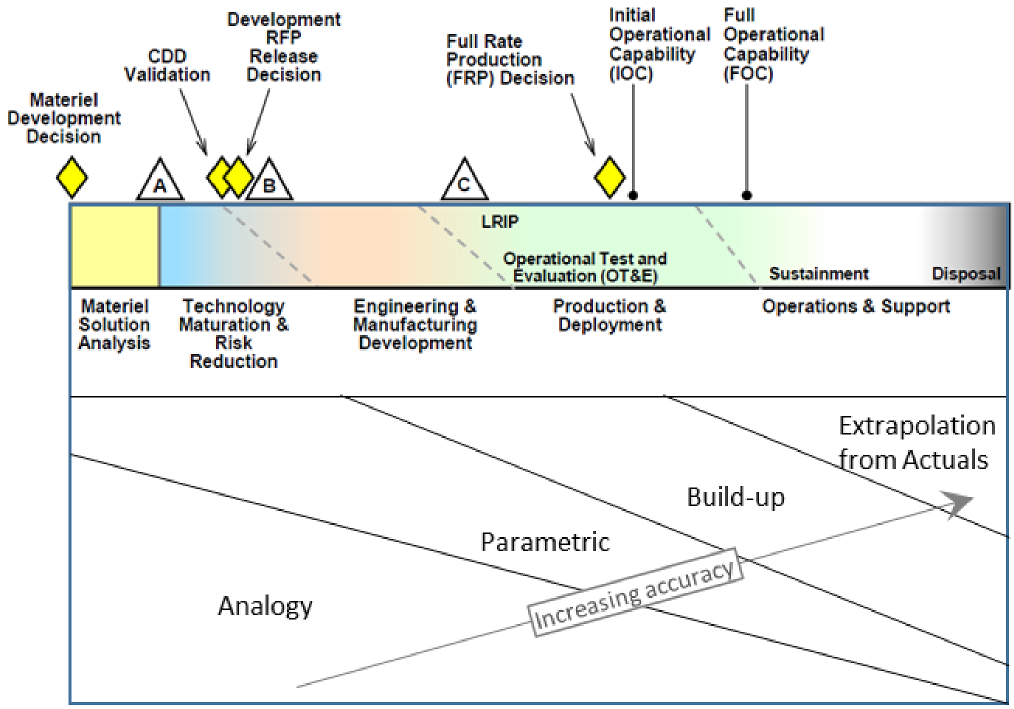


Figure 2: Estimating Method Applicability

6.2 Other Estimating Methods

In addition to the basic methods discussed in **Section 6.1**, the analyst has many other methods available to use that are applicable under certain circumstances. They include (listed alphabetically):

- **Expert opinion**: Relies on SMEs to give their opinion on what an element might cost or how the analyst should adjust its cost. Analysts often rely on SMEs during the early stages of a program, when they are making less detailed estimates.
- **Full-time Equivalents (FTEs):** One FTE represents the total hours available in a full-time schedule. The analyst estimates the total FTEs required and multiply by the FTE labor rate to arrive at cost. FTE estimates may be derived from an analogy, parametric equation, extrapolation of actuals, expert opinion, or other tools. A simple count of the number of people employed on the task is not a meaningful measure of the team's cost. Some members of the team may be hourly-on-call, some part-time, and others full-time. The required number of FTEs to perform a task[31] or to be constantly available (sometimes called the standing army) is a much more precise way to estimate effort and cost.
- **Industrial engineering standards**: Applies a realization factor to engineered work unit labor standard times. A unit time value for the accomplishment of a work task is determined from a work measurement program. Standard time is how long it takes to perform a particular task, based on time and motion studies done in controlled environments. Since the standards reflect an optimal production environment, the analyst calculates variance factors (also known as realization factors) based on measures of a company's actual experience compared to the standard. This approach can be a part of a build-up method.

[31] It is rarely true that doubling the size of the team will reduce duration by half. The bigger the team, the more effort spent in communications (e.g., meetings) and adhering to a collaborative work environment.

- **Tools:** Contains previously developed estimating structures and/or methods that the analyst uses to facilitate the development of a cost estimate. The tool is generally a software package and may come from internal government research or commercial sources specializing in cost estimating. The tools predicate their effectiveness on the ability to calibrate the tool to align with a given set of data or item. Since these models typically incorporate proprietary data and equations, visibility into their methods may be lacking. Therefore, their use as a primary estimating method is discouraged. However, there is utility in using these tools to crosscheck the reasonableness of an estimate. They can also serve as a last resort when no other method is viable.
- **Univariate analysis**: Is the statistical analysis of a single type of data, not a search for cause and effect relationships. Univariate analysis includes both descriptive and inferential statistics. Descriptive statistics yield measures of central tendency (mean, median, and mode) and variability (e.g., range, standard deviation, skewness, and kurtosis) of the data. The analyst can use inferential statistics to characterize the usefulness of the mean of the sample as the estimate for a new system. The advantage of using a univariate approach is that it is simple to apply and understand. It provides an objective basis to characterize the uncertainty of the result. The disadvantage is that it does not relate cost to a cost-driver and is therefore of no help in what-if or sensitivity analysis.

6.3 Additional Considerations

6.3.1 Correlation

Correlation is a measure of the degree two (or more) variables move together. It is a convenient tool to use to identify potential cost drivers. A good practice to build a correlation matrix, as illustrated in **Figure 3**[32]**,** to assess the correlation among the item estimated (dependent variable), potential cost drivers (independent variables), and the correlation *between cost drivers*. The example in **Figure 3** shows two types of correlation[33]**.**

- Pearson Product Moment correlation measures the *linear relationship* between variables. **Figure 3** shows a strong linear relationship between cost and aperture and between cost and power.
- Spearman Rank correlation measures the correlation *regardless of the relationship* type (e.g., linear, nonlinear, something else) between the variables.

It is good practice to measure both types of correlation, particularly if one of them suggests there is little or no correlation.

The results in **Figure 3** indicate a high correlation between power and aperture. This means power and aperture are not independent of each other, a behavior called multicollinearity. If an analyst regresses both power and aperture against cost, the CER/SER coefficients may change erratically in response to small changes in the data due to the interplay between power and aperture inputs. There are various ways to address multicollinearity if there is motivation to retain the influence of both parameters in the CER/SER. One way is to combine the two parameters into one, in this case: intensity. (See the 2018 JA CER Handbook for more detail on all aspects of this type of analysis.)

---

[32] **Figure 3** is a combined and modified version of Table 8 and 9 from the 2018 JA CER Handbook, pg. 40 and 43 respectively.

[33] The CORREL function in Microsoft Excel calculates the Pearson Product Moment correlation. Converting the data to ranks and applying the CORREL function yields the Spearman Rank correlation.

Guidance from and collaboration with applicable SMEs is particularly useful in the development of parametric relationships. SMEs can help propose or validate functional forms that make sense. It is not enough for independent variables to have a high correlation with cost, since correlation is not causation. The relationship should be logical, and ideally, a known scientific fact should relate the two. The assumption driving the parametric approach is that the same factors that affected cost in the past will continue to affect costs in the future.

	Normalized Data			Calculated Data
	Cost (BY20$K)	Power (kW)	Aperture (cm^2)	Intensity (kW/cm^2)
Project 1	$390	10.0	8.7	1.149
Project 2	$200	5.0	8.0	0.625
Project 3	$240	5.2	8.2	0.634
Project 4	$300	7.0		
Project 5	$460	12.0	9.0	1.333
Project 6	$560	17.8	9.5	1.874
Project 7	$700	21.0	9.2	2.283
Project 8	$800	25.0	9.7	2.577
Project 9	$500	18.0		

Pearson Product Moment Correlation				
	Cost	Power	Aperture	Intensity
Cost	1.000			
Power	0.981	1.000		
Aperture	0.939	0.943	1.000	
Intensity	***0.996***	*0.999*	*0.937*	1.000

Spearman Rank Correlation				
	Cost	Power	Aperture	Intensity
Cost	1.000			
Power	0.983	1.000		
Aperture	0.970	0.943	1.000	
Intensity	***0.995***	*0.996*	*0.964*	1.000

Figure 3: Notional Correlation Matrix Example

Correlation between uncertain variables and between estimating methods are important considerations when estimating total cost uncertainty. (See **Sections 6.4** and **7.4** for a discussion of estimating method uncertainty and cost model uncertainty.) The 2014 JA CSRUH provides guidance on how to address risk/opportunity and uncertainty correlation.

6.3.2 Cost Improvement Curve

The cost improvement curve (also known as a learning curve) is a technique to account for measured efficiencies in production when the manufacturer produces many units. The premise behind the use of the cost improvement curve is that people and organizations learn to do things better and more efficiently when they perform repetitive tasks, and the analyst should address the impact of this efficiency in the cost estimate. While the original research was rooted in manufacturing labor, the absence of repeated manual effort does not preclude its use. The same phenomenon is observable in successive production lots as the entire program enterprise incrementally learns and adapts to doing things better. The analyst's challenge is to define a reference cost and objectively identify the incremental improvement appropriate for the estimate.

An estimate derived from a cost improvement curve using inflation-adjusted CY dollars will be biased because RPC is neglected. The 2021 Inflation and Escalation Best Practices for Cost Analysis, Appendix D "*Normalizing for Learning Curves: Estimating Using Actuals*" provides a step-by-step example demonstrating this bias. Consequently, the best practice is to base cost improvement curves on CP$. The 2021 Inflation and Escalation Best Practices for Cost Analysis provides the authoritative detail on calculating CP$.

The premise of cost improvement curves is that each time the product quantity doubles the resources or cost required to produce the product is reduced by a determined percentage[34] (slope). For example, a 90% slope in unit cost improvement curve theory indicates an expectation that item 4 costs 10% less than item 2, item 8 costs 10% less than item 4, and so on. There is ongoing research to determine the application of cost improvement curves in the presence of digital production technology.

The equation is comprised of a theoretical first unit cost or hours (a), the applicable unit number (X) and an exponent (b)[35] as illustrated below.

$$Unit\ Cost = a * X^b$$

The cost improvement curve method is presented with the parametric method because in its simplest form, the cost improvement curve equation is consistent with the parametric nonlinear functional form introduced in **Section 6.1.4** where the parameter is unit number. While analysts often use parametric equations to estimate total cost from one or more parameters, this particular form of the cost improvement curve equation estimates a unit cost. A regression analysis of historical data from a similar program, or the actual data from the program of interest, derives the values for the first unit cost and the exponent[36]. There are many variations of the cost improvement curve equation to account for different theories (unit, average unit, lot) [37], impact of production rate, and breaks in improvement[38] (down time, engineering change, process change, etc.).

When using a cost improvement curve equation, the analyst needs to document if the selected form of the equation produces a cost for the unit, the average unit, a series of units (lot), or some other combination. In practice, an analyst may choose to use any estimating method to estimate the reference cost and exponent separately. If the available data leads to a reference cost that is not associated with the first unit or lot, the analyst can use the formula to estimate one (e.g., knowing the reference cost, the reference unit or lot number, and the exponent, calculate the first unit cost). The analyst can derive the exponent separately from historical data. For example, if the manufacturer has produced several production units or lots of an item, the analyst can derive the exponent from regression analysis of the actual unit or lot cost data. An analyst can also estimate the exponent by using observed exponents from the company's similar efforts on other programs.

Ideally, the exponent and "*a*" are determined together through a regression analysis. This has the advantage of generating an objective basis for the reference cost, the exponent, and the uncertainty associated with the cost improvement curve equation as a whole. However, there may be situations where the analyst must estimate the reference cost from one source and the exponent from another source or from expert opinion. In this case, the analyst may be tempted to apply uncertainty (if performing a simulation) or what-if analysis (as an alternative to simulation) to each of the reference

---

[34] Unit theory assumes the unit cost is reduced while cumulative average theory assumes the cumulative average is reduced. The choice of theory to use is made by the analyst with the proviso that only one is used throughout the model.

[35] Where "*b*" is the logarithm of the slope (e.g., 90%) divided by the logarithm of 2. Logarithm base 10 or natural logarithm can be used as long as it is used for both numerator and denominator.

[36] If the analyst uses regression to estimate both T1 and the exponent, then changes to either one invalidates the regression uncertainty results.

[37] See 2003 "*Statistical Methods for Learning Curves and Cost Analysis*", Matthew Goldberg et al. at: https://www.cna.org/CNA_files/PDF/D0006870.A3.pdf

[38] See CEBoK v1.2, 2013, Module 7 "*Learning Curve*"

cost and the exponent separately to estimate the uncertainty of the equation as a whole. Section 2.8.5 of the 2014 JA CSRUH provides guidance on how to address this situation.

6.3.3 Linear Without Intercept

A special form of the parametric linear relationship is one where the y-intercept is zero, meaning a regression analysis has revealed that the relationship is statistically stronger without the y-intercept coefficient. In a linear relationship between cost and one or more cost drivers the method becomes a straightforward multiplier. Multipliers can be categorized as:

- **Factor**: One cost is expressed as a multiple of another cost such as estimating the cost of data as a factor of PMP.
- **Rate**: One cost or duration is expressed as a factor of a non-cost parameter such as $/hour or hours/ton.
- **Ratio**: One non-cost parameter is expressed as a factor of another such as kilowatts per ton.

Analysts should remember that forcing the cost and cost driver relationship to have a zero intercept by eliminating the intercept from the regression has specific statistical consequences on the estimated relationship parameters and error term. Even when there is good reason to believe the cost should be zero dollars for zero input, it may be better to allow the data and regression to show this and allow for a non-zero intercept, which could represent some overhead or initial investment cost by including the intercept term when running the regression.

6.3.4 Outliers

An outlier is an observation (data point) that lies outside the overall pattern of the data. Detection and treatment of outliers are part of any regression analysis. Methods to detect outliers include scatterplots, residual analysis, and leave-one-out regression[39]. Treatment of outliers centers on understanding why they are so different compared to the other observations. (See **Section 5.5.5** for data analysis performed during data collection.) Their detection provides an opportunity for the analyst to further understand the behavior of cost (univariate analysis) or the behavior of a cost and cost driver relationship (parametric analysis). In addition to detecting the outlier, assessing its influence on the result is necessary. The analyst must identify and address outliers that have a significant influence on results by:

- applying appropriate statistical methods,
- accepting them as part of the dataset and the influence they have, or
- discarding the outlier data point(s).

The latter choice is only acceptable with strong supporting evidence. Discarding an outlier because it negatively influences the result is not a valid or acceptable reason because that point may reveal an important aspect of the relationship. The 2018 JA CER Handbook contains more detail on detecting and addressing outliers.

6.4 Introduction to Estimating Method Uncertainty

This section addresses the uncertainty associated with an individual estimating method. **Section 7.4.2** addresses the uncertainty associated with the total estimate.

[39] See 2018 JA CER Handbook, para. 4.3.1.4 "*Leave-One-Out Metrics*"

Most cost estimates use a mixture of estimating methods. Though analysts do identify and evaluate multiple estimating methods in the cost estimating process, a final estimate uses only one estimating method for a given element of the estimate structure. Regardless of how well the estimating method is developed and how accurate the inputs are, the resulting cost is always a point estimate, which is just one result from a range of possible outcomes. **Section 7.2** further discusses interpreting the point estimate within this range.

In the case of parametric and univariate estimating methods, statistical techniques can be used to calculate a prediction interval (PI) that defines a range within which the cost estimate is expected to appear. This is an objective basis for estimating the uncertainty of the univariate or parametric result[40].

Understanding and accounting for the estimating method uncertainty is an essential part of the cost estimating process. The analyst must properly characterize what the result of the selected estimating method represents. The estimating method can produce a mean, mode, median, or some other probability result. By characterizing each element of the estimate structure result in the documentation, it becomes apparent that the total estimate is a sum of many different types of methods. This is a key reason the analyst should not refer to the total estimate as the most likely. It is but one possible outcome (i.e., a point) in a range of possible outcomes. This gives rise to the term point estimate. Analysts must endeavor to ensure decision authorities are fully aware of the implications of relying too heavily on any point prediction without any assessment of where it may land in the range of possible outcomes. In the special case where the cost estimating method for every element of the estimate structure produces the mean, the total is also the mean. This is very rare.

Section 7.4.2 discusses how to estimate the combined effect of all sources of uncertainty in order to assess the probability of exceeding a given budget. From an estimating method point of view, the analyst must address the uncertainty of:

- parametric CERs/SERs including factors and cost improvement curve equations,
- CER inputs, complexity factors for analogies, engineering judgment,
- any other uncertain cost drivers (e.g., man-hours, FTEs, rates, ratios, overhead, fee), and
- the planned schedule (durations).

In addition to uncertainty, the cost model needs to have methods to estimate the impact of discrete risk/opportunity events, risk mitigation plans identified by the program office, and proposed opportunity initiatives. Risk/opportunity events are situations that result in an impact to the project performance, cost, or schedule if they occur. Therefore, a risk/opportunity event has three characteristics: a definable situation, a probability that situation will occur, and a consequence should the event occur. If the consequence is negative to the program, it is a risk. If the impact is positive, it is an opportunity. The program's Risk Register is a formal document that identifies all known risk and opportunity events. The challenge for the analyst is to determine what, if any, risk register elements that have the attention of the program manager are not captured by the estimating methods directly. Having identified them, the next challenge is to find a way to capture them in the cost estimate. If there are only a few, the analyst can treat them as what-if cases. The 2014 JA CSRUH provides guidance on how to capture the impact of many risk/opportunity events.

Thus far, uncertainty has been discussed in the context of one estimating method for one element of the estimate structure. Characterizing what the total cost estimate represents and its total uncertainty

[40] The 2018 JA CER Handbook para. 5.3 "*Generate Prediction Interval*", pg. 173 illustrates how much smaller a parametric CER/SER PI can be compared to the PI of an average cost.

is a function of the source data, the estimating methods used, and how the estimate is modeled, which **Section 7.4.2** discusses.

6.5 Estimating Methods References

- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7.5.1, "*Methods or Models*"
- Department of the Army, Cost Analysis Manual, 2020, Chap 4 "*Cost Estimating Methodologies*"
- DoD Independent Government Cost Estimate Handbook for Service Acquisition, 2018, "*Cost Estimation Methods*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 10, "*Step 7: Develop the Point Estimate*" and Chapter 12, *"Step 9: Conduct Risk and Uncertainty Analysis"*
- MARCORSYSCOM, Cost Analysis Guidebook, 2020, para. 2.1 "*Cost Estimating Methodologies*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Section 5.8 "*Develop the Point Estimate*"
- NASA, Cost Estimating Handbook, 2015, para. 2.2.2 "*Task 5: Select Cost Estimating Methodology*"
- NCCA, Cost Estimating Guide, 2010 para. 1.3.3 "*Develop CERs and Analyze Risks and Uncertainties*"
- NCCA, Joint Agency Cost Estimating Relationship (CER) Development Handbook, 2018, para. 2.2 "*Cost Estimating Methods*";, para. 2.3 "*Choosing Between Analogy, Straight Average or a CER*"; para. 2.4 "*Univariate Analysis*"; and Chapter 3 "Step 3: *Generate CER*"
- NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014, para. 2.5.2 "*Elicitation of Subjective Bounds from Subject Matter Experts (SMEs)"*, and para. 2.8 *"Special Considerations"*
- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, para. 5.a(3) "*Develop CERs and Analyze Risks and Uncertainties*"

6.6 Estimating Methods Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimating methods. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000 Fundamentals of Cost Estimating
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000 Advanced Cost Estimating
- CLB 023 Software Cost Estimating (*overview of the Software Cost Estimating process and highlights key issues*)
- CLB 029 Rates (*introduces the basics of wrap rate development as it relates to cost estimating*)
- CLB 034 Probability Trees (*focuses on probability or decision trees, as they are used in the context of cost estimating*)
- CLB 035 Statistical Analysis (*covers parametric and nonparametric analysis to support the cost estimating process*)

- CLE 076 Introduction to Agile Software Acquisition (*explain what agile software acquisition is and how it works for DoD software development*)

The ICEAA publishes the CEBoK. The follow modules are relevant to methods:

- CEBoK v1.2, 2013, Module 2 "*Cost Estimating Techniques*"
- CEBoK v1.2, 2013, Module 3 "*Parametrics*"
- CEBoK v1.2, 2013, Module 7 "*Learning Curve*"
- CEBoK v1.2, 2013, Module 8 "*Regression*"
- CEBoK v1.2, 2013, Module 11 "*Manufacturing Cost*"
- CEBoK v1.2, 2013, Module 12 "*Software Cost Estimating*"
- CEBoK v1.2, 2013, Module 13 "*Economic Analysis*"

The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

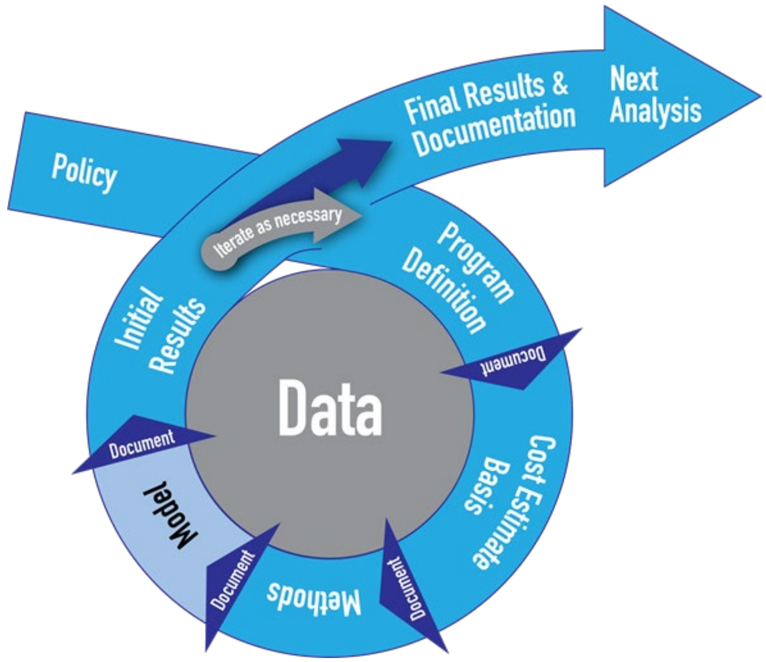
- FMF 1124 FMA 204 - Financial Management Concepts Course - Trend Analysis
- FMF 1551 QMT 490 - Current Topics in Cost Estimating
- FMF 1253 FMA 202 - Financial Management Concepts Course - Descriptive Statistics
- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 1503 FMA 201 - Financial Management Concepts Course - Cost Estimates for Support
- FMF 1560 DoD FM 101 - Cost Analysis
- FMF 2802 Army 1.5-Hour e-Cost Benefit Analysis (e-CBA) Training class
- FMF 6175 AFIT Cost 669 - Advanced Cost Analysis
- FMF 6540 Analytic Cost Expert Distance Phase (ACE dL)
- FMF 7536 Applied Financial Planning - Breakeven Analysis
- FMF 7883 Data Analytics

Training opportunities specific to CADE include:

- CADE training videos: designed as a handy reference for the first-time user or seasoned analysts that just need a refresher. Topics include: user guidance for the CADE portal, data and analytics, plus "how to" guidance on CCDR, SRDR and available libraries are available at https://cade.osd.mil/support/videos (public)
- CADE Pivot Tables for Analysts: https://cade.bridgeapp.com/learner/library (requires a CADE login)

7.0 BUILD COST ESTIMATE MODEL

Cost estimating model development should begin during program definition and continue through the cost estimate basis, data processes, and the estimating methods investigations. Starting the model building process as early as possible leads to a superior model design, helps focus discussions, inspires timely questions, and uncovers holes in the data requirements early in the process. This chapter summarizes the cost estimate model characteristics the analyst should be mindful of throughout the model building process.



7.1 Anatomy of a Cost Estimate Model

The estimate structure is the skeleton that holds the estimate together and establishes the cost model framework. The analyst populates elements of the estimate structure with estimating methods supported by the data collection process. The core estimate structure of a life-cycle cost estimate includes R&D, Production, O&S, and Disposal sections. The analyst assigns estimating methods at the lowest level elements of the estimate structure, drawing on input values and intermediate calculations performed elsewhere in the cost model. The analyst applies inflation, escalation, cost improvement curves, scaling factors, and phasing methods as appropriate. The analyst must also capture sunk cost in the estimating model.

Regardless of the tool used to create the cost estimate model, the structure should be centered around the estimate structure, which identifies all cost elements requiring a cost estimate. The analyst needs to use careful judgment to settle on the necessary level of detail in the estimate structure. Greater detail does not necessarily result in greater accuracy! The arrangement and level of detail needs to be sufficient to perform the anticipated what-if and sensitivity analysis and provide all data necessary to populate the required reports and charts. Building the model evolves in every step in the cost estimating process.

As the estimate structure is developed, the analyst applies estimating methods at the lowest level of detail and then sum the levels throughout the estimate. Each parent level is generally a simple sum of subordinate elements. Exceptions to this include the case whereby the subordinates to a particular parent element in the estimate structure do not capture all the anticipated cost and there is some valid reason for not adding another subordinate element. In this case, the parent level formula will not be a simple sum of its subordinate elements. This is just one possible exception to an otherwise simple estimate structure hierarchy summation. An analyst should document any deviations from the simple summation approach.

The analyst needs to apply cost estimating methods consistent with their derivation. For instance, the analyst may need to adjust available CER/SER inputs and results based on the particulars of the CER/SER. The analyst must make model adjustments when the:

- CER result produces a different unit of cost than other elements of the estimate structure (e.g., $K vs. $M),
- CER result has fee, General and Administrative Expense (G&A), and/or overhead, but other elements of the estimate structure in the cost model do not,
- CER source data comes from programs with significantly different framing assumptions, schedules, or risks/opportunities than the program being estimated,
- input parameters have different units than the data used to create the CER,
- source rates apply to a different labor mix than used in the estimate,
- CER source data durations are significantly different than the item being estimated, and/or
- source data risks/opportunities do not address all the current project risks/opportunities.

When elements of the estimate structure relate directly to one another, the model should establish a mathematical link whenever possible. For instance, if the quantity of one item is always an exact multiple of another, then the one element should be mathematically dependent upon the other in the model rather than having to manually change both quantities when performing what-if or sensitivity analysis. Minimizing the number of overrides necessary to achieve a given what-if or sensitivity result reduces the potential for manual entry errors, especially if many variations need to be explored. The analyst must apply functional relationships wherever feasible to:

- help ensure consistency between trade studies (what-if cases),
- minimize overrides necessary to achieve a balanced estimate for a specific alternative (e.g., if production doubles, O&S follows automatically),
- improve the performance of simulation methods to address risk/opportunity, and uncertainty, by helping to ensure the simulation behaves correctly (see **Section 7.4** for a discussion of simulation methods.), and
- reduce errors.

The following sections address specific considerations for the cost model.

7.1.1 Characteristics to Simplify the Cost Estimate Model

Due to the complex nature of the programs being estimated, it is easy for a cost model to become very complicated, very large, or both very quickly. Early in the development of the model, the analyst should consider how to keep the model as simple as possible. Possible design considerations include:

- creating the simplest structure possible, consistent with the intended purpose and scope,
- building the cost model such that it is easy to add, remove, and modify elements necessary to perform sensitivity and what-if analysis, and
- listing cost drivers and other parameters in a clean, systematic way and in a central location to avoid duplication of data,
- developing concise, clear, and complete model documentation,
- developing a disciplined, concise, and easy to find way to record the history of significant changes to the model, emphasizing changes from the previous version.

Model design suggestions that are more directly related to Microsoft Excel or other spreadsheet-based models include:

- color-coding the model elements,

- making good use of the cell and cell range naming features (take care to delineate between workbook and worksheet range names),
- exploiting array range names to reduce the number of unique formulae,
- creating conditional formatting and alerts that identify when impossible or irrelevant values occur in the model,
- avoiding long, difficult, and/or complex formulae where possible,
- adding comments to help explain unusual formulae,
- avoiding the use of Microsoft Excel functions that cannot be traced through the precedent/dependent feature,
- breaking down a complex section into its constituent parts,
- considering the use of a Data/Validation tool in Microsoft Excel to format cells so that another user cannot input inappropriate values into the model,
- keeping links between sheets to a minimum,
- avoiding links to other workbooks, and/or
- avoiding writing macros.

A word of caution, some analysts have found that excessive use of conditional formatting, links, complex formulae, and embedded features (e.g., cell validation) can severely impact performance. In particular, large cost models that also make use of simulation methods can be overly stressed. It is up to the analyst to find a balance between exploiting these features while retaining cost model stability and acceptable calculation speed.

7.1.2 Phasing

Phasing is the allocation of a cost estimate over the program's FYs to ensure adequate budget authority is in place to achieve key program event dates. It should also be consistent with any constrained budget realities. An analyst is required to forecast the spending profile across FYs in order to capture the impact of inflation/escalation and other program unique considerations (discussed below) to develop annual budget requests. It is essential that the model documentation explicitly defines the basis for the chosen phasing profiles. There are two fundamentally different ways to develop a phasing profile from historical data:

- **Obligations**: is where analyst bases the estimated obligation profile on historical or planned obligation data. In this case, the profile may be applied directly to a properly inflated/escalated cost estimate.
- **Expenditures**: is where the analyst bases the estimated spending profile on how the program intends to spend money, then converts to obligation authority. Typical sources for this method are CSDR or EVM data. In this case, the time-phased estimate (either a CY or CP dollar profile) of resources must be converted to an obligation profile, which involves a number of considerations, discussed next.

Converting a CY dollar expenditure profile using published appropriation indices is generally insufficient. For instance, if an estimate identifies $100 CY$ in the first year, the appropriation indices may only adjust this number by a few percent. In fact, given that many appropriations allow dollars to be obligated and expended over a number of years, it may be necessary to substantially increase the first year's CY dollar estimate. Inflation/escalation adjustments need to be applied consistent with the 2021 CAPE Inflation and Escalation Best Practices for Cost Analysis. Analysts are encouraged to complement the CAPE guidance with Component-unique procedures, as applicable. In general, the conversion of a CY dollar spend profile to a TY dollar should account for realities, such as:

- RPC (to convert to CP$), and

- an outlay profile that considers,
  - termination liabilities,
  - fee payment plan,
  - invoicing cycles,
  - long lead items, and
  - supply chain commitments.

An analyst can estimate phasing at the program level or at any lower level of the Program WBS. He/she should exercise caution when phasing at lower levels to ensure the total Program phasing profile is consistent with the total resource (e.g., staffing) levels estimated. Analysts commonly use spreading functions such as Uniform, Trapezoid[41], Beta, Rayleigh, and Weibull because they provide some control over how the model prorates costs across time[42]. Ideally, the analyst bases the selection of a spreading function on relevant historical data. However, Components may provide guidance on selecting and implementing preferred methods. In reality, these functions simply estimate the percent of total spending within a given time frame. Consequently, the analyst can use a percent-per-time-period directly to spread a total. The weakness of the percent-per-time-period spreading method is that it is not dynamic and requires a greater degree of manual intervention to perform time-sensitive what-ifs.

An important, and often overlooked, phasing aspect is the need for dynamic phasing and estimate structure linking:

- **Dynamic Phasing**: If baseline production quantities increase beyond the annual capacity, the analyst must account for procuring additional quantities and any O&S implications. It could mean increasing annual costs or extending production and/O&S durations. Ideally, the selected method for spreading the new quantities or estimating O&S costs changes dynamically to be consistent with annual capacity constraints.
- **Estimate Structure Linking**: In a schedule model[43], the start and/or finish date of one activity may influence the start or finish date of one or more other activities (called dependencies). Analysts purposely build schedule tools to apply activity dependencies and other scheduling attributes. Mimicking schedule model dependencies in a cost model is extremely difficult. However, the 2014 JA CSRUH para. 2.2.5 "*Duration Sensitive Cost Estimating Methods*" provides some guidance on where such linkages are feasible in a cost model and how to implement them. Doing so will not replace the need for a schedule model, but it does facilitate one of the most common cost estimating what-if drills: schedule changes.

The analyst should automate dynamic phasing and linking elements of the estimate structure as much as possible to minimize errors and to support any contemplated simulations. (See **Section 7.4** for a discussion on simulation methods.)

DoD is emphasizing the acceleration of program acquisition schedules by categorizing some programs as MTA. (See **Section 1.2.1,** 10 USC § 2430 for an introduction to MTA, and **Appendix G** for additional information on MTA cost estimate best practices). In order for a program to have a reasonable chance to meet rapid prototyping / rapid fielding schedules, the typical time phasing profile may not be

---

[41] Trapezoid is a convenient way to combine a ramp-up, steady state, and ramp-down spending profile.

[42] They are also common distributions used to model the uncertainty of equations or parameters in a simulation model.

[43] The 2015 GAO Schedule Assessment Guide describes schedule modeling. The preface states, "*A cost estimate cannot be considered credible if it does not account for the cost effects of schedule slippage*."

sufficient. Early material purchases, hardware/software prototypes, and dual supplier activities required to accelerate program schedule may drive up front funding requirements over and above durations for major capability programs. The cost analyst should consider making discrete adjustments to phasing profiles drawn from major capability programs. He/she should exercise caution with this phasing strategy because it may incentivize the program to maintain higher staffing levels for a longer period of time in the event schedule delays occur. **Figure 4** illustrates how an accelerated program may impact the program budget and the potential consequences of subsequent schedule delays.

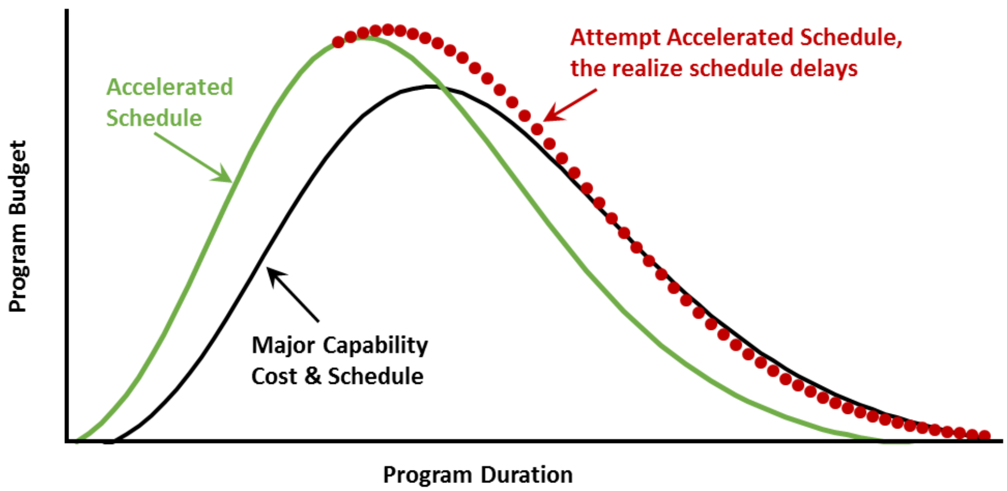


Figure 4: Notional Major Capability Acquisition Budget Profile vs. a Notional MTA Program Schedule

Determining the impact on annual funding requirements from different production quantity phasing profiles or OPTEMPOs are common what-if drills. Building a model that facilitates such investigations should be a priority. The 2014 JA CSRUH recognizes the challenge of developing schedule features into a spreadsheet based cost model. Chapter 2 of that handbook provides guidance on how to build a cost model that automates changes in duration[44] that influence the cost estimate results. (See the 2015 GAO Schedule Assessment Guide for schedule modeling best practices.)

7.1.3 Sunk Cost

A sunk cost is a cost that the program has already incurred and cannot be readily recovered by the program. This is usually in the form of costs expended or obligated in the current year or prior years. If the program being estimated is well into development or production, it may be necessary to incorporate sunk costs and adjust estimating methods to address the remaining cost (cost to-go[45]). An analyst may draw the sunk cost from actual early R&D and production costs (for acquisition costs) and fielded systems (for O&S costs). In addition to capturing the sunk cost to build a complete cost estimate, the analyst can use findings of the completed work to refine the estimate. For example, the analyst should use test and evaluation results, including reliability and maintainability projections, to refine O&S cost estimating methods.

[44] The 2014 JA CSRUH focuses the concept of a "cost informed by schedule method" (CISM) suitable for spreadsheet models. It also introduces the "fully integrated cost/schedule method" (FICSM), which require special purpose tools. Variations on FICSM are embraced by NASA, the oil and gas industry, and others.

[45] The cost estimate for specific elements of the estimate structure will be the sum of sunk costs and the cost remaining, referred to in this guide as the "cost to-go".

An analyst may deem authorized and obligated program funds from prior years as sunk costs even if the program has not yet completely expended them. A life-cycle cost model should contain current and prior-year sunk cost as part of a system's total life-cycle cost. The cost estimating model should report sunk costs and cost to-go in order to facilitate comparisons with the total cost of previous estimates.

Updating an estimate to include sunk cost can be complex, particularly if the analyst needs to allocate sunk costs across elements of the estimate structure. The process begins with a firm grasp on the difference between costs produced by the estimating model and the collected sunk costs. The analyst must consider if the sunk cost is in terms of obligation or expenditure in light of how the model has been time-phased as described in **Section 7.1.2**. Typically, the analyst should trace the source of the sunk cost back to the obligation year and apply that accordingly in the cost estimate. The 2014 JA CSRUH, paragraph 2.8.2 "*Sunk Costs*" provides a detailed discussion of this process and an example.

Reports such as IPMRs or CSDRs represent actuals-to-date and forecasts for contracts and may not include the detailed estimate structure information necessary to trace the cost back to the obligation year. If using these data sources, the analyst makes adjustments so that the accruals are properly entered as a sunk cost into an obligation estimate.

Addressing the impact of sunk costs on the estimating method can be complicated. The analyst generally derives the estimating method from an analysis of total cost, not on cost to-go from some point in the source program(s). Subtracting the sunk cost from the total estimate method to arrive at cost to-go may make sense, but defining how much of the risk/opportunity, and uncertainty remains in the cost to-go portion is more difficult to assess. Again, the 2014 JA CSRUH, paragraph 2.8.2 "*Sunk Costs*" provides some guidance.

7.1.4 Cost Modeling Tools

Analysts build most DoD cost estimating models in Microsoft Excel or Automated Cost Estimating Integrated Tools (ACEIT). Some organizations have built Microsoft Excel templates in an effort to bring consistency to model building and facilitate their management. The Army requires the use of ACEIT on all ACAT I and II programs[46]. There are also many tools available to support specific parts of the cost estimating process such as statistical analysis, software cost estimating, data visualization, and simulation. In addition to Microsoft Excel and ACEIT, system dynamics models and data science applications like R[47] and Python are becoming popular for specific analysis, especially as data files get larger. Analysts need to select tools to support the cost estimating process as outlined in this guide. Analysts should not tailor the cost estimating process simply to accommodate the constraints of any particular tool. Each Component promulgates their own guidance and preferences for the use of tools and identifies the available training.

7.1.5 Multiple Cost Models for One Program

Large cost estimates are often broken into pieces to cope with very large programs, geographically disperse analyst teams, and related realities. For example, an aircraft procurement cost model could be broken into structure, propulsion, avionics, and then everything else. In such cases, the owners of each cost model must collaborate to a high degree in order to combine the estimates and ensure a universal

---

[46] Office of the Assistant Secretary of the Army Memorandum "*Automated Cost Estimating Integrated Tools (ACE-IT)*", 15 April 2004

[47] R Core Team (2013). "R: A language and environment for statistical computing", R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/ .

understanding of common variables and results. The cost team should identify a single lead who is made responsible for defining and integrating all the cost model pieces.

7.1.6 Common Cost Metrics

Although every cost estimate is unique, there are common metrics that the cost community uses to discuss or compare estimates. Analysts should be aware of these metrics and build the cost model so they are easily calculated.

The most common metrics are:

- **Flyaway/Sailaway/Rollaway Cost**: Sum of prime mission equipment, SEPM, system test and evaluation, warranties, engineering changes, nonrecurring start-up production costs, and other installed GFE.
- **Weapon System Cost**: Procurement cost of prime mission equipment plus the procurement cost for support items.
- **Procurement Cost**: Cost of prime mission equipment, support items, and initial spares.
- **Acquisition Cost**: Sum of development costs for prime mission equipment and support items plus the sum of the procurement costs for prime mission equipment, support items, initial spares, and system-specific facilities.
- **Life-Cycle Cost**: Total cost of the program including development, procurement, O&S, and disposal.
- **Total Ownership Cost**: Life-cycle cost plus related infrastructure or business process costs not necessarily attributed to the program.

Figure 5 represents the general relationship between these six terms. Commodity specific versions of this chart may exist at the Component level.

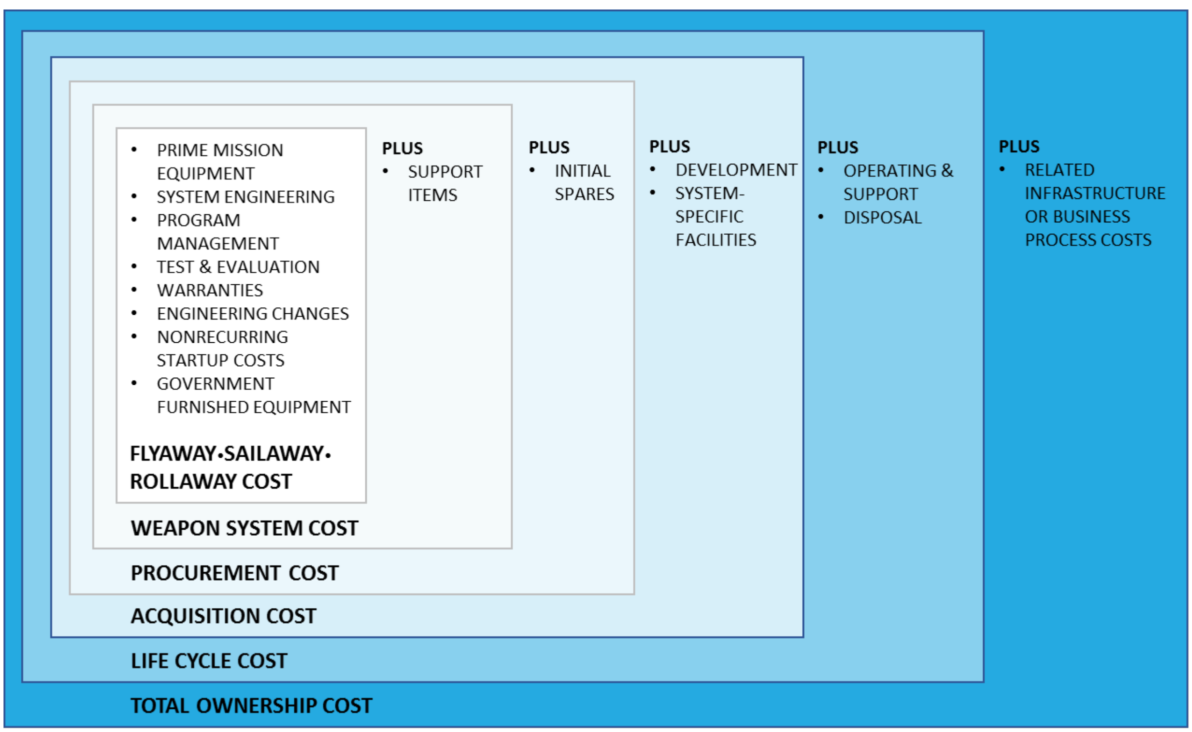


Figure 5: Total Ownership Cost Composition

Additional metrics include:

- **APUC**: Total program procurement cost divided by the production quantity.
- **PAUC:** Acquisition cost divided by the sum of development and production quantities.
- **O&S $/year**: Total O&S Cost[48] divided by number of years of sustainment.
- **O&S $/operating metric/year**: Total O&S Cost divided by the system's usage metric divided by the number of years of sustainment. The operating metric will vary by commodity. Common operating metrics are flying hours (aircraft), steaming hours (ships and submarines), and driving hours (vehicles).
- **Average Unit Manufacturing Cost (AUMC)**: Includes the costs of all materials, labor, and other direct costs incurred in the fabrication, checkout, paint, preparation for shipment to its acceptance destination. It also includes processing and installation of parts, sub-assemblies, major assemblies, and subsystems needed for the final system, and associated burdens (i.e., overhead, general and administrative, cost of money, and profit/fee) necessary to build complete production vehicles by the prime contractor and all subcontractors. AUMC includes the labor and other direct costs to integrate GFE into the final vehicle if completed prior to final acceptance. To calculate AUMC, total costs in the above categories are divided by the total number of fully-configured end items to be procured. The Army commonly uses this metric.

7.2 Develop and Interpret the Baseline Cost Estimate

A systematic and well-documented process for the development of the baseline cost estimate simplifies the interpretation and use of the estimate. This section offers best practices to create the baseline cost estimate.

7.2.1 Develop the Baseline Cost Estimate

The analyst should relate the baseline cost estimate directly to the program definition. The what-if or uncertainty analysis should address the degree to which the model may underestimate or overestimate cost. Estimating method drivers (e.g., weight, code count, volume, power, hours, rates) should reflect documented baseline values and not some lower or upper bound. Additionally, the baseline cost estimate should not include extra dollars inserted to address risk/opportunity or uncertainty (unless directed by the program manager) because they are handled separately. However, the cost of risk mitigation plans that the program manager intends to execute as part of the program of record should be included in the baseline cost estimate.

The cost estimate type, purpose, scope, and Component guidelines all influence how to develop the baseline estimate. The analyst needs to ensure the model:

- is consistent with the program definition and the cost estimate basis,
- employs the best estimating method for every element of the estimate structure that requires one,
- addresses any linkage between elements of the estimate structure and between input variables where appropriate,
- applies inflation, escalation, phasing, cost improvement curves, and adjustments in a defendable way,
- traces the cost drivers back to the CARD or other program definition documentation and properly normalizes them,

[48] O&S cost is fully described in the 2020 CAPE Operating and Support Cost Estimating Guide.

- properly accounts for sunk cost and the affected estimating methods are adjusted to reflect the cost to-go, rather than a total cost, and
- results at every level in the estimate structure are in a consistent dollar type (e.g., CY or TY), year, and unit (e.g., $K, $M, $B).

After developing the baseline estimate, the analyst interprets the results at all model levels as discussed in the next section.

7.2.2 Interpreting the Baseline Cost Estimate Results

Interpreting the cost estimate results begins with understanding where each estimating method's result is located within the range of possible outcomes. The total cost estimate is the sum of all cost elements and analysts often call it a point estimate because the result represents only one possible outcome. Methods to estimate the bounds on the total estimate are discussed in **Sections 7.3.2, 7.3.3, and 7.4.2**. **Figure 6** illustrates how plotting the minimum, point estimate, and maximum of subordinate elements can improve the understanding why the point estimate at the total level falls where it does. In this case, it is quickly evident that all the point estimates gravitate towards the minimum, in some cases significantly. This may be cause for further investigation to verify the results are realistic.

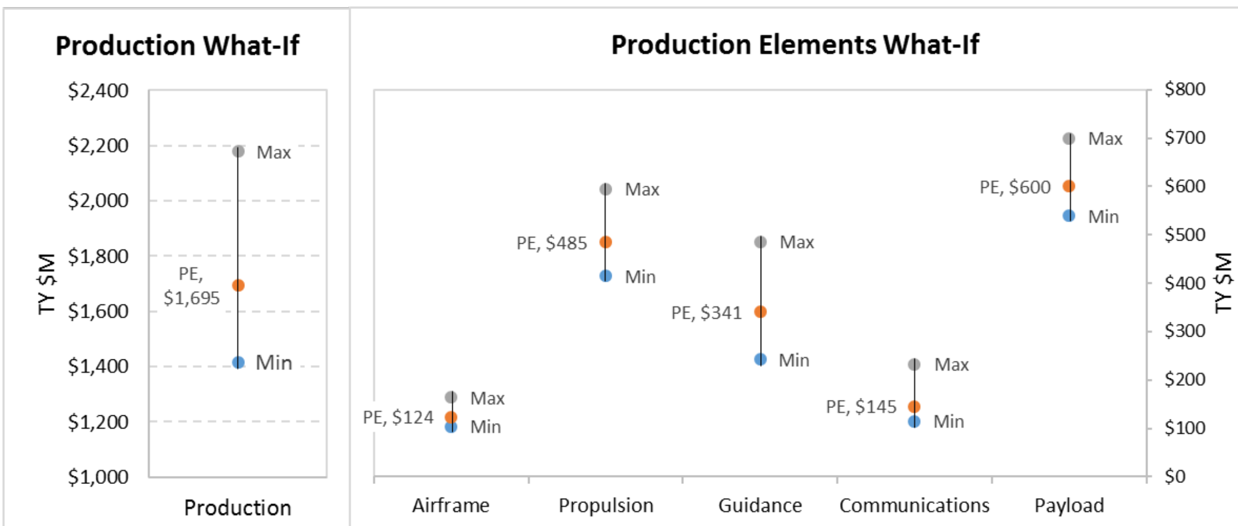


Figure 6: Point Estimate Location Within a Range of Possible Outcomes

If an analyst uses a simulation method to estimate the point estimate bounds, then he/she should use the point estimate for each of the lowest level results as a reference point to define the distribution of possible outcomes. The location of the point estimate in the distribution[49] of the estimating method result is a critical step in building a simulation model. Whether simulation is used or not, understanding what the cost model is delivering (e.g., mean, median, mode, or something else) at each level of the estimate structure is an important step towards interpreting and using the cost model results.

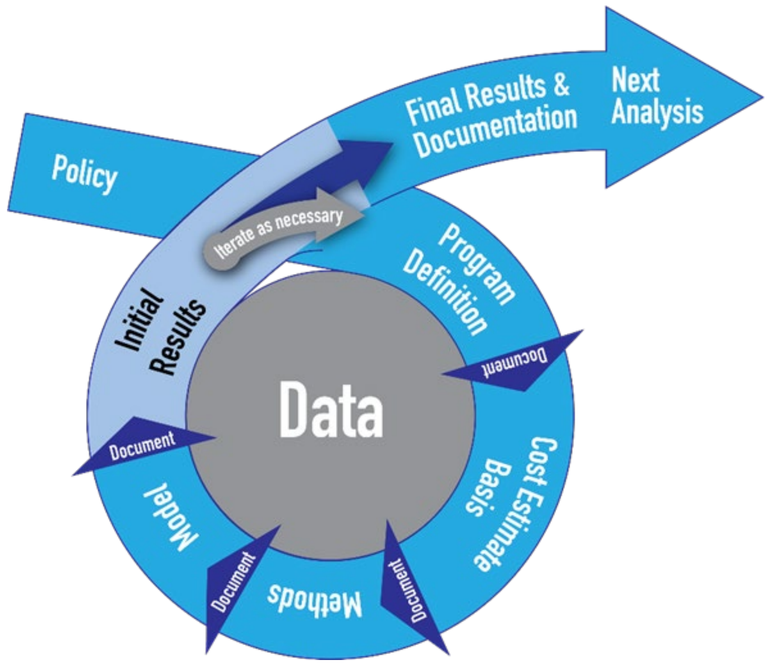
[49] It is not always possible to anchor an uncertainty distribution to the point estimate result for a particular element of the estimate structure, but it is an excellent way to help ensure the distribution scales and/or changes shape properly when performing a simulation on a what-if drill. In most cases, the point estimate can serve as one point (mean, median, upper bound, lower bound, something else) and the other distribution parameters required to uniquely define the distribution can be scaled off of it. This is an effective way to help ensure distributions remain meaningful when applied to what-if cases.

The analyst simplifies result interpretation if they use only estimating methods that produce a mean (or average) cost. In that case, the result at each aggregate level is also the mean. However, since this is rare, the following are a few cases where a result interpretation may differ across elements of the estimate structure:

- **Analogy**: The analogy method adjusts an actual cost from the analogous program. The estimating methods used to develop the adjustments to actual cost (e.g., additions, subtractions, scaling factors) drive results interpretation.
- **Build-Up**: The build-up estimating method itself is exact. For example, hours times a labor rate produces an exact cost. The uncertainty of a build-up result is a function of how the analyst derives the inputs (hours and labor rates). Hours, for instance, could come from a parametric estimating method. The labor rate could be a weighted average composite of an assumed labor mix that may or may not match the program.
- **Extrapolation from actuals**: Extrapolation is often a specific type of univariate or parametric estimating method. However, instead of using historical data from analogous programs, the extrapolation method uses actual costs from the program being estimated. This does not eliminate uncertainty in the estimate. The analyst needs to interpret the result consistent with the mathematics used to perform the extrapolation.
- **Parametric**: Some parametric regression methods include an objective calculation of the estimate error. The distribution of the error is an assumption, not necessarily a fact. For the ordinary least squares (OLS) regression method, the assumption is that the method produces the mean of a normal distribution. A log-linear form, however, yields the median of the potential results (unless a correction factor is applied). True nonlinear regression methods are not so straight forward to interpret, and the analyst may refer to the 2018 JA CER Handbook for guidance.
- **Univariate**: The univariate method delivers several result types to choose from. For example, if the analyst collects labor rates from a number of manufacturers (because the performing company has not been selected), he/she could choose the mean or the median value. If there are enough data, the analyst may choose to fit them to a distribution shape and select the mode[50].
- **Tools**: Some tools provide a framework to facilitate building, troubleshooting, and generating documentation (e.g., Microsoft Excel, ACEIT). Other tools (e.g., commercial parametric models) contain built in estimating methods to develop a point estimate. The analyst must interpret the tool's point estimate, which the tool may or may not have documented. The analyst also needs to know how well the data supporting the tool results compares to the program.
- **Expert Opinion**: Interviews with individuals or teams of experts invariably lead to estimates identified as "most likely" or "most probable" or "on average". That type of characterization is never enough. The potential bounds of the estimate are essential for the analyst to interpret the estimate meaning. There should be no comfort taken in labeling an estimate as most likely or the average without also knowing the range of possible outcomes. There could easily be compelling evidence that demonstrates a high probability of an adverse outcome (e.g., the underlying spread of potential values is highly skewed). Identifying the potential spread is an essential part of the expert opinion interpretation.

[50] Just because the analysis yields a mode, that is insufficient to characterize the estimate. A most likely value may still have a high probability of overrun if it is the mode of a highly, right skewed distribution.

7.3 Review the Initial Results



At this point in the cost estimating process, the analyst has a preliminary cost estimate to review and validate. This guide describes validation as performed to ensure the cost estimate is consistent with the program definition and that it is traceable, accurate, and reflects realistic assumptions[51]. The objective of the validation process is to ensure the cost estimate is credible, comprehensive, accurate, and well documented. Iterating through previous steps to refine and correct initial results is a normal part of the model building and validation process. The estimate achieves credibility and comprehensiveness, in part, by showing the estimate has captured all aspects of the program, including all excursions required by the stakeholder. Validating cost estimate behavior also address credibility and accuracy. **Chapter 8.0** discusses documentation in more detail.

Once the analyst builds the model, he/she validates its credibility and accuracy via crosschecks, sensitivity analysis, and what-if analysis. This section discusses each of these topics.

7.3.1 Crosschecks

First-level crosschecks simply apply common sense (also known as sanity checks). For example, knowing that the results should be in millions, but the results are in billions is evidence something is awry with units in the estimate. Adding new elements with no discernable change to the total is similar evidence of an error in the modeling logic.

Once past the sanity checks, an analyst can perform more detailed crosschecks by entering cost driver data for analogous programs and verifying the model results reasonably match. For larger models, it may not be feasible to do these at all levels. In such cases, the analyst needs to find ways to perform a crosscheck for as many of the lower level elements of the estimate structure as possible. Sources for crosschecks might include comparisons with similar historical programs and realism checks with SMEs.

It is good practice and often necessary to employ more than one cost estimating method for the more contentious, complex, and/or expensive elements of the estimate structure to serve as crosschecks for these particular elements. The analyst expects the chosen primary estimating method to yield the best

[51] The 2010 NCCA Cost Estimating Guide, para. 1.5 "*Verify and Validate Cost Estimate*" and the 2008 AFCAA Cost Analysis Handbook, para. 14-11 "*Independent Verification and Validation*" treat verification and validation separately. The 2020 GAO Cost Assessment Guide Chapter 16, "*Auditing and Validating the Cost Estimate*", as does this guide, treats the same concepts under one heading.

results in terms of realism, accuracy of the result[52], completeness, and supportability of the estimate. The analyst should use second and possibly third alternative crosscheck methods to corroborate the primary method results. The crosscheck methods can serve as fallback positions in the event of data non-availability, disappointing statistical results, or if the analyst anticipates significant controversy among stakeholders. Additionally, incorporating several methodologies can help establish bounds for the purposes of evaluating sensitivity and uncertainty.

The model can include crosschecks alongside the primary method but tagged in such a way that they do not sum to the total. At a minimum, the analyst should perform crosschecks for the most important cost drivers.

7.3.2 Sensitivity Analysis

Sensitivity analysis assesses the extent to which costs at various cost estimate levels react to changes in cost drivers. If a specific cost driver change results in a relatively large change in an element of the estimate structure, then the analyst can consider the cost estimate sensitive to that cost driver. Analysts perform sensitivity analyses to test that the model delivers realistic results for cost driver values over their potential range. In good sensitivity analyses, the analyst changes cost driver values based on a careful assessment of their underlying uncertainties. If the model behaves correctly, then the analyst should test the limits of the model by assigning cost driver values outside the expected bounds to allow for unexpected values during what-if excursions and the application of simulation methods.

Best practice cost models incorporate the ability to perform sensitivity analyses without altering the model, other than changing through-puts[53] or cost driver values. This is where the analyst's effort to automate the cost model can pay off. The analyst conducts sensitivity analysis by changing a single cost driver and holding all other model inputs constant. Automation should ensure that linked cost drivers that must change with the one undergoing sensitivity analysis do so in an appropriate manner. For example, if the program must procure three of item A for every one of item B, the model should automatically account for this relationship. Additionally, if one element of the estimate structure is a function of the total cost of one or more other elements of the estimate structure, the analyst should build that link into the model. A well-automated model provides a more realistic assessment of cost driver sensitivity. A systematic analysis yields those cost drivers that have the most impact on the model. The estimating methods associated with the top cost drivers are the ones that are the most important to refine.

The analyst documents the source (e.g., SMEs, historical information, contract documents), rationale and results associated with the sensitivity analyses along with potential best and worst case values. Analysts often use tornado charts (see **Section 8.3.3**) to present this type of information.

Sensitivity analysis helps identify where the analyst should focus risk/opportunity and uncertainty analysis. It can identify areas in which design research (risk mitigation) may be warranted or areas in

[52] In this guide, accuracy in the context of choosing between estimating methods is defined as the result with the narrowest uncertainty range. The term realism is used to describe how closely the result compares to the correct result. Accuracy of the collected data is discussed in **Section 5.5.3**.

[53] Through-puts are cost or cost driver values entered directly into the model. Catalogs (**Section 6.2**) and Sunk cost (**Section 7.1.3**) are an example of cost values that can be entered as a through-put.

which the program can improve performance without a significant impact on cost. The impact of changing more than one cost driver in the model is the subject of the next section.

7.3.3 What-If Analysis

The analyst performs sensitivity analysis to verify that the model behaves realistically when a single cost driver is changed and to identify those cost drivers that have the most influence on cost. A what-if analysis assesses the impact of changing multiple cost drivers, and automation facilitates the modeling of numerous what-if drills. The analyst must take care to ensure that changes in one or more cost drivers do not invalidate estimating method inputs values that are not linked. For example, if quantities and production rates are changed, the coefficients of any associated cost improvement curve may have to change.

Many times, the program manager will ask the analyst to run excursions (often known as drills) on different programmatic parameters like quantity, schedule, or fuel prices. This is also a type of what-if analysis.

7.4 Addressing Risk/Opportunity, and Uncertainty

Section 1.5.8 defined risk/opportunity, and uncertainty. Analysts address risk/opportunity and uncertainty in different ways. Each approach has its place, and each Component provides specific guidance on how to address them. A summary of the most common methods (listed alphabetically) include:

- **Case-based Risk**[54]: The analyst develops one or more what-if cases from a detailed analysis of what could go wrong or right in the program; the baseline estimate does not capture these aspects. The focus is on determining how the schedule and the cost per unit duration (dollars per hour, per month, etc.) changes should the risk/opportunity event occur. For example, if a test fails, the analysis establishes the impact to the schedule and the resulting impact to the model's duration-sensitive estimating methods. Additionally, the analyst must assess how the program might have to change to address the test result. The strength of this process is that the analyst can directly link the cost change to one or more specific events in a way that is easy to understand. It also provides the program office the basis for devising effective risk mitigation plans. The CAPE prefers the case-based risk method.
- **Method of Moments**[55]: This is an analytical approach to estimating total program uncertainty. It relies on the fact that the sum of individual elements of the estimate structure means and variances equals the mean and variance at the total level. A closed form analytical method is also available to account for how correlation across elements of the estimate structure impact the total variation.[56] The total mean and variation defines an assumed distribution shape at the total level such as normal, lognormal, or beta. Method of moments is useful when there is a need to sum large numbers of correlated uncertain elements.

---

[54] A different process with similar goals is documented in Garvey, Paul R. 2008. "*A Scenario-Based Method for Cost Risk Analysis*" Journal of Cost Analysis and Parametrics.

[55] Young, Philip H. 1992. "*FRISK: Formal Risk Assessment of System Cost Estimates*"

[56] See 2014 JA CSRUH para. 3.3.3 "*The Impact of Correlation on a Cost Model*"

- **Simulation[57] (Inputs-Based)**: Analysts use this problem solving technique to approximate the probability of certain outcomes by executing multiple trial runs. The analyst assigns a probability distribution to each uncertain cost driver and estimating method to describe its possible values. The analyst either builds correlation across uncertain elements into the functional arrangement of the model or applies it as required. Additionally, the analyst can model events to address risk/opportunities that the uncertainty assessment does not capture. He/she uses a tool (or Microsoft Excel) to randomly select values for all uncertain variables to create and then calculate a what-if case. The tool repeats this process enough times (hundreds or thousands) to generate statistically significant distributions of outcomes for the cost elements of interest. Analysts must take care to ensure the simulation does not generate trials where the combination of cost driver values represents an impractical scenario. He/she can mitigate this by using functional (mathematically linking inputs) and applied (user inputs into the simulation tool) correlation.
- **Simulation (Outputs-Based)**: This variation of the simulation method applies uncertainty directly to the cost model outputs rather than to the model's estimating methods and inputs. The analyst assigns uncertainty distributions to the outputs of elements in the estimate structure to address the combined uncertainty of the cost method and the cost method inputs[58]. He/she can also assign the impact of risk/opportunity events.

The need to address correlation in the method of moments and simulation methods cannot be over emphasized. Aggregate uncertainties can be significantly understated if correlation in these methods is ignored. There are techniques available to measure the correlation present in a simulation model to identify where it may be under or overstated. Guidance on how to measure, interpret, and address correlation in simulation methods is fully addressed in the 2014 JA CSRUH paragraph 3.3 "*Measure Then Apply Correlation".*

7.4.1 Risk/Opportunity

The program office is responsible for identifying risks/opportunities that may affect cost, schedule, and performance. Program office documents provide starting points for determining what areas of risk and opportunity to address. Additionally, framing assumptions, ground rules, and cost estimating assumptions (see **Section 4.2**) may identify potential risks/opportunities. The program office usually produces a risk register, which lists risk/opportunity events, the probability of the event occurring, and the impact the event will have on the program should the event occur. The challenge for the analyst is to determine which, if any, of the risk register events he/she has not already captured in the baseline point estimate through the estimating methods directly or the process used to address estimating method uncertainty. It begins with a thorough understanding of the risks/opportunities addressed in the source data used to generate the estimating methods. This is a good example of when SME advice is indispensable. Program managers need assurance that the cost model is not double or triple counting risks/opportunities. Knowing the data, knowing the program risk register (which should also capture opportunities), and pointing to advice from the appropriate SMEs is a good way to address this challenge.

---

[57] Simulation is often referred to as "Monte Carlo". In fact, Monte Carlo is but one way to develop a string of random numbers, the heart of the simulation method. There are many others; Latin Hypercube may be the most popular.

[58] One source for outputs based distributions is the 2010, AFCAA Cost Risk and Uncertainty Analysis Metrics Manual (CRUAMM).

Risks that should not be captured in cost models includes the possibility of labor strikes, natural disasters (e.g., hurricanes, earthquakes), industry collapses (e.g., bankruptcies, litigation), mission changing events (e.g., space shuttle disaster), and world events (e.g., September 11th).

Capturing risk/opportunity impacts in the cost model can be simple if there are only a few such events. If there are only a few, then the analyst builds what-if cases to assess the impact if the risk/opportunity is realized. If there are many, it may be necessary to build a simulation. The 2014 JA CSRUH provides guidance on how to capture risk/opportunity in a simulation model. The next section addresses uncertainty.

7.4.2 Uncertainty

Program managers and stakeholders need to have a sense of the likelihood that the cost estimate may be exceeded. An analyst can establish this probability by estimating the risk/opportunity, and uncertainty resident in the estimate. To estimate the uncertainty of the results, the analyst first needs to determine which elements of the estimate structure to assess for uncertainty. In general, the analyst should assess the estimating methods and inputs of the elements of the estimate structure that contribute the most to the total should be considered. Their estimating methods and their inputs need to be assessed.

There are cost model data that an analyst can be treat as certain. They include:

- **Statute and Policy**: Values such as formally published discount rates.
- **A design fact**: For example, for each item A, the system requires three of item B.
- **Sunk cost:** Money that has already been spent and cannot be recovered.
- **Unit of measure conversion factors**: For example, yards to meters.

Data that can vary, but best treated as what-if cases when applying the simulation method, include:

- **Quantities**: It is uncommon to allow quantities to be flexible. Typically, they are either X or Y amounts and as such, best treated as discrete what-if cases.
- **Schedule**: While there are methods available to cause cost models to be somewhat reactive to uncertain schedules (see 2014 JA CSRUH), cost models tend to treat changes in schedule as a what-if case. This can make it easier to explicitly identify the cost impacts across the program for a schedule slip.
- **Custom Inflation/Escalation**: Both are highly uncertain, but there is no widely accepted method to capture their uncertainty in a cost model.

The analyst can estimate uncertainty for the lowest level elements of the estimate structure through what-if analysis. This is accomplished by estimating the results when inputs to the estimating method are their most favorable, most likely, and most unfavorable. Total uncertainty can likewise be investigated through the what-if analysis of specific scenarios (most favorable, most likely, most unfavorable results) for a combination of elements of the estimate structure. The advantages of this method include that it is straight forward to perform, the what-if cases are easily understood, and potential model behavioral problems are more easily detected. A key disadvantage is that each estimate is itself uncertain, representing just one possible result for a given set of conditions.

Method of moments is the next level of analytics to estimate total uncertainty. However, method of moments can quickly become unmanageable as the complexity of the cost model increases. Even simple estimating methods that rely on uncertain inputs to a method that itself is uncertain adds complications that can be time consuming to address.

Simulation is a popular method to address uncertainty. The 2014 JA CSRUH provides detailed instructions for building a simulation model that is independent of the tool used to perform the simulation. The 2014 JA CSRUH applies the simulation method to a realistic cost model to show that the uncertainty results throughout the model are effectively the same, regardless of the tool used. This is demonstrated by building the model in three different simulation products and comparing results at any level in the estimate structure.

7.5 Iterate as Necessary

At this point in the process, the cost model is almost complete and is producing results. There are many reasons to circle back through the cost estimating process. While **Figure 1** indicates iteration near the end of the process, in reality it can happen at any point in the process. It may not be necessary to circle back to program definition, but it is a good idea to do so to ensure the all aspects of the estimate remain relevant and intact. Reasons to iterate include:

- **Cost estimate basis change**: Changes to the program requirement, framing assumptions, ground rules, or cost estimate assumptions.
- **Unexpected results or requirements**: Unexpected results or the unexpected need for results the model cannot deliver.
- **Validation problems**: When there is evidence the model is not behaving properly.
- **Account for sunk costs**: This is not a simple as it sounds. See **Section 7.1.3**.
- **Automation**: More automation may be required to facilitate what-if drills.
- **New data**: One or more of the estimating methods may need refining or replacing on the discovery of new data.
- **Superior estimating methods**: The discovery of new and better ways to perform the estimate can surface at any time.

7.6 Build Cost Model References

- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7.5.2, "*Baseline Cost Estimate*" and Chapter 7.5.35.3.5, "*Sensitivity Analysis*"
- Department of the Army, Cost Analysis Manual, 2020, Chap 3 "*Cost Estimating Process*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 10 "Step 7: *Develop the Point Estimate*", Chapter 11 "*Step 8: Conduct Sensitivity Analysis*", Chapter 12 "*Step 9: Conduct Risk and Uncertainty Analysis*"
- MARCORSYSCOM, Cost Analysis Guidebook, 2020, para. 3.2 "*Develop A Baseline Cost Estimate*", para. 3.3 "*Conduct Risk/Uncertainty Analysis*", and para. 3.4 "*Verify and Validate the Cost Estimate*"
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Section 5.9 "*Conduct Sensitivity Analysis*" and Section 5.10 "*Conduct Risk and Uncertainty Analysis*"
- NASA, Cost Estimating Handbook, 2015, para. 2.3 "*Part 3: Cost Estimate Tasks*" and para. 4.1 "*Sensitivity Analysis*"
- NCCA, Cost Estimating Guide, 2010, para. 1.3 "*Develop a Baseline Cost Estimate*", para. 1.4 "*Conduct Risk and Uncertainty Analysis*", and para. 1.5 "*Verify and Validate the Cost Estimate*"
- NCCA, Joint Agency Cost Estimating Relationship (CER) Development Handbook, 2018, Chapter 4 "Step 4: *Validate CER*"
- NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014, Chapter 2 "*Cost Informed By Schedule Method Model*" and Chapter 3, "*Finish And Assess The CISM Model*"

- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, para. 5 "*Develop Baseline Cost Estimate*", para. 6 "*Conduct Risk and Uncertainty Analysis*", and para. 5 "*Verify and Validate Cost Estimate*"

7.7 Build Cost Estimate Model Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimating models. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

- BCE 1000 Fundamentals of Cost Estimating
- BCE 0010 Introduction to Cost Modeling
- BCF 206 or BCF 206V Cost Risk Analysis
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCF 250 or BCF 250V Applied Software Cost Estimating
- BCE 3000 Advanced Cost Estimating
- CLB 031 Time Phasing Techniques (*focuses on the methods that cost estimators can use to time phase a cost estimate*)
- CLB 038 Comparative Analysis (*how various comparative analyses should be used to support the cost estimating process*)
- CLB 042 Cost Risk and Uncertainty Analysis (*introductory framework for quantifying the risk and uncertainty in cost estimates*)

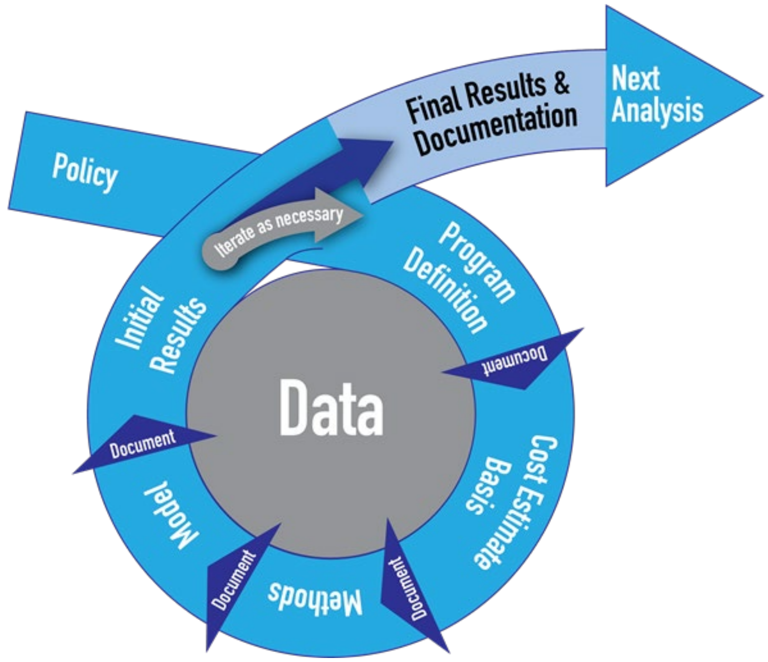
The ICEAA publishes the CEBoK. The follow modules are relevant to modeling:

- CEBoK v1.2, 2013, Module 9 "Risk"
- CEBoK v1.2, 2013, Module 13 "*Economic Analysis*"
- CEBoK v1.2, 2013, Module 14 "*Contract Pricing*"

The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 7883 Data Analytics
- FMF 7815 WKSP 0672 Data Analytics Tools and Techniques
- FMF 7816 WKSP 0673 Applied Concepts of Data Analytics Tools and Techniques
- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 6175 AFIT Cost 669 - Advanced Cost Analysis
- FMF 6716 Risk and Risk Management
- FMF 3002 DCS 204 - Financial Management Concepts Course - Risk Management
- FMF 6540 Analytic Cost Expert Distance Phase (ACE dL)
- FMF 1503 FMA 201 - Financial Management Concepts Course - Cost Estimates for Support Agreements
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

8.0 FINAL RESULTS AND DOCUMENTATION



The cost estimate documentation is a living document, and the analyst should maintain and update it as the program and cost estimate evolve. Each of the Component cost estimating guides and handbooks includes instructions and best practices on documentation. The primary keyword used in these reference documents with respect to documentation is: understand. Readers of the documentation should be able to gain a full understanding of the cost estimate, and another analyst should be able to validate or replicate the estimate. The estimate documentation needs to clearly identify:

- the organization that performed it,
- when the estimate was performed,
- the reason for the estimate, and
- how was it developed.

Most of the estimate documentation should be devoted to how the estimate was developed. The analyst shares the estimate documentation with stakeholders to ensure a complete and common understanding of the results. The estimate documentation should portray a cost estimate that is comprehensive, credible, and accurate. Finally, cost estimate documentation serves as a reference to support future cost estimates.

Documentation varies in size depending on numerous factors, including the:

- size and complexity of the program,
- amount and level of data used in the development of estimate methodologies,
- number and type of different methodologies used in the estimate, and/or
- range of tabular and graphic reports required.

It is worth noting that analysts should not confuse the estimate documentation with a Basis of Estimate (BOE). Although they contain much of the same information, a BOE is a formal term used by the DCMA and the Defense Contract Audit Agency (DCAA). BOEs are formal deliverables provided by vendors delivering products and services to the DoD. Estimate documentation normally includes this scope of work in addition to the remaining program office activities beyond what the vendor provides.

8.1 Documentation Contents

The cost estimate documentation should include all thought processes and calculations used to develop the results required by the stakeholders. Typical content includes the:

- purpose and scope of the estimate.

- description of the program definition,
- framing assumptions,
- program ground rules,
- cost estimating assumptions,
- estimate structure that expands on the program WBS to address purpose, scope and anticipated what-if analysis,
- estimate structure index with dictionary,
- summary of the program IMS,
- cost, programmatic, performance, technical, and schedule data needed to support the estimate,
- sources of data, explanation of veracity, and explanation of any exclusion and/or adjustments,
- how data was normalized,
- identification of outliers and how they are handled,
- phasing of the project scope and deliverables,
- identification of potential risk/opportunities and uncertainty areas,
- proposed risk mitigation plans that impact the cost estimate,
- description of the estimating methods used to develop specific results,
- discussion of other estimating methods considered and why discarded,
- identification of estimating method limitations (e.g., viable range of inputs),
- recommendations for improving estimating methods and modeling approach in the next iteration (e.g., identification of data which should/will become available, alternative estimating methods that could not be investigated in this version)
- description of the inputs to define a baseline cost estimate,
- discussion of crosschecks, sensitivity, and what-If analysis (as required),
- cost estimate results including necessary charts and tables,
- cost estimate results match the final, post reconciliation numbers,
- changes to previous versions of the cost estimate, and
- description of how risk/opportunity and uncertainty is addressed.

Appendix H contains an Air Force documentation checklist for ACAT I, II, and II weapon system programs cost estimates. Many of the questions are applicable to other types of programs or could be easily modified to another type of cost estimate documentation.

Congress often tasks the GAO to evaluate DoD programs to ensure that cost estimates are accurate, credible, comprehensive, and well documented. The GAO has a standard series of questions they ask a program office in order to establish the quality of the cost estimate. The questions are grouped by estimate characteristic, based on best practices, and follows the 12-step cost estimating process defined in the 2020 GAO Cost Estimating and Assessment Guide. Answers to these questions along with program documentation serve as a basis for the GAO to make a quantitative assessment of the reliability of the program's cost estimate. DoD programs should understand each of these questions and be able to provide documented answers and supporting documentation to each in preparation for a GAO audit. This list of questions is included as **Appendix I** to this guide. The checklist is mentioned here as a means for the analyst to assess the completeness of his/her estimate documentation.

8.2 Generate Final Documentation Report

The analyst should finalize and archive the list of documentation elements identified in **Section 8.1** after each estimate and maintain it throughout the life of the program. Ideally, overarching documentation is consolidated into as few files as possible, preferably one, referencing all other documents supporting the estimate. The analyst must retain all referenced documents.

There are several common elements in the cost estimate documentation. **Table 10** provides a notional organization for the cost estimate documentation content. These tables and figures serve as the focal point for the reader as they provide a summary of the cost estimate. Although not every cost estimate type requires each of the listed elements, most are applicable. **Table 10** provides examples for content, but the analyst should choose their documentation content on the specific cost estimate's and stakeholder's needs. Additionally, the elements of **Table 10** should indicate whether a cost estimate result is reported in CY or budgeted TY dollars and identify the cost impacts associated with risk, opportunity, and uncertainty.

The analyst must thoroughly document the estimating method, including the raw data set and the data source. Subjective estimating methods must be documented with details on the source and the estimate reasoning. The documentation of analogy adjustments and univariate estimating methods should include applicable descriptive and inferential statistics. The 2018 JA CER Handbook fully addresses how to document parametric CERs/SERs. Documentation of parametric CERs/SERs should contain a succinct summary of the equation in a human readable form and include definitions for each independent variable, their units of measure, and usage notes, such as the applicable range for each independent variable. Analysts document parametric CERs/CERs developed from regression analysis by explaining their derivation, the list of alternatives, and how the analyst evaluated the alternatives. Parametric CER/SER documentation should summarize fit and predictive statistics along with the tools or software used to calculate these statistics.

Fit statistics summaries should include t-statistics (significance of each coefficient) and the F-statistic (significance of the CER/SER as a whole) to identify candidate CERs/SERs. If the CER/SER did not pass any of the fit statistics, but is still used in the estimate, then the analyst should document the reasoning for continuing with the CER/SER.

Analysts rely on predictive statistics to select the best CER/SER from the candidate CERs/SERs. Predictive statistics (how well the CER/SER predicts the data and the estimate) include the coefficient of determination (how well the CER/SER explains the variation in the data), standard error of the estimate, confidence interval, prediction interval, and mean absolute deviation. These should be included in the documentation. If any of the predictive statistics are unusual, the analyst should document the justification for continuing with the CER/SER.

In situations where an estimate uses SME input(s) as its basis or for calibration, the documentation should include the SME name, organization, and rationale for the input.

Table 10: Common Cost Estimate Documentation Organization

Term	Definition
Summary Description	Key elements of project definition and the basis of estimate to adequately explain the purpose, scope, and structure of the cost estimate. Also includes framing assumptions, ground rules, and cost estimate assumptions.
Schedules	Programs with long and complex schedules should include a summary level schedule that identifies key milestones, quantities, and deliverable dates.
Estimate Structure Dictionary	Explains what is in (and, where appropriate, what is excluded from) each element of the estimate structure to help ensure the appropriate data and data types are defined and categorized.
Cost Model and Results Organized by Estimate Structure	A summary description of the cost model and results organized by estimate structure. Results are normally organized by life-cycle phase and dollar type (CY vs. TY).
Sand Chart	The total cost estimate by year and by phase or by year and by appropriation. The chart illustrates the overlapping of funds. A tabular form of the Sand Chart data often includes prior approved values and current budget controls for comparison.
Pareto Chart	A ranking of the top cost contributors (elements of the estimate structure) to a target total cost.
Tornado Chart (Cost Contributors)	A ranking of cost contributors (elements of the estimate structure) based upon their potential impact on a target total cost estimate.
Tornado Chart (Cost Drivers)	A ranking of cost drivers based upon their potential impact on a target total cost estimate.
What-If Analysis	Cost estimate of configurations other than the baseline estimate. A thorough report on the scenario includes sand, pareto and tornado charts for promising what-if candidates.
CERs/SERs	A summary of the data sources, their normalization, and cost estimating methods employed to develop the CERs/SERs for the top cost contributors along with relevant validation results. Identification of outliers and how handled. Identification of risk/opportunity events and risk mitigation and how implemented in the model

8.3 Present and Defend Results

In addition to detailed documentation, the cost team will prepare and present a cost estimate summary for stakeholder consumption. The analysts tailor the presentation to meet the objectives of the review and the needs of the decision makers and stakeholders. Clear, concise, and presented in a logical order, these presentations normally begin with an overview of the key program definition and basis of estimate elements that set the stage for the presentation objectives and the materials that follow. The analyst is free to develop any tables and charts that are useful for telling the presentation story. The analyst should have developed many of the tables and figures in the final results documentation (see **Section 8.2)**.

Any presentation should attempt to capture the entirety of the cost estimate documentation, only those elements required to support the presentation objective. If stakeholders are fully aware of the program definition, it may be appropriate for the presentation to begin with the relevant framing assumptions, ground rules, and cost estimate assumptions. The estimating methods presentation should be limited to the general approach, any specific difficulties in the process, and how the analysts overcame those difficulties. The presentation should quickly get to the results for the stakeholders. Discussions of estimating methods and mathematical calculations for the most important cost contributors and drivers should be available, but presented on an as needed basis. Although the briefer(s) should be in position to answer detailed questions regarding any aspect of the cost estimate, the presentation should provide adequate information such that the audience gains an understanding of the estimate and provides sufficient content to allow stakeholders to feel comfortable they are making decisions based on sound and accurate results.

The remainder of this section provides an introduction to some commonly used charts. Components generally provide specific guidance for presentation content. The sequence of the charts introduced in the remainder of this session are loosely arranged to address: how much and when, what costs the most, what is driving the cost, how are the funds allocated, and the program funding request.

8.3.1 Sand Chart

The sand chart displays values over time as areas. A common use is to illustrate the total cost estimate by year and by phase or by year and by appropriation. This chart renders the different phased costs or appropriations as layers (resembling layers of colored sand) or as stacked bar charts. The analyst should use the layered version thoughtfully as it may be misleading in some use cases. For example, the data supporting **Figure 7** contains zero funding for FY 2018. **Figure 7** however, suggests that funding is ramping up during FY 2018 when it is not. A workaround is to begin the chart with FY 2019. However, by ending the chart in FY 2035 (to avoid the appearance of dollars in FY36) leaves the question open: does funding end in FY 2035 or did the x-axis end too early? The stacked bar chart, **Figure 8,** is less ambiguous, though perhaps not as visually appealing as the sand chart.

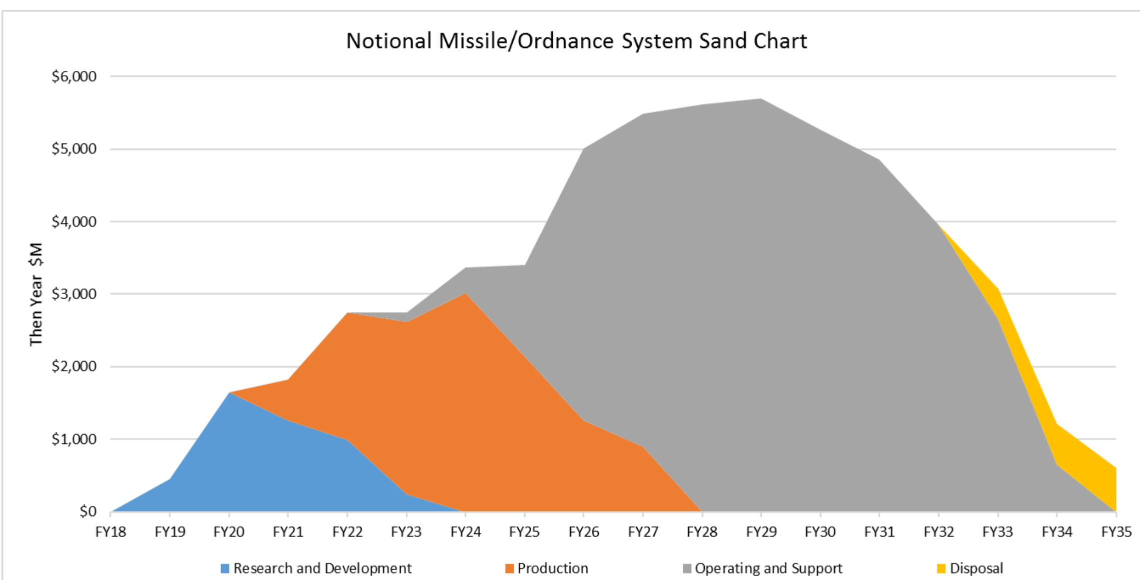


Figure 7: Sand Chart (Layered) (notional)

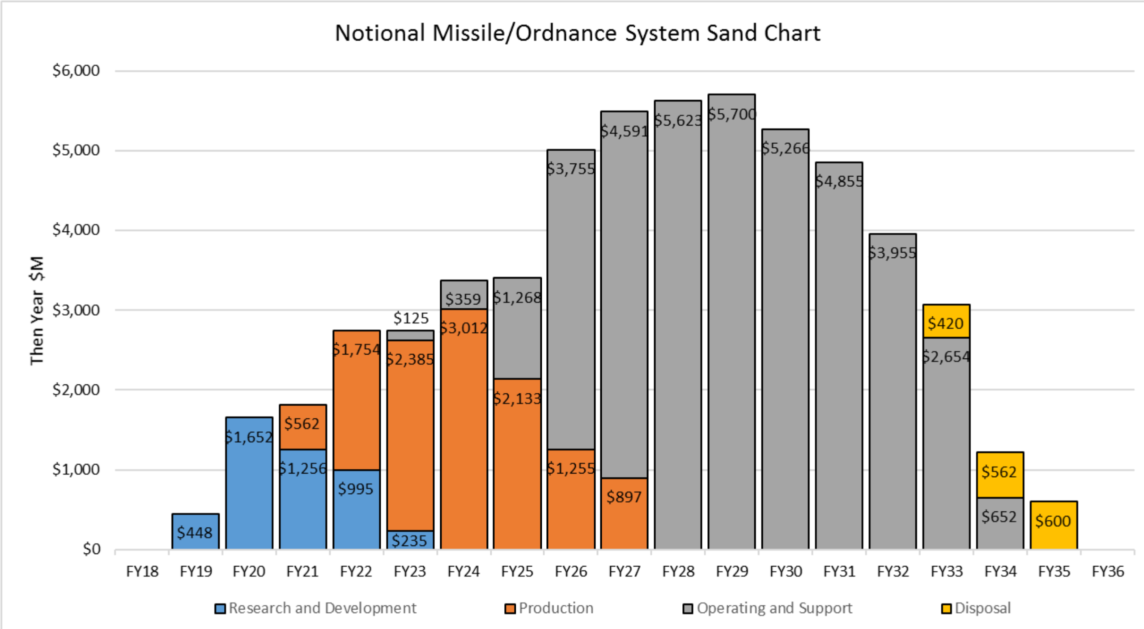


Figure 8: Sand Chart (Stacked Bar) (notional)

8.3.2 Pareto Chart

The pareto chart displays the rank order of contributors to a selected item in descending order and a line representing a cumulative total percentage. For example, **Figure 9** presents the immediate cost contributors to the production cost of a notional missile/ordnance system. In this example, payload is the largest cost contributor immediately below production in the estimate structure. Typically, such charts display the top elements that sum to 70-90% of the cost, depending on the number of elements involved. The most left columns identify the biggest program cost contributors to the selected total cost (in this case, production). However, they may not be the top potential contributors from a risk/opportunity and uncertainty perspective. Tornado charts provide that insight and are discussed next.

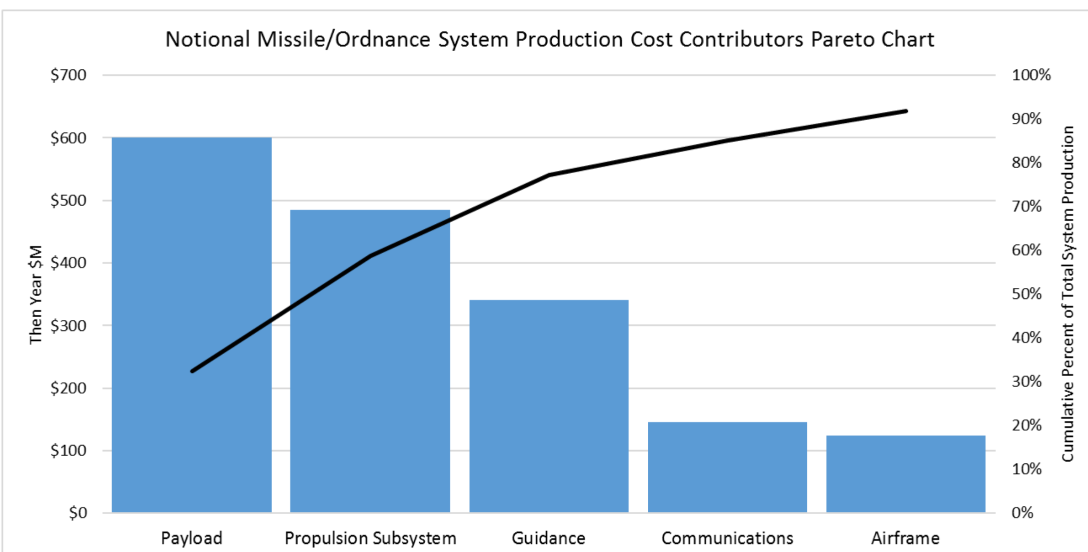


Figure 9: Pareto Chart (notional)

8.3.3 Tornado Charts

A tornado chart displays either sensitivity (**Section 7.3.2**), what-if (**Section 7.3.3**) or simulation (**Section 7.4**) results. The chart objective is to identify the cost drivers (sensitivity) and cost contributors (what-if) that can have the most impact on the total program cost. The horizontal bar chart orders the widest range in potential program cost at the top, with successive smaller impacts plotted below. The shape resembles a tornado, giving rise to the chart's name.

8.3.3.1 Cost Driver Tornado Chart

The cost driver tornado chart shows the results of a systematic sensitivity analysis. The analyst uses three point estimates to construct each horizontal bar[59] in **Figure 10**. The vertical line represents the program baseline point estimate ($1,845 TY$M). The bar to the left represents the potential savings if the cost driver takes on its most favorable value. The bar to the right is the most unfavorable value (from a cost point of view). The bars in **Figure 10** represent parameters and not elements of the estimate structure.

The cost driver tornado chart is a useful tool for identifying parameters the program office may want to consider for risk mitigation plans. In the case of **Figure 10**, speed is identified as the characteristic of the missile that has the most impact on cost, and therefore worthy of attention.

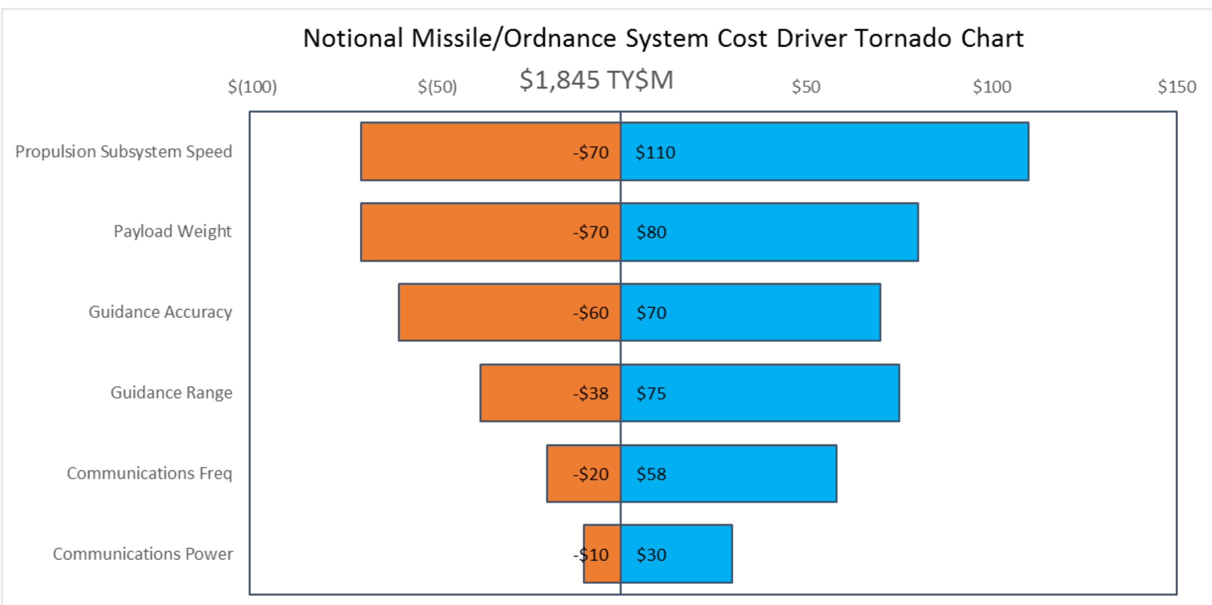


Figure 10: Tornado for Cost Drivers Chart (notional)

8.3.3.2 Cost Contributor Tornado Chart

The analyst derives the cost contributor chart from what-if analysis. Each bar in **Figure 11** represents the cost impact after setting the cost drivers for one element of the estimate structure at a time to its most favorable and unfavorable values. In this case, while the analysis identifies the propulsion subsystem speed as the most important cost driver (see **Figure 10**), the combined uncertainty of the

[59] Tornado charts can also be produced from simulation results. (See the 2014 JA CSRUH, para. 4.1.5 for more detail.)

guidance cost element inputs (accuracy and range) actually has a bigger potential impact. The bars in the cost contributor chart are cost elements in contrast to parameters in the cost driver chart.

The analyst should not rely on one chart or one analysis to identify where the biggest impacts may occur in the cost estimate. The pareto, cost driver tornado, and cost contributor tornado charts combined may tell a more complete story than any one of them on its own.

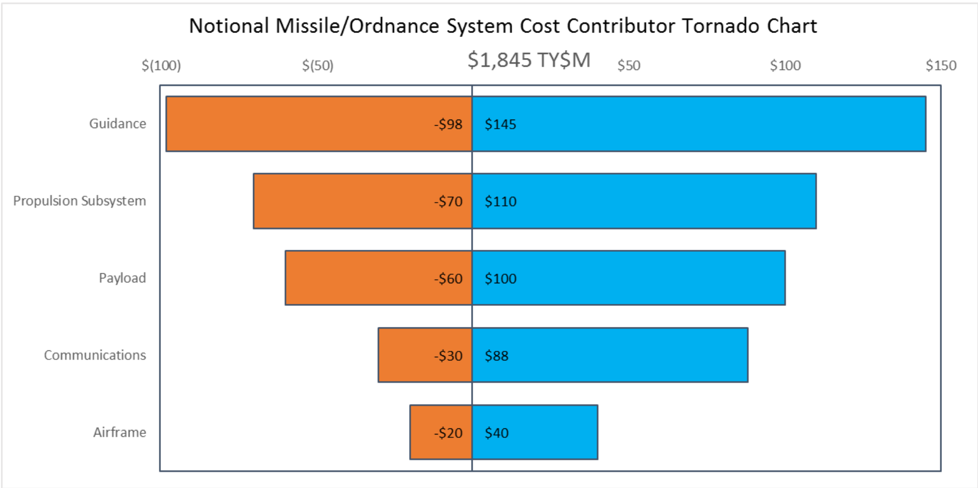


Figure 11: Tornado for Cost Contributors Chart (notional)

8.3.4 Cost Element Chart

A cost element chart provides insight into how what-if cases or different estimates compare to each other. **Figure 12** compares a current O&S estimate (new program) with the ICE, a previous estimate, and the legacy system. The chart should present the results in CY dollars if the legacy program spans a vastly different timeframe. The type of analysis would dictate whether the analyst should include element 6.0 Indirect Costs. An analyst could produce similar charts for R&D, production, or any lower level of the estimate structure. Supporting charts must explain any differences.

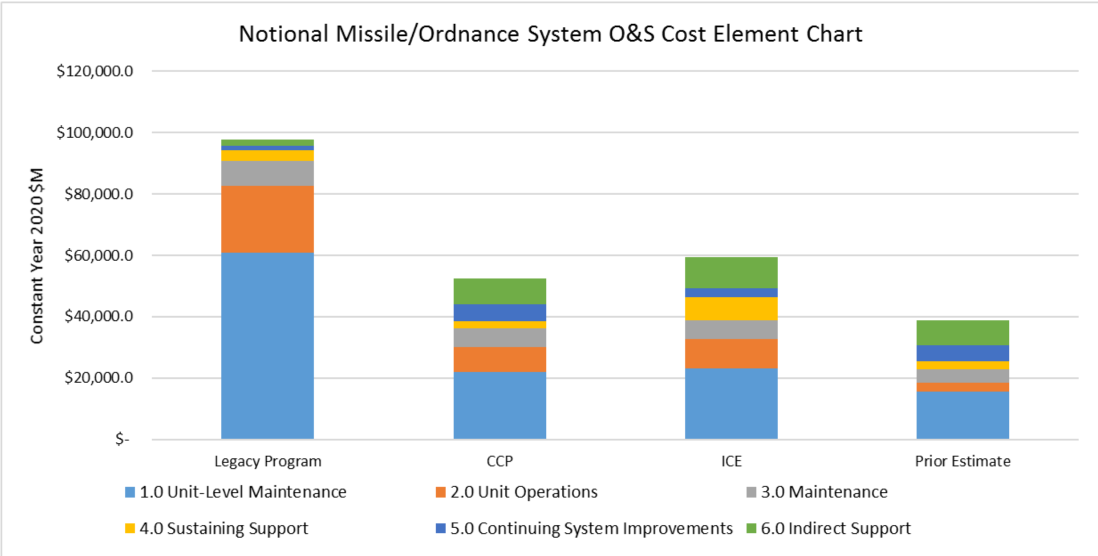


Figure 12: O&S Cost Element Chart (notional)

8.3.5 Program Funding and Quantities Chart

Figure 13 provides an overview of key cost and quantity elements of a program cost estimate[60], and the analysts updates it throughout the acquisition process. The following is a brief summary of the elements in the POM 2021 version of the chart. For detailed instructions, see the latest guidance from USD(A&S). Variation to the chart are common (e.g. it may be organized by program phase or organized appropriation) per Component requirements or best practices.

- **Primary Line Items**: List the primary budget line item(s) that fund the program. Footnotes may be used for clarification/amplification.
- **Prior**: PB position submitted prior to the Current budget position.
- **Current**: Latest approved budget position.
- **Required**: Latest estimate of funds required to successfully execute program, e.g., support the Warfighter and not simply match available budget TOAs. Typically, this would reflect the Will-Cost[61] estimate, CCP, or POE that has not yet been validated by a Component Cost Agency or the CAPE.
- **System Operations and Maintenance (O&M)**: O&M-funded costs from initial system deployment through end of system operations.
- **Total Required Acquisition (BYXX$M)**: Current Estimate of total RDT&E, procurement, military construction (MILCON) and acquisition-related O&M in BY dollars as reported in the program's latest approved budget position. The percentage displayed is the portion of the Acquisition cost out of the sum of Acquisition and O&S costs.
- **Total Required O&S (BYXX$M)**: Current Estimate of total O&S costs in BY dollars. Disposal costs should not be included in this value.
- **Curr Est (APUC)**: Program manager's current estimate of Average Procurement Unit Cost in BY dollars (see **Section 7.1.6**).
- **Curr Est (PAUC)**: Program manager's current estimate of Program Acquisition Unit Cost, in BY dollars (see **Section 7.1.6**).
- **Δ Current**: Program's current APUC or PAUC divided by the program's current APB Unit Cost Reporting (UCR) baseline or equivalent, as applicable.
- **Δ Original**: Program's current APUC or PAUC current estimate divided by the program's original APB UCR baseline, as applicable.

---

[60] It is commonly known as the "Spruill chart", named after Dr. Nancy Spruill a prominent figure in the Acquisition community for many years and originator of this format.

[61] See the should-cost, will-cost implementation memorandum at: https://www.acq.osd.mil/fo/docs/USD(ATL)_Memorandum_on_Implementation_of_Will-Cost_and_Should-Cost_Management_042211.pdf

Program Funding & Quantities	Acquisition to O&S Cost Ratio			(BY 2019)	Curr Est	Δ Current	Δ Original
	Total Required Acq (BY$M):	$14,782	32%	PAUC:	581.9M	+4.6%	+10.2%
	Total Required O&S (BY$M):	$31,245	68%	APUC:	740.1M	-3.2%	+60.2%

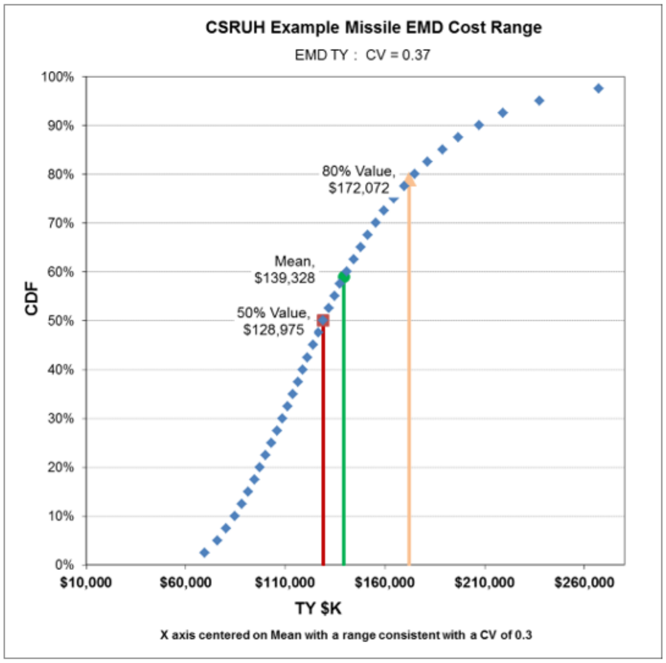
($ in Millions / Then Year)	Prior	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY21-25	To Comp	Prog Total
RDT&E	BLIs:										
Prior $ (PB 20)		416.5	1,718.1	1,092.7	1,005.0	220.9	16.0	0.0	2,334.6	0.0	4,469.1
Current $ (POM 21)		**447.8**	**1,652.0**	**1,256.0**	**995.0**	**235.0**	**0.0**	**0.0**	2,486.0	**0.0**	4,585.8
Delta $ (Current - Prior)		31.3	(66.1)	163.3	(10.0)	14.1	(16.0)	-	151.4	-	116.7
Required[1] $		**488.1**	**1,635.5**	**1,205.8**	**985.1**	**251.5**	**0.0**	**0.0**	2,442.3		4,565.8
Delta $ (Current - Required)		**(40.3)**	**16.5**	**50.2**	**10.0**	**(16.5)**	-	-	**43.7**	-	**20.0**
PROCUREMENT	BLIs:										
Prior $ (PB 20)		0.0	0.0	522.7	1,999.6	2,313.5	2,650.6	2,346.3	9,832.5	1,872.2	11,704.8
Current $ (POM 21)		**0.0**	**0.0**	**562.0**	**1,754.0**	**2,385.0**	**3,012.0**	**2,133.0**	9,846.0	**2,152.0**	11,998.0
Delta $ (Current - Prior)		-	-	39.3	(245.6)	71.6	361.4	(213.3)	13.5	279.8	293.2
Required[1] $		**0.0**	**0.0**	**562.0**	**1,859.2**	**2,385.0**	**2,861.4**	**2,026.4**	9,694.0	**1,974.1**	11,668.1
Delta $ (Current - Required)		-	-	-	**(105.2)**	-	**150.6**	**106.7**	**152.0**	**177.9**	**329.9**
MILCON	BLIs:										
Prior $ (PB 20)		0.0	1.5	1.7	0.0	1.7	16.0	2.9	22.3	15.3	39.1
Current $ (POM 21)		**0.0**	**1.4**	**1.7**	**0.0**	**2.0**	**2.1**	**3.0**	8.8	**12.6**	22.8
Delta $ (Current - Prior)		-	(0.1)	(0.0)	-	0.3	(13.9)	0.1	(13.5)	(2.7)	(16.3)
Required[1] $		**0.0**	**1.5**	**1.8**	**0.0**	**2.0**	**2.2**	**3.3**	**9.3**	**12.6**	**23.4**
Delta $ (Current - Required)		-	**(0.1)**	**(0.1)**	-	-	**(0.1)**	**(0.3)**	**(0.5)**	-	**(0.6)**
SYSTEM O&M[2]	BLIs:										
Prior $ (PB 20)		0.0	0.0	0.0	0.0	141.3	16.0	1,230.0	1,387.2	37,051.0	38,438.2
Current $ (POM 21)		**0.0**	**0.0**	**0.0**	**0.0**	**125.0**	**359.0**	**1,268.0**	**1,752.0**	**37,051.0**	**38,803.0**
Delta $ (Current - Prior)		-	-	-	-	(16.3)	343.0	38.0	364.8	-	364.8
Required[1] $		**0.0**	**0.0**	**0.0**	**0.0**	**118.8**	**362.6**	**1,318.7**	**1,800.1**	**35,198.5**	**36,998.5**
Delta $ (Current - Required)		-	-	-	-	**6.3**	**(3.6)**	**(50.7)**	**(48.1)**	**1,852.6**	**1,804.5**
TOTAL											
Prior $ (PB 20)		416.5	1,719.6	1,617.1	3,004.5	2,677.3	2,698.6	3,579.1	13,576.6	38,938.5	54,651.2
Current $ (POM 21)		**447.8**	**1,653.4**	**1,819.7**	**2,749.0**	**2,747.0**	**3,373.1**	**3,404.0**	**14,092.8**	**39,215.6**	**55,409.6**
Delta $ (Current - Prior)		31.3	(66.2)	202.6	(255.5)	69.7	674.5	(175.1)	516.2	277.1	758.4
Required[1] $		**488.1**	**1,637.0**	**1,769.6**	**2,844.3**	**2,757.2**	**3,226.2**	**3,348.4**	**13,945.6**	**37,185.1**	**53,255.8**
Delta $ (Current - Required)		**(40.3)**	**16.5**	**50.1**	**(95.3)**	**(10.2)**	**146.9**	**55.6**	**147.2**	**2,030.5**	**2,153.8**
QUANTITIES											
Prior (PB 20)		0	2	1	2	4	6	2	15	3	20
Current (POM 21)		**0**	**2**	**1**	**2**	**4**	**6**	**2**	**15**	**3**	**20**
Delta Qty (Current - Prior)		0	0	0	0	0	0	0	0	0	0
Required Qty[3]		**0**	**2**	**1**	**2**	**4**	**6**	**2**	**15**	**3**	**20**
Delta Qty (Current - Required)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

Figure 13: Program Funding and Quantities (Spruill) Chart (notional)

8.3.6 S-Curve

An S-curve derives its name from its shape. It is one of the most common products of a simulation model, and analysts use it to illustrate how cost changes with the probability. The analyst can also produce it from the method of moments or applying a representative distribution from a source such as the 2013, AFCAA CRUAMM. The CRUAMM can be found at: https://www.ncca.navy.mil/tools/csruh/CRUAMM%20Version%2016Nov2011%20with%20Preface%2005April2013.pdf.

There are many ways to build and present an S-curve. Components are encouraged to establish guidelines to promote a consistent and credible way to create them. **Figure 14** is from Figure 4-8 of the 2014 JA CSRUH, which provides more detail on the content of and how to construct this particular version of the S-curve. The CV in the subtitle stands for coefficient of variation. This is a useful metric obtained by dividing the sample standard deviation by the average. Because the CV has no units, it can be used to compare uncertainty across different elements in the estimate structure or across programs. The 2014 JA CSRUH provides more detail on its use and interpretation.



Probability	TY K$
90%	$207,255
80%	$172,072
70%	$155,334
60%	$140,795
50%	$128,975
40%	$118,768
30%	$108,375
20%	$97,122
10%	$84,554

Cost Uncertainty Drivers
- SW Months
- Design Cost/Mth
- SW labor Rate
- EMD Duration

Figure 14: S-Curve Example (notional) [62]

8.4 Lessons Learned

The analyst should formally document lessons learned that stem from developing, maintaining, and updating a cost model and estimate. Lessons learned identify potential areas of risk/opportunities and/or concerns that impacted a program's cost estimate. Lessons learned databases document what did and did not work in past programs, in the hopes that future programs can avoid the same pitfalls. Lessons learned should be stored where the cost community can access them. The Community Knowledge feature in CADE provides a resource to share lessons learned. This feature is accessible from each Program's Dashboard. An analyst with CADE access may use this feature to store lessons learned for use by future analysts. The analyst may also use the feature to research lessons learned by others.

Lessons learned may include any type of information that the estimator believes may be beneficial to a future estimator that is updating the subject estimate or developing/updating a similar estimate. Generally, lessons learned are only remembered for a short time, or by a select group of people. Documenting lessons learned enhances the longevity of the lessons and increases the breadth of those who are given a chance to learn from them.

The primary criterion for including a lesson learned is: does the analyst believe that knowing it in advance it would have been beneficial. For example, a lesson learned might be that the planned analogy required an adjustment to remove the effects of a year-long contractor labor strike that occurred at the start of the analogous product's manufacturing. Since events such as labor strikes should not be accounted for in a cost estimate forecast, the analyst would explain the known labor strike and its effects on the analogy, and how he/she adjusted the analogy to exclude these effects. The analyst might want to include when the labor strike took place, as well as source documentation on the labor strike. In this case, documentation might show that the analyst searched the CADE Community

[62] Acronyms used in Figure 12 include: cumulative distribution function (CDF), software (SW), month (Mth), and Engineering and Manufacturing Development (EMD)

Knowledge feature for the program of interest, and downloaded lessons learned for the analogous program. Ideally, the content will confirm the labor strike occurred and provide insight into its impact. This information serves as the basis to adjust the analogy. In this case, the analyst learned that he/she needed to remove the labor strike impact from the analogy. Other, more straight forward, lessons learned include: where to look for data, efficient estimate structure structure(s), most promising estimating methods, unique and unexpected findings, where attention should have been focused, and anything else that had the analyst known earlier, would have made the job easier.

Although documenting lessons learned takes time, the entire cost community can benefit from the effort.

8.5 Documentation and Results References

- CAPE, Operating and Support Cost-Estimating Guide, 2020, Chapter 7.5.5, "*Documentation and Presentation"*
- Department of the Army, Cost Analysis Manual, 2020, Chap 3 "*Cost Estimating Process*", pg. 18 and Appendix 7 "*Example Documentation*"
- GAO, Cost Estimating and Assessment Guide, 2020, Chapter 13 "*Step 10: Document the Estimate*" and Chapter 14 "*Step 11: Present the Estimate to Management*"
- MARCORSYSCOM, Cost Analysis Guidebook, 2020, para. 3.6 "*Defend Cost Estimate Results*",
- Missile Defense Agency, Cost Estimating and Analysis Handbook, 2021, Section 5.11 "*Document the Estimate*"
- NASA, Cost Estimating Handbook, 2015, para. 2.2.2 "*Task 5: Select Cost Estimating Methodology*"
- NCCA, Cost Estimating Documentation Guide, 2012
- NCCA, Cost Estimating Guide, 2010 para. 1.6 "*Present and Defend the Cost Estimate*"
- NCCA, Initial Cost Review Board (CRB) Guidance, 2015, Slides 11-34 (*Various briefing contents*)
- NCCA, Joint Agency Cost Estimating Relationship (CER) Development Handbook, 2018, Chapter 6 "*Step 6: Document CER*"
- NCCA, Joint Agency Cost Schedule Risk and Uncertainty Handbook, 2014, para. 2.6 *"Document Cost Method and Cost Driver Uncertainty*" and Chapter 4 "*How to Present the CISM Risk and Uncertainty Story*"
- NCCA-AFCAA, Software Cost Estimating Guide, 2008, Appendix F "*System-Level Estimate Case Study*", and Appendix G "*Component-Level Estimate Case Study*"
- SPAWAR, Inst 7110.1 Cost Estimating and Analysis, 2016, Enclosure 1, Chapter 8 "*Present and Defend Cost Estimate*"

8.6 Documentation and Results Training

The DAU Cost Estimating certification program for members of the Defense Acquisition Workforce offers training relevant to the cost estimating results and documentation. Additional information on each course may be found in the DAU iCatalog (https://icatalog.dau.edu/).

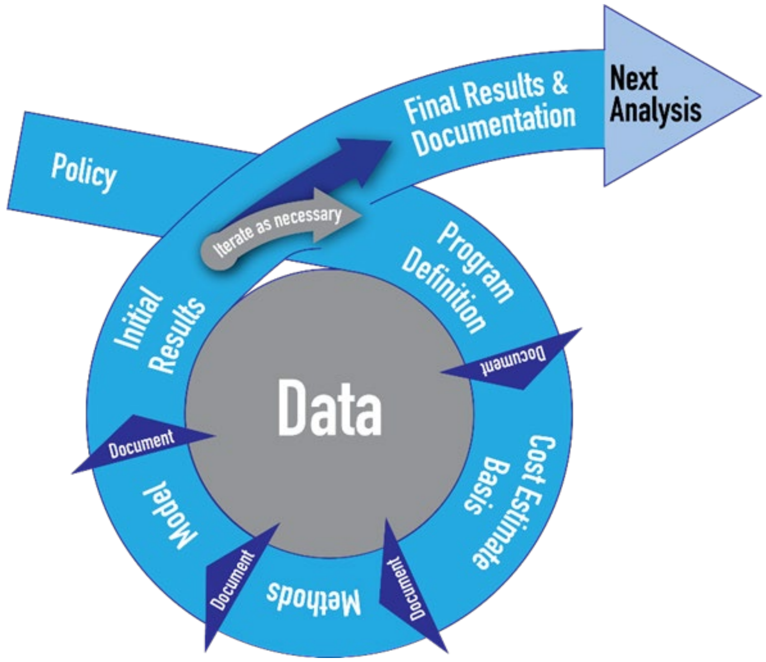
- BCE 1000 Fundamentals of Cost Estimating
- BCF 206 or BCF 206V Cost Risk Analysis
- BCF 216 or BCF 216V Applied Operating and Support Cost Analysis
- BCE 2000V Intermediate Cost Estimating
- BCE 3000 Advanced Cost Estimating

- Continuous Learning, Management (CLM) 052 Developing Stakeholder Engagement (*understand how effective stakeholder relationships contribute to improved acquisition outcomes*)

The following course numbers starting with FMF refer to the course number assigned by the FM Certification process. Information on these courses (including eligibility requirements) can be found in the FM myLearn system: https://fmonline.ousdc.osd.mil/FMmyLearn/Default.aspx.

- FMF 6016 FMA 301 - Business Case Analysis
- FMF 1550 QMT 290 - Integrated Cost Analysis
- FMF 1551 QMT 490 - Current Topics in Cost Estimating

9.0 NEXT ANALYSIS



At the conclusion of the final results and documentation, the cost estimate team should begin evaluating and preparing for the next analysis. This may be a continuation with the same program or an entirely new project. In either case, the final results and documentation of the completed project should be made available to the DoD cost estimating community.

It would be impossible for any guide to cover every possible scenario or circumstance relevant to the development of a DoD cost estimate, but this guide does provide foundational knowledge for the DoD cost community. **Appendix J** contains a Recommended Reading List of items that further enhance an analyst's knowledge on cost estimating, operations research, risk/uncertainty, and weapons acquisition. **Appendix K** contains a case study that applies the cost estimating process described in this guide to a fictional program cost estimate at Milestone C.

The CAPE intends to update this guide as necessary to reflect policy changes, new estimating methods and techniques, better ways to present findings, and to capture evolving best practices within the community. The authors welcome suggestions from the cost estimating community for additional content. Readers may email suggestions to osd.pentagon.cape.mbx.cost-assessment@mail.mil.

APPENDICES

The following appendices are included:

- Appendix A Acronyms
- Appendix B Appendix B Cost Estimating Flowcharts from Multiple Organizations
- Appendix C Sample SME Interview Form
- Appendix D Sample Questions to Get Started
- Appendix E WBS/CES Examples
- Appendix F Assessments of Estimating Method Application
- Appendix G Middle Tier of Acquisition
- Appendix H Department of the Air Force Cost Estimate Documentation Checklist for ACAT I, II, and III Cost Estimates
- Appendix I GAO Audit Preparation
- Appendix J Recommended Reading List
- Appendix K Cost Estimating Case Study

APPENDIX A ACRONYMS

$K, $M, $B	Thousands, Millions, and Billions of Dollars, respectively
AACEI	Association for the Advancement of Cost Engineering International
AAP	Acquisition, Analytics, and Policy
ACAT	Acquisition Category
ACDB	Automated Cost Database
ACE dL	Analytic Cost Expert Distributed Learning
ACEIT	Automated Cost Estimating Integrated Tools
ACQ	Acquisition Management
ADA	Acquisition Data and Analytics
ADM	Acquisition Decision Memorandum
ADVANA	Advanced Analytics
AFCAA	Air Force Cost Analysis Agency
AFI	Air Force Instruction
AFIT	Air Force Institute of Technology
AFLCMC	Air Force Life Cycle Management Center
AFTOC	Air Force Total Ownership Cost
AMCOS	Army Military-Civilian Cost System
AoA	Analysis of Alternatives
AP	Acquisition Plan
APB	Acquisition Program Baseline
APUC	Average Procurement Unit Cost
AS	Acquisition Strategy
ATP	Authority to Proceed
AUMC	Average Unit Manufacturing Cost
BCA	Business Case Analysis
BCAC	Business Capability Acquisition Cycle
BCAT	Business System Category
BCE	Business Cost Estimating
BCF	Business, Cost Estimating, and Financial Management
BES	Budget Estimate Submission
BFM	Business Financial Management
BOE	Basis of Estimate
BOM	Bill of Material
BY	Base Year
C/CFO	Comptroller/Chief Financial Officer
CADE	Cost Assessment Data Enterprise
CAE	Component Acquisition Executive
CAPE	Cost Assessment and Program Evaluation
CARD	Cost Analysis Requirements Description
CBAR	Contract Business Analysis Repository
CCA	Cost Capability Analysis
CCDR	Contractor Cost Data Report
CCE	Component Cost Estimate
CCEA™	Certified Cost Estimator/Analyst (ICEAA)
CCP	Certified Cost Professional (AACEI)
CCP	Component Cost Position

CCRL	Collaborative Cost Research Library
CDD	Capability Development Document
CDF	Cumulative Distribution Function
CDRL	Contract Data Requirements List
CEBoK	Cost Estimating Body of Knowledge
CEMM	Cost Estimating Methodology Matrix
CEP	Certified Estimating Professional (AACEI)
CER	Cost Estimating Relationship
CES	Cost Element Structure
CFSR	Contract Funds Status Report
CIO	Chief Information Officer
CISM	Cost Informed by Schedule Method
CKB	Capabilities Knowledge Database
CLB	Continuous Learning, Business
CLE	Continuous Learning, Engineering
CLM	Continuous Learning, Management
CLS	Contractor Logistics Support
cm^2	Centimeter squared
CONOPS	Concept of Operations
COTS	Commercial-Off-The-Shelf
CP	Constant Price
CPD	Capability Production Document
CRB	Cost Review Board
CRUAMM	Cost Risk and Uncertainty Analysis Metrics Manual
CSDR	Cost and Software Data Reports (CSDR = CCDR + SRDR)
CWBS	Contract Work Breakdown Structure
CY	Constant Year
DACIMS	Defense Automated Cost Information Management System
DAE	Defense Acquisition Executive
DAES	Defense Acquisition Executive Summary
DAU	Defense Acquisition University
DAVE	Defense Acquisition Visibility Environment
DAWIA	Defense Acquisition Workforce Improvement Act
DBS	Defense Business System
DCAA	Defense Contract Audit Agency
DCAPE	Director of Cost Assessment and Program Evaluation
DCMA	Defense Contract Management Agency
DFAS	Defense Finance and Accounting Service
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DoDM	Department of Defense Manual
DON	Department of the Navy
DOT&E	Director, Operational Test and Evaluation
DPC	Defense Pricing and Contracting
DSOR	Depot Source of Repair
DSS	Decision Support System
DTIC	Defense Technical Information Center

DTMHub	Datasets, Tools, and Models hub
EA	Economic Analysis
EAC	Estimate At Completion
EDA	Electronic Document Access
EDM	Engineering Development Model
EMD	Engineering and Manufacturing Development
ERP	Enterprise Resource Planning
ESWBS	Expanded Ship WBS
ETAB	Estimating Technical Assurance Board
EVAMOSC	Enterprise Visibility and Management of Operating and Support Cost
EVM	Earned Value Management
EVM-CR	EVM Central Repository
FA	Framing Assumptions
FFRDC	Federally Funded Research and Development Center
FICSM	Fully Integrated Cost and Schedule Method
FM	Financial Management
FMECA	Failure Mode Effects and Criticality Analysis
FMS	Foreign Military Sales
FOC	Full Operating Capability
FPR	Forward Pricing Rates
FPRA	Forward Pricing Rate Agreement
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FRP	Full Rate Production
FTE	Full Time Equivalent
FY	Fiscal Year
G&A	General and Administrative
GAO	Government Accountability Office
GBL	Government Bills of Lading
GFE	Government Furnished Equipment
GFI	Government Furnished Information
ICD	Initial Capabilities Document
ICE	Independent Cost Estimate
ICEAA	International Cost Estimating and Analysis Association
IGCE	Independent Government Cost Estimate
ILA	Independent Logistics Assessment
ILSP	Integrated Logistics Support Plan
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
IOC	Initial Operational Capability
IOT&E	Initial Operational Test and Evaluation
IPMR	Integrated Program Management Reports
ISP	Integrated Support Plan
IT	Information Technology
IUID	Item Unique Identification
JA CER Handbook	Join Agency Cost Estimating Relationship (CER) Development Handbook
JA CSRUH	Joint Agency Cost Schedule Risk and Uncertainty Handbook
JSCC	Joint Space Cost Council
JST	Job Support Tools

kW	kilowatt
LCMP	Life-Cycle Management Plan
LCSP	Life-Cycle Sustainment Plan
LFT&E	Live Fire Test and Evaluation
LRIP	Low-Rate Initial Production
MADW	Maintenance and Availability Data Warehouse
MARCORSYSCOM	Marine Corps System Command
MCA	Major Capability Acquisition
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MILCON	Military Construction
MIL-STD	Military Standard
MSA	Materiel Solution Analysis
MTA	Middle Tier of Acquisition
mth	month
MYP	Multiyear Procurements
NACA	Non-Advocate Cost Assessment
NASA	National Aeronautics and Space Administration
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVWAR	Naval Information Warfare Systems Command
NCCA	Naval Center for Cost Analysis
NDA	Non-Disclosure Agreement
NDAA	National Defense Authorization Act
NPS	Naval Postgraduate School
NPV	Net Present Value
O&M	Operations and Maintenance
O&S	Operating and Support
ODASA-CE	Office of the Deputy Assistant Secretary of the Army for Cost and Economics
ODC	Other Direct Cost
OLS	Ordinary Least Squares
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
OPTEMPO	Operating/Operational/Operations Tempo
OSMIS	Operating and Support Management Information System
OT&E	Operational Test and Evaluation
OTA	Operational Test Agency
OTP	Operational Test Plan
PARCA	Program Assessment and Root Cause Analysis Office (now ADA)
PAUC	Program Acquisition Unit Cost
PB	President's Budget
PCEA™	Professional Cost Estimator/Analyst Certification (ICEAA)
PCO	Procurement Contracting Officer
PEO	Program Executive Officer
PI	Prediction Interval
PIR	Post Implementation Review
PMP	Prime Mission Product
PMT	Program Management

POA&M	Plan of Action and Milestones (also POAM)
POE	Program Office Estimate
POM	Program Objective Memorandum
PPBE	Programming, Planning, Budgeting, and Execution
PPP	Program Protection Plan
PS	Product Support
PSR	Program Sufficiency Review
PWS	Performance Work Statement
R&D	Research and Development
RDT	Resource Distribution Table
RFP	Request For Proposal
ROI	Return on Investment
RPC	Real Price Change
S-CAT	Services Acquisition Category
SAR	Selected Acquisition Report
SCE	Should Cost Estimate
SEP	Systems Engineering Plan
SEPM	Systems Engineering and Program Management
SER	Schedule Estimating Relationship
SLOC	Software Lines of Code
SME	Subject Matter Expert
SOO	Statement of Objectives
SOW	Statement of Work
SPAWAR	Space and Naval Warfare Systems Command (changed to Naval Information Warfare Systems Command (NAVWAR) June 3, 2019)
SRDR	Software Resource Data Report
STAMP	Store Technical and Mass Property
SW	Software
SWaP	Size, Weight, and Power
TEMP	Test and Evaluation Master Plan
TMRR	Technology Maturation and Risk Reduction
TOA	Total Obligation Authority
TRA	Technology Readiness Assessment
TRD	Technical Requirements Description
TRL	Technology Readiness Level
TY	Then Year
UC100	Unit Cost of the 100th Item
UCR	Unit Cost Reporting
USC	United States Code
USD(A&S)[63]	Under Secretary of Defense for Acquisition and Sustainment
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(R&E)	Under Secretary of Defense Research and Engineering
VAMOSC	Visibility and Management of Operating and Support Costs
VOLT	Validated On-line Life-Cycle Threat
WBS	Work Breakdown Structure

[63] The 2017 NDAA separated the USD(AT&L) into the USD(R&E) and the USD(A&S).

APPENDIX B COST ESTIMATING FLOWCHARTS FROM MULTIPLE ORGANIZATIONS

It is recognized that some of the language in these graphics and flowcharts might be out of date with current terminology. However, they do illustrate how other organizations describe cost estimating.

B.1 Government Accountability Office

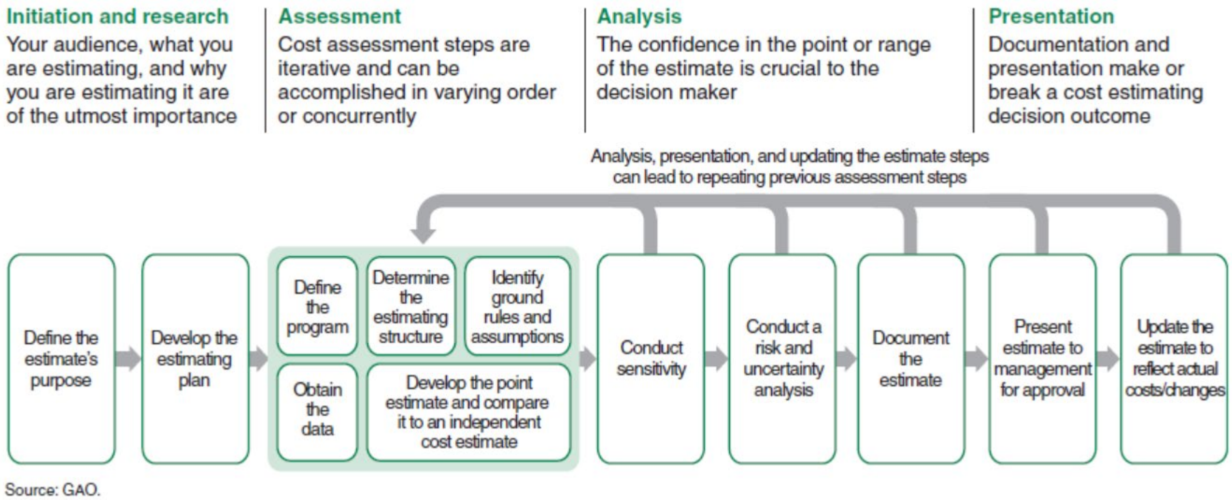


Figure 15: GAO Cost Estimating Process

GAO, Cost Estimating and Assessment Guide, 2020, Chapter 3 Figure 5

B.2 CAPE

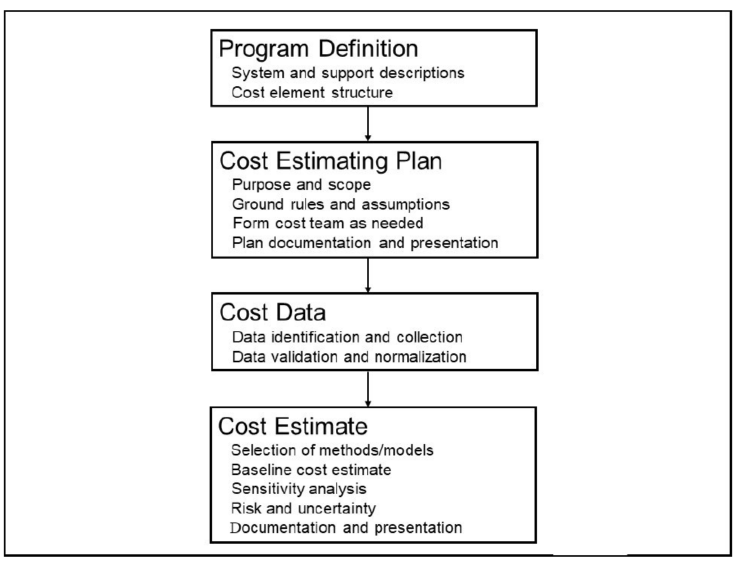


Figure 16: CAPE Recommended Analytic Approach for O&S Cost Estimate

CAPE, O&S Cost-Estimating Guide, 2020, Chapter 7, Figure 7-1

B.3 Department of the Army

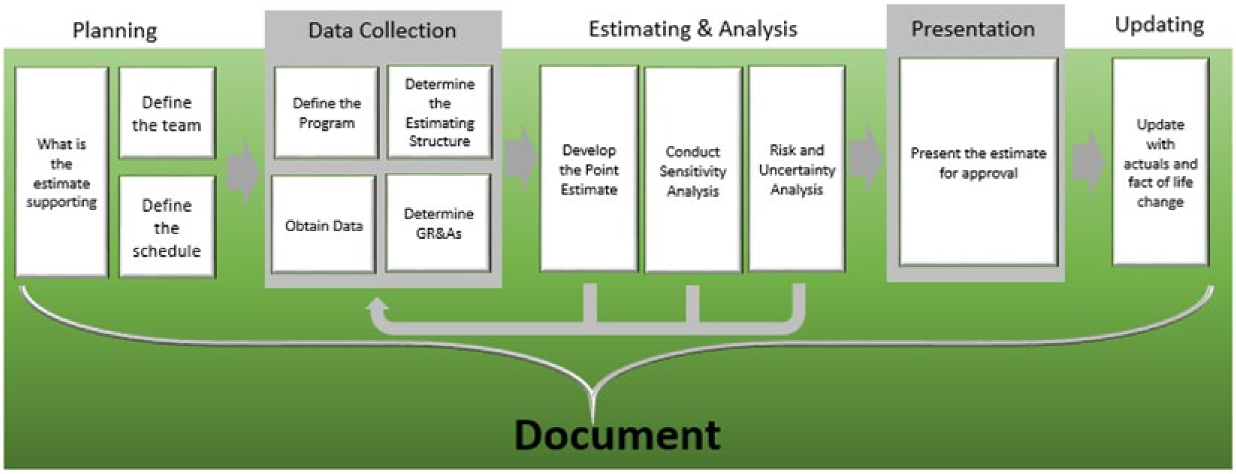


Figure 17: Department of the Army Cost Estimating Process

Department of the Army, Army Cost Analysis Manual, 2020, Chapter 3 "Cost Estimating Process," pg. 9.

B.4 Department of the Navy

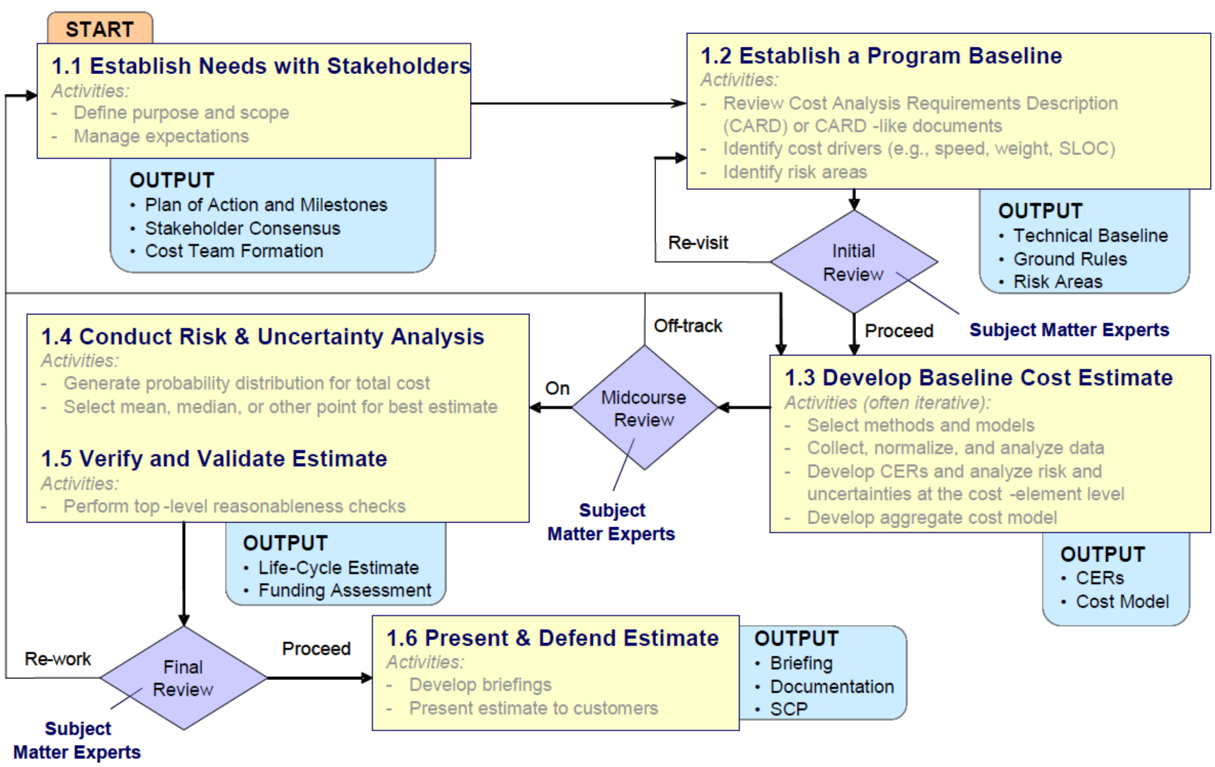


Figure 18: DON Cost Estimating Process Flow

DON, Cost Estimating Guide, 2010, Figure 2, pg. 10
(CEMM: Cost Estimating Methodology Matrix; ETAB: Estimating Technical Assurance Board)

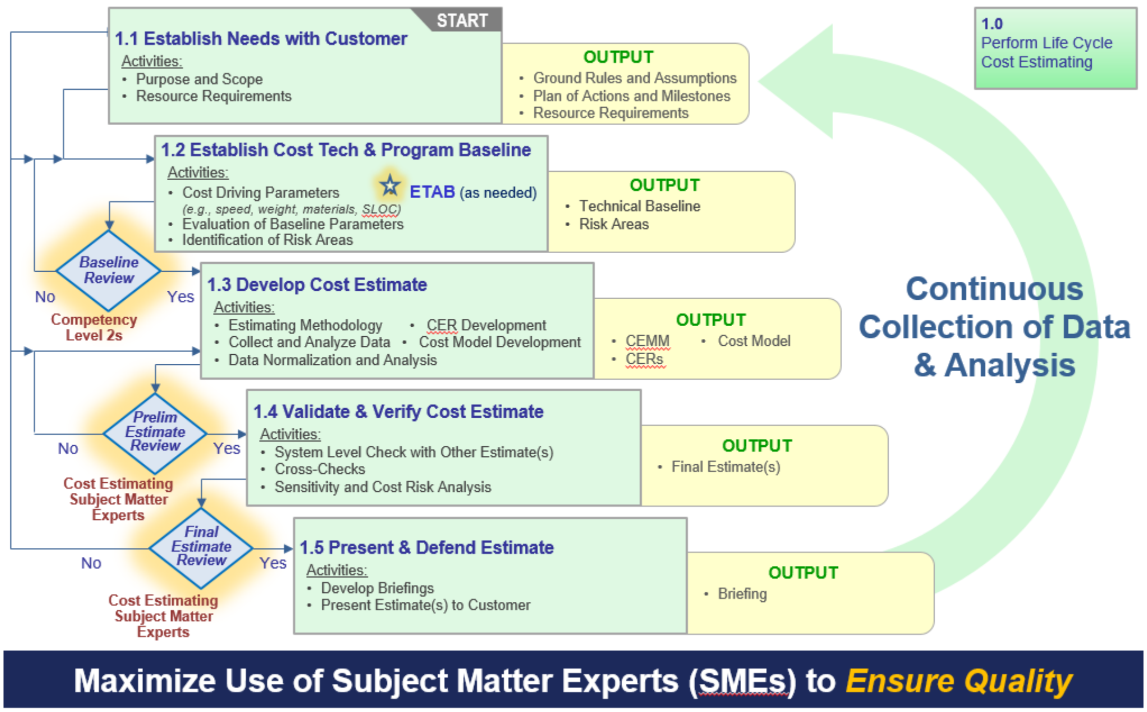


Figure 19: Naval Air Systems Command (NAVAIR) Life-Cycle Cost Estimating Process Flow (Sep 2019)

The NAVAIR Life-Cycle Cost Estimating Process Flow diagram was provided directly by NAVAIR.

B.5 Department of the Air Force

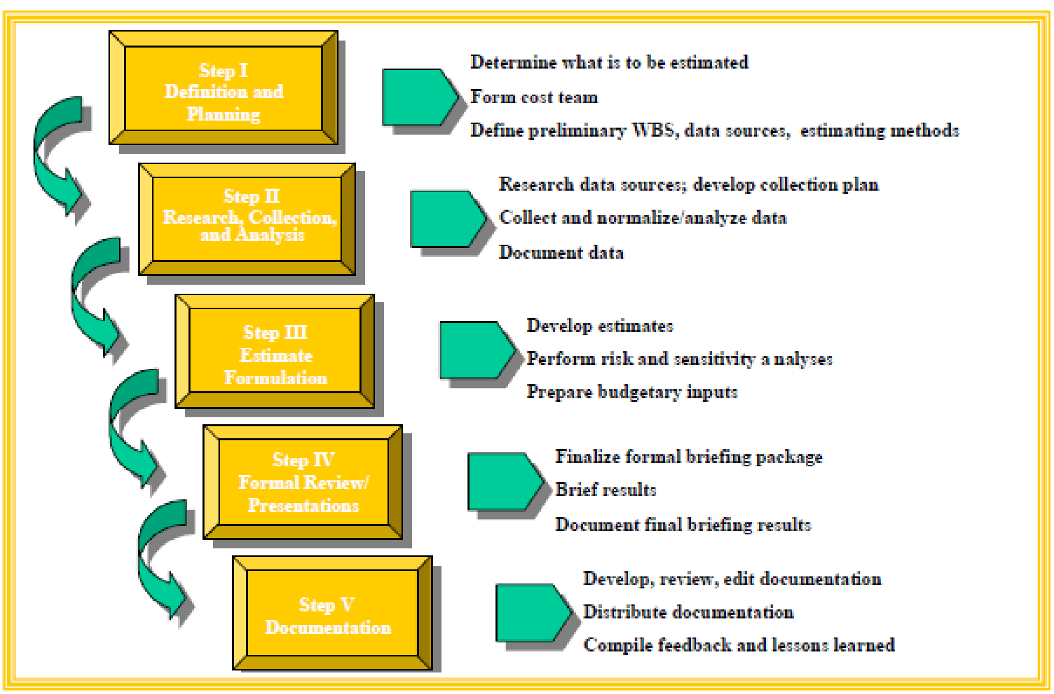


Figure 20: AF Basic Cost Estimating Process

AFCAA, Air Force Cost Analysis Handbook, 2008, Exhibit 3-2, pg. 3-5

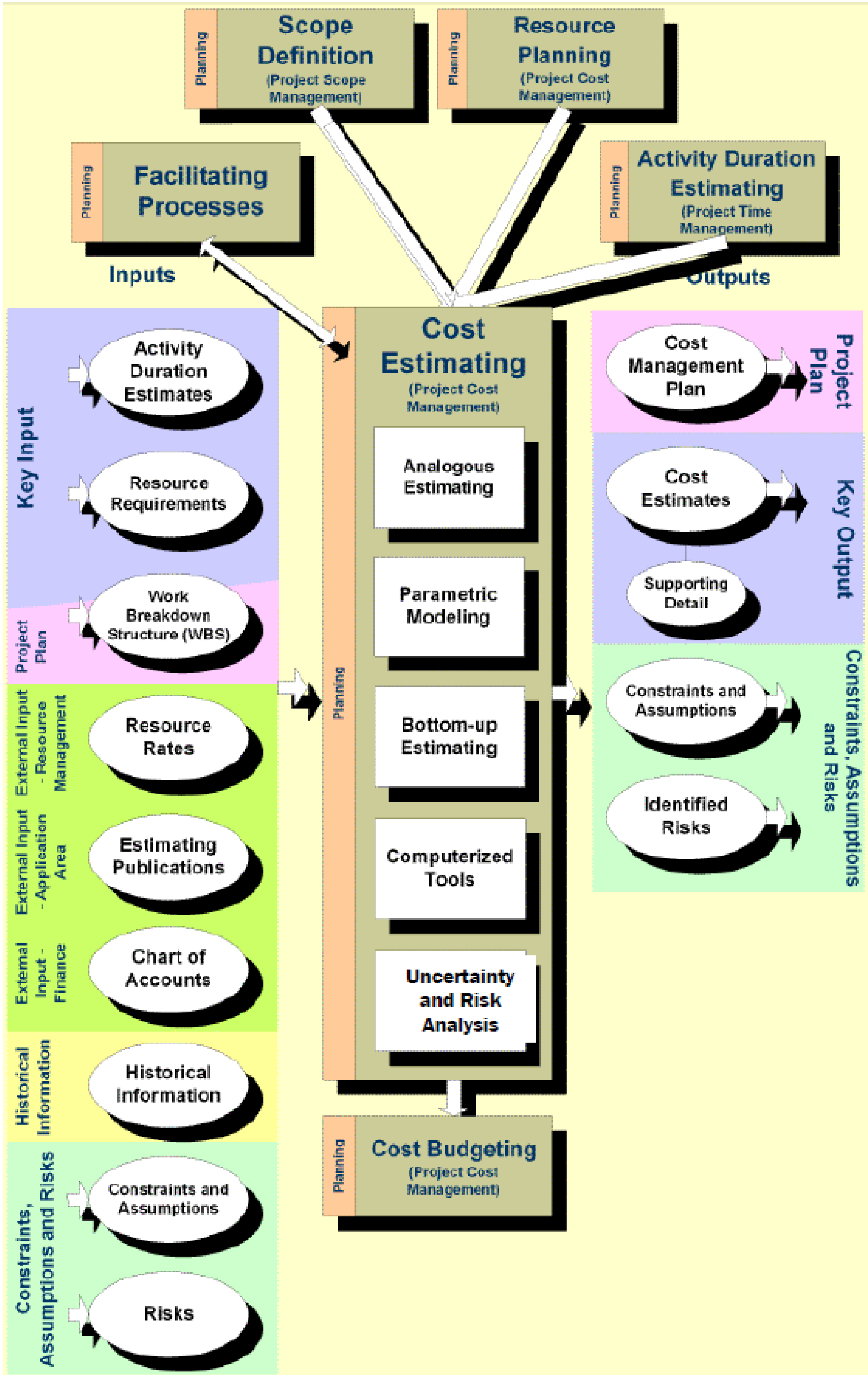


Figure 21: AF Cost Estimating Overview

AFCAA, Air Force Cost Analysis Handbook, 2008, Exhibit 3-1, pg. 3-3

B.6 Joint Space Cost Council (JSCC)

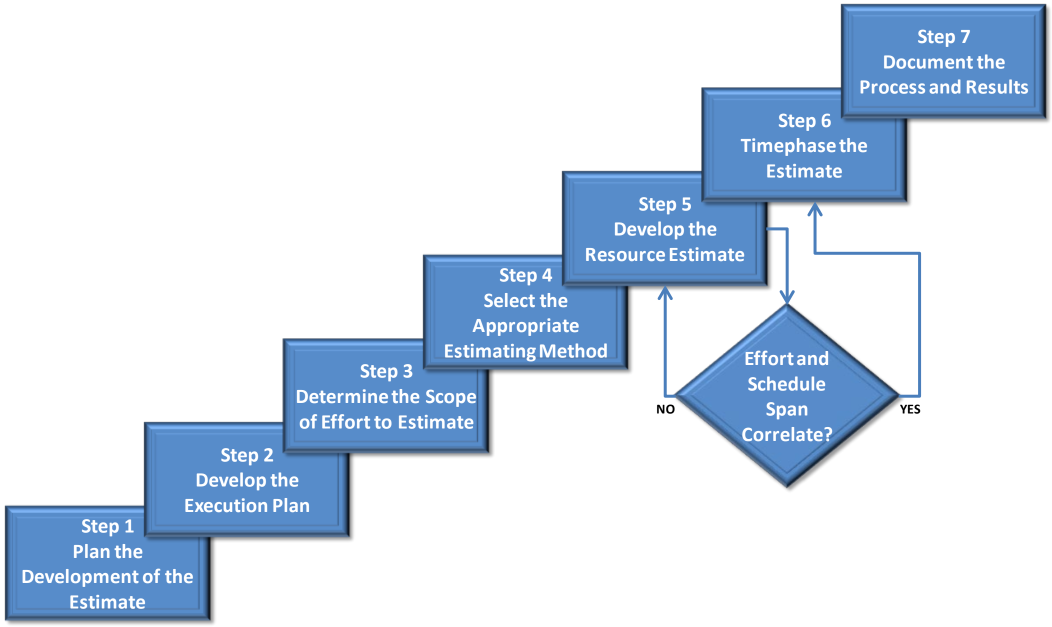


Figure 22: Joint Space Cost Council (JSCC) Cost Estimating Process

Draft JSCC Cost Estimating Guidebook, October 08, 2019, Table 5.3.1, pg. 33 (as applied to a Basis of Estimate) and Figure 6-1, pg. 40 (as applied to a Realistic Cost Estimate)

B.7 NASA

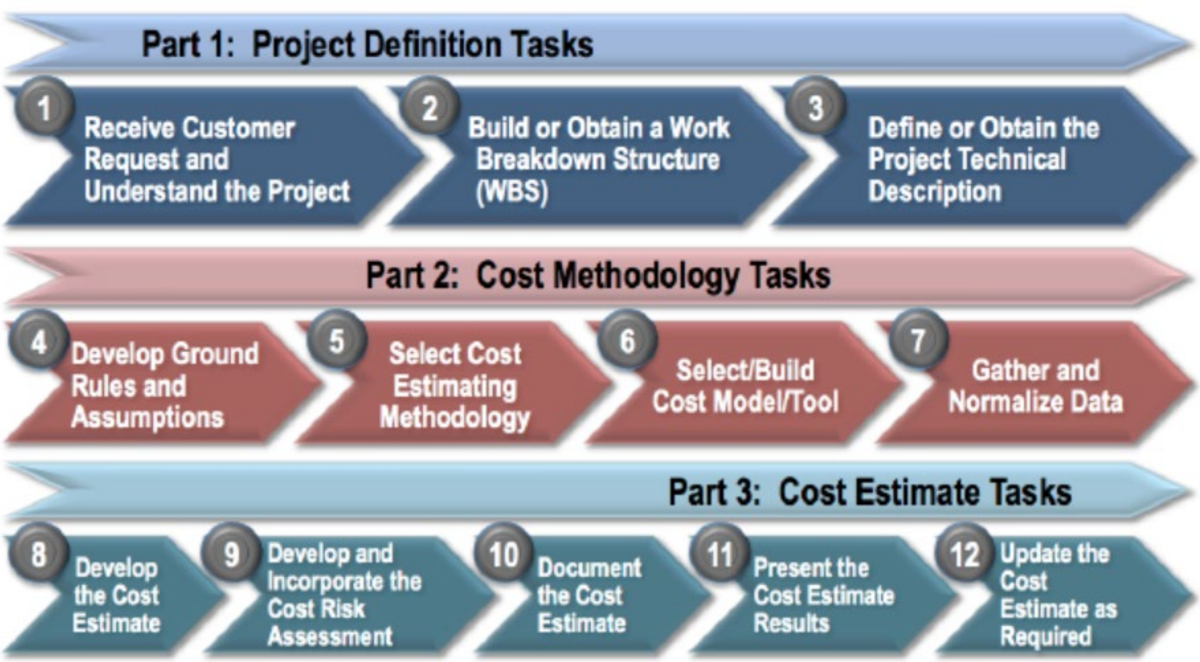


Figure 23: NASA Cost Estimating Process

NASA, Cost Estimating Handbook, 2015, Figure 2, pg. 3

APPENDIX C SAMPLE SME INTERVIEW FORM

Subject Matter Expert (SME) Documentation

Subject Matter Expert (SME) Name	
SME Title	
Estimator Name	
Program Office Name	
Product Office Name	
Date	
WBS Line Item Number	
WBS Line Item Name	
WBS Line Item $BY Amount	
Complexity/Scaling Factor	
Source of Data Point	
Period of Performance	
SME Rationale	
Supporting Documentation Attached	☐ Yes ☐ No ☐ N/A

SME Signature*

Estimator Signature*

APPENDIX D SAMPLE QUESTIONS TO GET STARTED

D.1 Sample Kickoff Meeting Questions

- How did this estimate/analysis become a requirement? How was it originated?
- What is the purpose of this estimate? Is this MS A/B/C? Something else?
- Which acquisition pathway is this program using?
- Are there any predecessor programs (pedigree) to this system, e.g., this is Increment 2, or it is using 50% of System XYZ?
- Are there any policy implications or drivers specifically impacting this estimate, e.g., out of cycle estimate, Middle Tier Acquisition Program?
- Is any other system that relies upon the development of this system, e.g., System XYZ will be delayed if this system schedule slips?
- Does this system rely upon the development of any other system? e.g., this system schedule will be delayed if the System XYZ schedule is delayed?
- Is this a completely new cost estimate or can a prior cost estimate be adapted/modified/used in some fashion?
    - If this can be a modified cost estimate, e.g., a cost model exists and can be adapted, who built the prior cost model?
    - If a prior cost model/estimate exists how familiar are you with the prior model?
    - If a prior cost model/estimate exists, what are the primary changes that have to be made?
- What is the schedule for the cost estimate? Do you think there is sufficient time in the schedule to complete it?
- Regarding the stakeholders for this cost estimate:
    - Who is the Decision Authority for this program?
    - Does the program manager/PEO have any cost estimate result expectation?
    - Are the Prime/Sub contractors providing the information you need?
    - What is the size and makeup of the program office? Are any areas understaffed?
- What are the prime and subcontractor relationships, their contract types, cost reporting, and challenges with the program manager and with each other?
- Will I have the support needed for this cost estimate/briefing/product?
- Is there a checklist of items to be accomplished by this cost estimate?
- What Project Definition documentation is available?
- Who is the POC for arranging data gathering visit to the program manager and the contractor/subcontractors?

D.2 Sample Program Definition Questions

Questions about the CARD and Performance/Technical Baseline.

- Do you have concerns with the CARD?
- What areas of the CARD are incomplete or do not have enough detail?
- Was a CARD Narrative and CARD Microsoft Excel tables developed/delivered?
    - Who drafted the CARD?
    - Has the program manager reviewed the CARD? Approved it?
    - Does anybody in the program office think that any element of the CARD is inaccurate?
- Is there a program WBS in the CARD? If not, why?

- Does the CARD make clear what the program office is funding vs. what it is not funding, e.g., GFE?
- How well defined are the program risk/opportunity areas in the CARD?
- Are any of the technical parameters in the CARD confusing or ill defined?
- Does the CARD indicate whether the software development process is Agile, Waterfall, or some other process?
- Are the quantities development, (e.g., prototype/engineering development model (EDM)), test, and production, (e.g., LRIP, FRP) well defined or still changing?
- If integration is required, is it adequately addressed in the CARD?
- Has the program manager conveyed or mentioned any apprehension about the integration effort/cost?

Questions Related to Schedule:

- Does the program acquisition schedule seem appropriate?
- Do you think the development/production schedule will slip? Why?
- Has the program manager mentioned this is a compressed/accelerated schedule?
- What is on the critical path?
- What program item is the most likely element to cause a delay in the schedule?

Questions Related to O&S:

- Where is the O&S strategy defined? Is it sufficient?
- Are sustainment review requirements sufficiently addressed in the CARD?
- Are Tech refresh requirements adequately addressed in the CARD?
- Are obsolescence issues adequately considered?
- Has disposal been defined?
- What else, if anything, should be included in O&S, but was omitted?

Ground Rules and Assumptions:

- Is there a clear distinction between ground rules (requires program manager approval to change) and assumptions?
- What are the major, cost contributing ground rules and assumptions?
- Does everybody agree on all of the ground rules and assumptions, including the CY, inflation/escalation, quantities, phasing, shared production lines, technical readiness levels, equipment lifetime, etc.?
- Are any of the assumptions likely to change? If so, what is the impact if they change?

APPENDIX E WBS/CES EXAMPLES

For the purposes of the DoD Cost Estimating Guide, a program estimating structure typically consists of a program WBS, one or more contractor WBSs, and a CES. The contractor WBS is a portion, and often lower level breakdown, of the program WBS which represents the specific contractor work content. The CES is an O&S breakdown structure. In some cases, the user might further decompose the WBS and/or CES into functional categories (e.g., engineering and manufacturing labor; overhead).

This appendix provides examples to illustrate the differences between the program WBS, a contractor WBS, and the O&S CES. **Table 11** contains an example of an Aircraft estimating structure with a program WBS, one contractor WBS, and an O&S CES. **Table 12** contains an example of a ground vehicle estimating structure with a program WBS, two variants with a separate contractor WBS, and an O&S CES. **Table 13** contains an example of an Unmanned Maritime System (UMS) program WBS, a contractor WBS, a subcontractor WBS, and an O&S CES. **Table 14** contains an example of a Space program with a program WBS, a contractor WBS, an O&S CES, and a contractor O&S CES.

Note: the following examples for contractor estimating structure WBS only show a portion of the overall structure, to illustrate that CWBS are often more detailed than the program WBS. A reader should expect other areas of the program WBS to apply within the CWBS.

Table 11: Example of Aircraft Estimating Structure

Estimating Structure		
Aircraft Program WBS	**Air Vehicle Contractor WBS**	**O&S CES**
1.0 Aircraft System		
1.1 Aircraft System IATC		
1.2 Air Vehicle	1.2 Air Vehicle	
	1.2.1 Air Vehicle IATC	
	1.2.2 Air Frame	
	1.2.3 Propulsion	
	1.2.4 Vehicle Subsystems	
	1.2.5 Avionics	
	1.2.6 Armament/Weapons Delivery	
	1.2.7 Auxiliary Equipment	
	1.2.8 Furnishings and Equipment	
	1.2.9 Air Vehicle Software Release	
	1.2.10 Other Air Vehicle	
1.3 Payload/Mission System		
1.4 Ground/Host Segment		
1.5 Aircraft System Software Release		
1.6 Systems Engineering		
1.7 Program Management		
1.8 System Test and Evaluation		
1.9 Training		
1.10 Data		
1.11 Peculiar Support Equipment		
1.12 Common Support Equipment		
1.13 Operational/Site Activation by Site		
1.14 Contractor Logistics Support (CLS)		
1.15 Industrial Facilities		
1.16 Initial Spares and Repair Parts		
		1.0 Unit-Level Manpower
		1.1 Operations Manpower
		1.2 Unit-Level Maintenance Manpower
		1.3 Other Unit-Level Manpower
		2.0 Unit Operations
		2.1 Energy
		2.2 Trng Munitions and Expendable Stores
		2.3 Support Services
		2.4 Temporary Duty Travel
		2.5 Second Destination Transportation
		3.0 Maintenance
		3.1 Consumables
		3.2 Depot Level Reparables
		3.3 Intermediate Maintenance
		3.4 Depot Maintenance
		4.0 Sustaining Support
		4.1 System-Specific Training
		4.2 Support Equipment Replace & Repair
		4.3 Sustaining/Systems Engineering
		4.4 Program Management
		4.5 Data and Technical Publications
		4.6 Simulator Operations and Repair
		4.7 Other Sustaining Support
		5.0 Continuing System Improvements
		5.1 Hardware Modifications
		5.2 Software Modifications

Table 12: Example of Ground Vehicle Estimating Structure

Estimating Structure			
Ground Vehicle Program WBS	**Lead Variant Contractor WBS**	**Variant 2 Contractor WBS**	**O&S CES**
1.0 Ground Vehicle System			
1.1 Family of Vehicles			
1.1.1 Lead Variant	1.1.1 Lead Variant		
	1.1.1.1 Lead Variant IATC		
	1.1.1.2 Hull/Frame/Body/Cab		
	1.1.1.3 System Survivability		
	1.1.1.4 Turret Assembly		
	1.1.1.5 Suspension/Steering		
	1.1.1.6 Vehicle Electronics		
	1.1.1.7 Power Package/Drive Train		
	1.1.1.8 Auxiliary Automotive		
	1.1.1.9 Fire Control		
1.1.2 Variant 2		1.1.2 Variant 2	
		1.1.2.1 Variant IATC	
		1.1.2.2 Hull/Frame/Body/Cab	
		1.1.2.3 System Survivability	
		1.1.2.4 Turret Assembly	
		1.1.2.5 Suspension/Steering	
		1.1.2.6 Vehicle Electronics	
		1.1.2.7 Power Package/Drive Train	
		1.1.2.8 Auxiliary Automotive	
		1.1.2.9 Fire Control	
1.1.3 Equipment Kits			
1.2 Secondary Vehicle			
1.3 Systems Engineering			
1.4 Program Management			
1.5 System Test and Evaluation			
1.6 Training			
1.7 Data			
1.8 Peculiar Support Equipment			
1.9 Common Support Equipment			
1.10 Operational/Site Activation by Site			
1.11 Contractor Logistics Support (CLS)			
1.12 Industrial Facilities			
1.13 Initial Spares and Repair Parts			
			1.0 Unit-Level Manpower
			2.0 Unit Operations
			3.0 Maintenance
			4.0 Sustaining Support
			5.0 Continuing System Improvements

Table 13: Example of Unmanned Maritime System (UMS) Estimating Structure

Estimating Structure			
UMS Program WBS	**Shipboard Contractor WBS**	**C2 Subsystem Subcontractor WBS**	**O&S CES**
1.0 Unmanned Maritime System (UMS)			
1.1 UMS IATC			
1.2 Maritime Vehicle			
1.3 Payload			
1.4 Shipboard Segment	1.4 Shipboard Segment		
	1.4.1 Shipboard Segment IATC		
	1.4.2 UMS Command & Control Subsystem	1.4.2 UMS Command & Control Subsystem	
		1.4.2.1 UMS Control Console	
		1.4.2.2 Payload Control Console	
	1.4.3 Communication Subsystem		
	1.4.4 Power Subsystem		
	1.4.5 Launch and Recovery Equipment		
	1.4.6 Storage Subsystems		
	1.4.7 Vehicle Handling Equipment		
	1.4.8 Auxiliary Equipment		
	1.4.9 Shipboard Software Release 1		
	1.4.10 Other Shipboard Subsystems 1		
1.5 Shore Segment			
1.6 Transportation Segment/Vehicles			
1.7 UM System Software Release 1			
1.8 Systems Engineering			
1.9 Program Management			
1.10 System Test and Evaluation			
1.11 Training			
1.12 Data			
1.13 Peculiar Support Equipment			
1.14 Common Support Equipment			
1.15 Operational/Site Activation by Site			
			1.0 Unit-Level Manpower
			2.0 Unit Operations
			3.0 Maintenance
			4.0 Sustaining Support
			5.0 Continuing System Improvements

Table 14: Space Example of Space Estimating Structure

Estimating Structure			
Space Program WBS	**Vehicles and Shelters Contractor WBS**	**O&S CES**	**Contractor O&S CES**
1.0 Space System			
1.1 SEIT/PM and Support Equipment			
1.2 Space Vehicle			
1.3 Ground Segment			
1.3.1 SEIT/PM and Support Equipment			
1.3.2 Ground Functions			
1.3.3 Ground Terminal/Gateway (GT)			
1.3.4 External Network (T-COMM)			
1.3.5 User Equipment			
1.3.6 Facilities			
1.3.7 Vehicles and Shelters	1.3.7 Vehicles and Shelters		
	1.3.7.1 SEIT/PM and Support Equipment		
	1.3.7.2 Vehicles		
	1.3.7.3 Shelters		
	1.3.7.4 Pre-Operations Maintenance		
1.4 Orbital Transfer Vehicle (OTV)			
1.5 Launch Vehicle			
		1.0 Unit-Level Manpower	
		2.0 Unit Operations	
		3.0 Maintenance	
		4.0 Sustaining Support	4.0 Sustaining Support
		4.1 System-Specific Training	4.1 System-Specific Training
		4.2 Support Equipment Replace & Repair	4.2 Support Equipment Replace & Repair
		4.3 Sustaining/Systems Engineering	4.3 Sustaining/Systems Engineering
			4.3.1 Reliability and Maintainability Eng
			4.3.2 Logistics Engineering
			4.3.3 Obsolescence Engineering
			4.3.4 Configuration Management
		4.4 Program Management	4.4 Program Management
		4.5 Data and Technical Publications	4.5 Data and Technical Publications
		4.6 Simulator Operations and Repair	4.6 Simulator Operations and Repair
		4.7 Other Sustaining Support	4.7 Other Sustaining Support
		5.0 Continuing System Improvements	
		5.1 Hardware Modifications	
		5.2 Software Modifications	5.2 Software Modifications
			5.2.1 Bus Software
			5.2.2 Payload Software
			5.2.3 Ground Station Software

APPENDIX F SAMPLE ASSESSMENTS OF ESTIMATING METHOD APPLICATION

The following figures demonstrate a rough consensus of when the basic estimating methodologies are applicable. **Figure 24** is Exhibit 3-11 from page 3-29 of the 2008 AFCAA Cost Analysis Handbook.

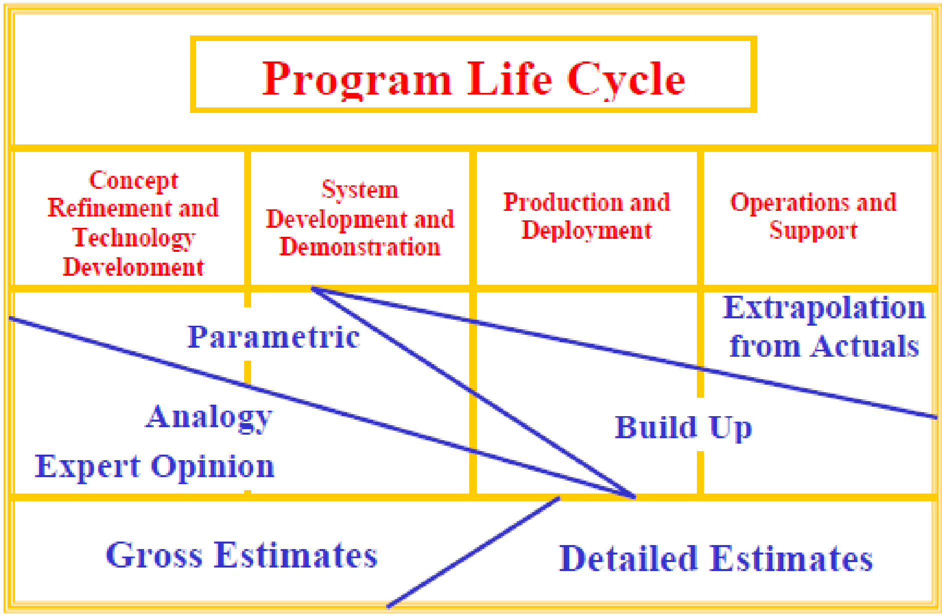


Figure 24: AFCAA: Selection of Methods

Figure 25 is Figure 5 from page 14 of the 2015 NASA Cost Estimating Handbook.

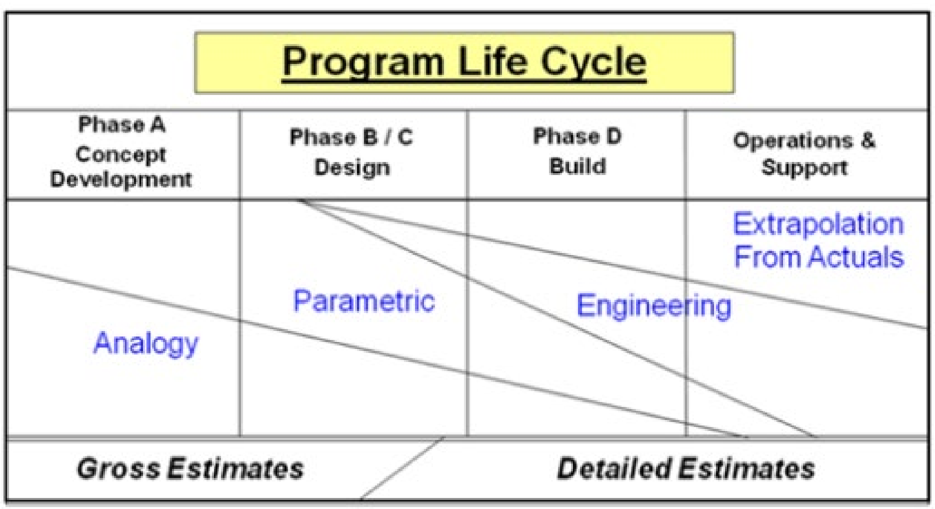


Figure 25: NASA: Use of Cost Estimating Methodologies by Phase[64]

[64] The NASA figure contained the following footnote: Defense Acquisition University, "Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management Framework chart (v5.2)," 2008, as reproduced in the International Cost Estimating and Analysis Association's "Cost Estimating Body of Knowledge Module 2".

APPENDIX G MIDDLE TIER OF ACQUISITION

Introduction

A Middle Tier of Acquisition (MTA) program is one of six acquisition pathways defined in DoDI 5000.02, Operation of the Adaptive Acquisition Framework. Its primary purpose is to fill the acquisition gap between urgent capability acquisitions, which take two years or less to develop and field, and major capability acquisitions, which take significantly longer to develop and field. The DoDI 5000.80, Operation of the Middle Tier of Acquisition (MTA), implements policy to address the statutory requirements of Section 804 of the 2016 National Defense Authorization Act (NDAA). However, the DoDI 5000.80 lacks specificity relative to cost estimating requirements for MTA programs. While the DoDI 5000.73, Cost Analysis Guidance and Procedures, provides additional guidance, the practical implementation of estimating MTA programs differs across the DoD. In conjunction with this guide, this Appendix provides the latest information (as of the publication date of the DoD Cost Estimating Guide) on the current, practical implementation and limitations of cost estimating processes for MTA programs.

Key Concepts

The DoDI 5000.80 addresses rapid prototyping, an acquisition development activity required to take less than five years, and rapid fielding, an acquisition fielding activity required to take less than five years. A rapid prototyping and rapid fielding MTA program are completely separate from each other, but may be included in other acquisition pathways (e.g., a major capability acquisition (MCA) program could include one or more MTA programs). However, estimated costs and data collection for these combined acquisition programs should be separable.

The current DoDI 5000.73 requires a CAPE-developed life-cycle cost estimate only for rapid prototyping and rapid fielding MTA programs that exceed the major defense acquisition program (MDAP) thresholds in DoDI 5000.85, Major Capability Acquisition. CAPE may delegate this responsibility to the applicable Component. DoDI 5000.80 does not identify a course of action when different organizations prepare cost estimates for a single MTA program; however, the Decision Authority (DA) and the advisory board for MDAP level MTA programs, will consider all cost estimates to help determine budget and acquisition pathway decisions. The Components must determine cost estimate requirements for rapid prototyping programs that do not meet the MDAP thresholds. Components must perform cost analysis for rapid fielding programs that do not meet the MDAP thresholds. These requirements are visually summarized in **Figure 26**.

The advisory board established in DoDI 5000.80 assesses the use of the MTA authority for those MTA programs that exceed the MDAP thresholds. For a rapid prototyping MTA program, that threshold is $525 million in Fiscal Year (FY) 2020 constant dollars for research, development, and test and evaluation (RDT&E). For a rapid fielding MTA program, the threshold is $3.065 billion FY 2020 constant dollars for procurement. The MTA advisory board provides a recommendation regarding entrance into the MTA pathway or if the program should utilize another pathway based upon the cost estimates, schedule difficulties, and/or other considerations.

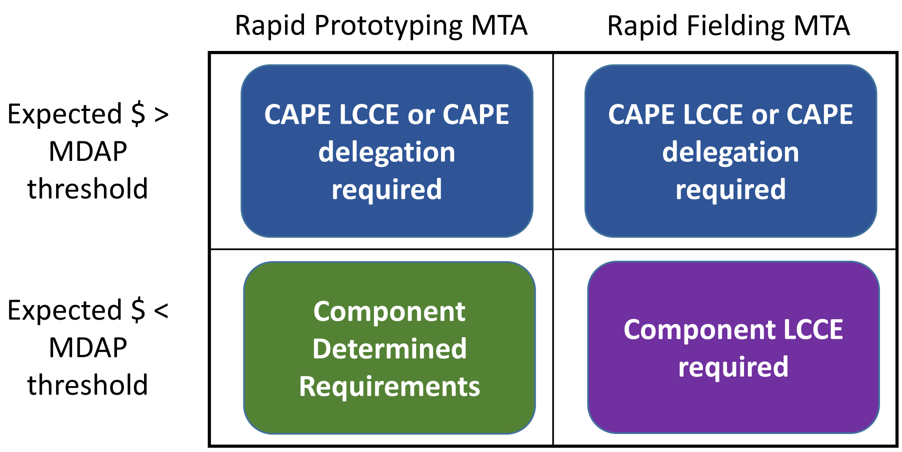


Figure 26: Cost Estimating Requirements for Entrance into the MTA Pathway

MTA programs are not subject to DoD Directive (DoDD) 5000.01, The Defense Acquisition System. For the cost estimator, this means that there will be much less documentation and fewer details available for the cost estimate. Table 1 in DoDI 5000.80 requires that all prospective MTA programs have an ADM signed by the DA, a succinct requirements document, and an acquisition strategy. This minimal documentation is a significant reduction from the MCA requirements for capability documents, e.g., capability development document (CDD), test and evaluation master plan (TEMP), cost analysis requirements description (CARD), analysis of alternatives (AoA), etc. A life-cycle sustainment plan is required for rapid fielding MTA programs. While a CARD is not required for a rapid prototyping or rapid fielding MTA program, the program office should provide a program description that conveys some of the critical items a CARD usually contains.

With a significantly reduced timeframe to develop the MTA program documentation, there is an increased chance that the programmatic information may not align across multiple documents, such as testing requirements or quantities. The cost estimator should review all available documentation from the program office for consistency across each document and be proactive in requesting assumptions and documentation that may be missing but are necessary to complete the estimate. The cost estimator should focus on defining assumptions for an MTA cost estimate because the program office is likely to provide fewer details on the requirements. It is vitally important to fully understand the proposed scope and schedule of these MTA programs. Therefore, with the reduced documentation and fewer details for the program scope, program risk and uncertainty should be an increased focus for the cost estimator. This additional risk and uncertainty is partially the reason for the DoDI 5000.73 cost and software data reporting (CSDR) threshold of $20M per contract for MTA programs that exceed $100M.

Less documentation, details, available data, and a shortened estimating timeframe for MTA programs are all significant challenges to overcome for the cost estimator. The cost estimating guide identifies various techniques to address these challenges including the type of estimate in Section 6.1 and the inclusion of risk/uncertainty in the cost estimate from Section 6.4 and Section 7.4. Few program details and a short timeframe to develop the cost estimate are more suited for a parametric or analogy estimating method. The analogy estimating method will have additional challenges until more MTA program data is available. While it is possible to use the development portion of an MCA program as an analogy, the cost estimator must fully understand the scope, schedule, manning, performance requirements, and testing differences in order make an adequate analogy. Since some of this information may not be available in adequate detail, the cost estimator will need to increase the application of risk and uncertainty in the MTA program cost model where details are unclear. It is also vitally important that the cost estimator convey these increased risks and uncertainties to the DA and the advisory board.

Rapid Prototyping

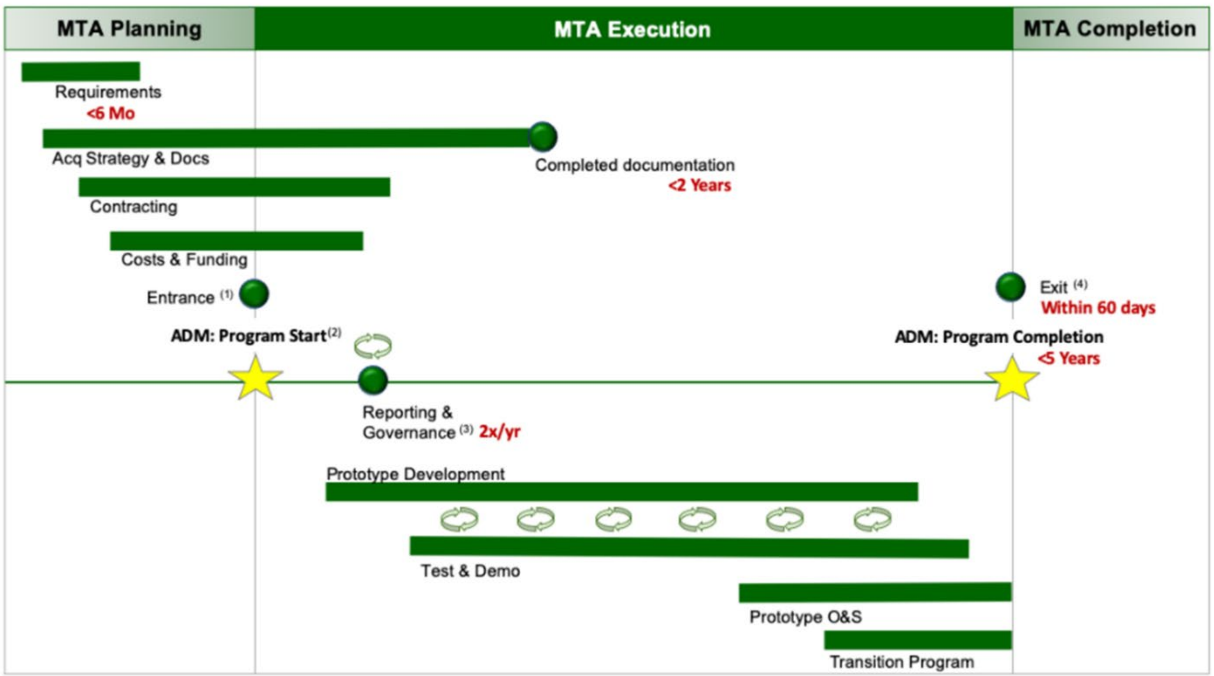
For a rapid prototyping MTA program, time is immensely important to the cost estimator. As **Figure 27** displays, there is an indeterminate amount of time in the planning phase prior to the ADM establishing the beginning of the five-year timeline. With all of the preparations to establish the MTA program, the program office often leaves the cost estimator with a significantly reduced amount of time to prepare the cost estimate, sometimes as little as two months. The cost estimate must be completed within 60 days of the DA's decision to pursue an MTA program. While there is a requirement for a cost estimate for the advisory board assessment if the rapid prototyping MTA program is an MDAP level program, unless the performance or outcomes are not as expected, the DA or higher organization are likely to only request estimates to support the budget over the remaining timeframe.

As the cost estimator builds the initial estimate, differences between this type of estimate and an estimate for an MCA program become obvious. The program office has less time to solidify the program requirements in the few months prior to the decision point. The program office and/or the requirements community creates a succinct requirements document and acquisition strategy, typically with far fewer details than seen in an MCA program. In some cases, the program office might produce a less detailed TEMP, CARD, or other typical acquisition document. For example, there may be a CARD narrative, but no CARD tables, or a PowerPoint presentation of the top level system description and requirements. The cost estimator should have a strong relationship with the program office and obtain any other documentation that will help in the development of the cost estimate. Actual program data, such as earned value, is likely unavailable and historical analogous data is currently minimal on rapid prototyping MTA programs prior to contract award. Cost and software data reporting (CSDR) data are likely unavailable this early in the program as well. However, as rapid prototyping MTA programs become more common, the cost estimator will have additional CSDR data that might be analogous or useful from a schedule or specific work breakdown structure (WBS) element for the required estimate. The cost estimator should review all rapid prototyping MTA program data available in the Cost Assessment Data Enterprise (CADE) portal (https://service.cade.osd.mil/cadeportal/site/home.aspx).

A full life-cycle cost estimate requires defining production and O&S requirements, which are typically not part of the rapid prototyping MTA program content. If a rapid prototyping MTA program cost estimate is a full life-cycle cost estimate, the cost estimator should ensure the five-year development portion can easily be separated from the cost estimate.

There is an expectation that rapid prototyping MTA programs have an increased commerciality basis and/or are leveraging partially/fully proven technologies requiring minimal additional development. The cost estimator should explore any documents the program office can provide related to the commerciality and proven technologies for rapid prototyping MTA programs. The cost estimator should become fully familiar with the proposed MTA program schedule because it may be useful as a comparison with MCA development programs, which often require more than five years. Understanding the differences and similarities between the proposed rapid prototyping MTA program and other rapid prototyping/MCA development efforts/timeline can be critical to developing the cost estimate. The cost estimator should convey through briefings and added cost estimate risk once it becomes apparent the rapid prototyping MTA program has significant risk of exceeding the five-year development schedule.

If OSD CAPE performs a life-cycle cost estimate on an MDAP level rapid prototyping MTA program (i.e., CAPE did not choose to delegate the authority for the conduct of the ICE to the Component), additional time should be included to review the estimates and understand the differences between cost estimates. If there are significant differences that cannot be resolved between the OSD CAPE cost estimate and any other estimate for the rapid prototyping MTA program, OSD CAPE will convey those differences to the DA and the advisory board to support the assessment of the appropriate acquisition pathway for the program.



(1) *Major Systems*: Acquisition Decision Memorandum(ADM) signed by the Decision Authority (DA), Acquisition Strategy (which includes [1] Security, Schedule & Production Risks; [2] Test Strategy/Results; and [3] Transition Plan), and Program Identification Data (PID)
Non-Major Systems: ADM signed by the DA, PID
(2) Major Defense Acquisition Programs (MDAPs) require Under Secretary of Defense for Acquisition & Sustainment (USD(A&S)) Prior Written Approval
(3) Updated PID submitted twice a year with President's Budget and Program Objective Memorandum submissions to Office of Secretary of Defense (OSD)
(4) Signed Outcome ADM, Final PID, Assessment of Test Results

Figure 27: Life-cycle View of Rapid Prototyping (https://aaf.dau.edu/aaf/mta/prototyping/)

Rapid Fielding

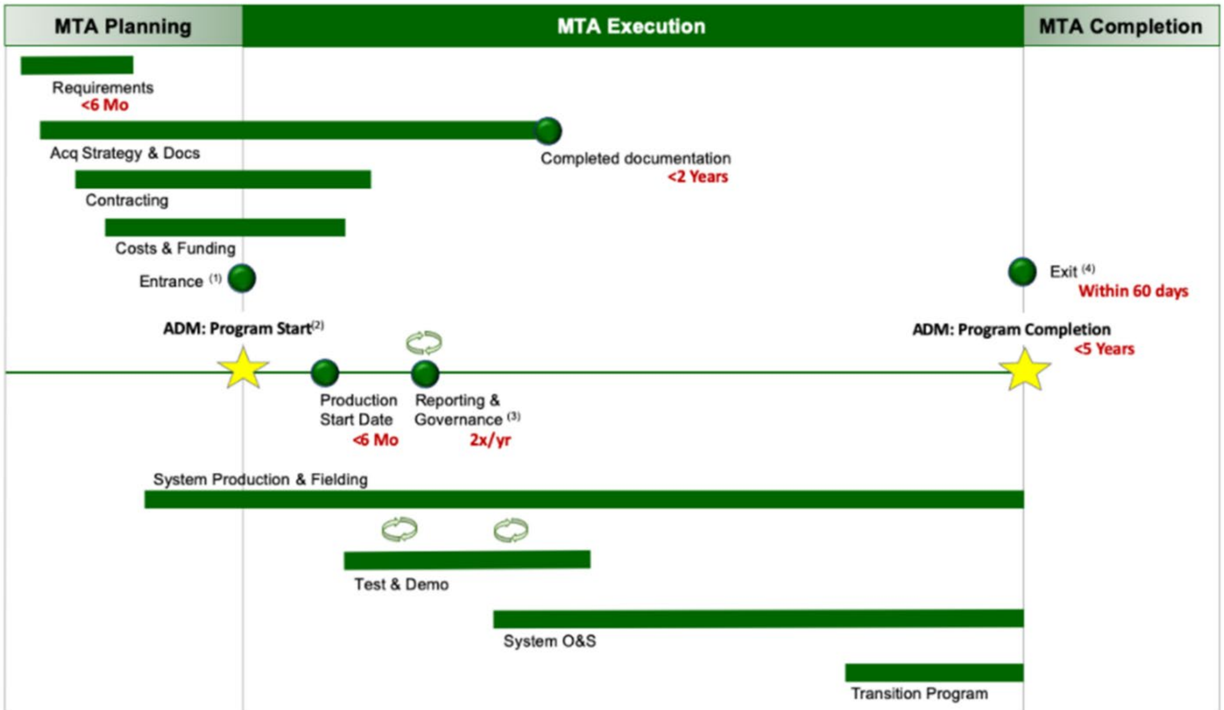
Similar to the rapid prototyping MTA program, the cost estimator should endeavor to discover when planning begins for a rapid fielding MTA program. As **Figure 28** displays, there is an indeterminate amount of time for the planning phase prior to the ADM establishing the beginning of the five-year timeline. The cost estimator will likely have a shortened amount of time to prepare the cost estimate, possibly as little as little as two months. However, development, commerciality, and other prior information about the fielded end item(s) should be available from the program office. This information will help to develop the cost estimate required prior to the DA issuing an ADM declaring the program will follow the MTA acquisition pathway. While the advisory board requires a cost estimate for its assessment when the rapid fielding MTA program is an MDAP level program, unless the performance or outcomes are not as expected, the DA or higher organization are likely to only request estimates to support the budget over the remaining five years. However, if the rapid fielding program transitions to sustainment, updated cost estimates are likely to be required before entering sustainment.

As with the rapid prototyping MTA program, the rapid fielding MTA program will have less program documentation. The requirements document will be a summary of the capability production document (CPD) and CARD while the acquisition strategy contains the test requirements and fewer details than typically contained in a full acquisition strategy. Different from the rapid prototyping MTA program, a life-cycle sustainment plan (LCSP) is required for this MTA program, which implies the cost estimate should include an operations and support (O&S) estimate. However, this LCSP is also likely to contain fewer details than an MCA LCSP for the O&S portion of the cost estimate. There is a possibility that the program office, or prior program office, created a reduced TEMP, CARD, or other acquisition document during its development. The cost estimator should attempt to find and obtain all acquisition documents that will help conduct the cost estimate and ensure the programmatic details in those documents are consistent. As such, it is vitally important to have a strong relationship with the program office to help obtain other program documentation that might exist. If the rapid fielding MTA program expects to transition to sustainment, the program office and cost estimator should review current DoD and Service level policies to understand the documentation requirements for a program in sustainment since these requirements are likely different from a rapid fielding MTA program.

Cost data from the development of this rapid fielding MTA program may be available in CADE. Earned value data might be available from the development effort as well, but is unlikely to be available for the fielding effort. If the rapid fielding MTA program is a modified commercial item, pricing data may be available from the prime contractor or publicly available. CSDR data on other rapid fielding MTA programs is available in the CADE portal and the cost estimator should review and determine if other MTA data may be useful as an analogy in this cost estimate. The cost estimate should include costs for the production line setup, risk associated with the yearly production requirements, testing, deployment, and O&S. An O&S estimate is included in this rapid fielding MTA program cost estimate because the program may transition to sustainment rather than to another acquisition pathway. If sunk cost from the development of this rapid fielding MTA program is available, this information could be useful and informative for the cost estimate and/or DA.

If the rapid fielding MTA program exceeds the MDAP procurement threshold, OSD CAPE will conduct a life-cycle cost estimate for the program. The program office and component cost analyst should anticipate additional time to review the estimates and understand the differences prior to the DA and advisory board review and assessment. If there are significant differences between the OSD CAPE cost estimate and any other estimate for this program, OSD CAPE is likely to convey those differences to the DA and advisory board to support the assessment of the appropriate acquisition pathway for the program.

This appendix conveys the policy status and best practices for estimating MTA programs as of the date of this publication. Cost estimators are encouraged to review new statutes and policies governing the operation of MTA programs as they become available. As more MTA programs submit CSDRs to CADE, the basis for estimating MTA programs should shift to rely more upon this available, possibly analogous, data. As this shift occurs, cost estimators can reduce the risk and uncertainty in their cost models for MTA programs because risk and uncertainty are already included in the CSDR data, especially for completed MTA programs.



(1) Major Systems: Acquisition Decision Memorandum(ADM) signed by the Decision Authority (DA), Acquisition Strategy (which includes [1] Security, Schedule & Production Risks; [2] Test Strategy/Results; and [3] Transition Plan), and Program Identification Data (PID)
Non-Major Systems: ADM signed by the DA, PID
(2) Major Defense Acquisition Programs (MDAPs) require Under Secretary of Defense for Acquisition & Sustainment (USD(A&S)) Prior Written Approval
(3) Updated PID submitted twice a year with President's Budget and Program Objective Memorandum submissions to Office of Secretary of Defense (OSD)
(4) Signed Outcome ADM, Final PID, Assessment of Test Results

Figure 28: Life-cycle View of Rapid Fielding (https://aaf.dau.edu/aaf/mta/fielding/)

APPENDIX H DEPARTMENT OF THE AIR FORCE COST ESTIMATE DOCUMENTATION CHECKLIST FOR ACAT I, II, AND III COST ESTIMATES

The following checklist is adapted from: AFI 65-508, Attachment 3, 12 June 2018

H.1 Introduction

1.2. Table of Contents.

1.3. Program title and Program Elements.

1.4. Reference to the current program decision, if applicable, and CARD.

1.5. Purpose and scope of the estimate.

1.6. Cost estimate team members listed by organization, phone number, and area or estimating responsibility.

1.7. Description of system or effort being estimated, with program phases estimated and excluded costs identified.

1.8. Program schedule; buy and delivery schedules.

1.9. Applicable contract information.

1.10. Cost estimate summary by fiscal year in CY and TY dollars.

1.11. Ground rules and assumptions.

H.2 Body

2.1. Basis of estimate, by phase and appropriation, by program WBS or O&S CES.

2.2. Detailed methods, sources, and calculations provided by the program WBS or O&S CES along with fiscal year phasing and rationale for phasing.

2.3. Rationale for selecting a specific cost estimating method, by the program WBS or O&S CES.

2.4. Source of data used when referencing analogous systems.

2.5. Contractor Cost Data Report and Software Resources Data Report

2.6. Cross checks, reasonableness and consistency checks addressed by the program WBS or O&S CES. Specific references to studies, analogous systems or other appropriate documented references.

2.7. Track to prior estimate, and rationale for differences.

2.8. Reconciliation between the Non-Advocate Cost Assessment (NACA)/ICE and POE. The body of the cost estimate documentation should provide information (e.g., source data, estimating methods, and results) sufficient to make it possible for a qualified analyst to recreate the estimate using only the written documentation.

H.3 Additional checklist considerations identify whether:

3.1 All life-cycle costs are included

3.2. Estimates are organized consistently and logically

3.3. Learning curve slopes and factors are reasonable, similar system slopes and factors are included as cross checks.

3.4. Actual historical data at or near program completion was used, when available.

3.5. Current inflation rates were used, documented and properly applied.

3.6. Historical data used is presented in the documentation, with rationale given as to why that data/program is applicable for use as an analogy and, where applicable, extrapolation is applicable.

3.7. Where systems have previously produced development or production units, unit or lot quantity and associated costs are provided.

3.8. Briefing charts reference program funding provided in the most current budget (President's Budget or POM). If shortfalls exist, a zero —shortfall option is provided.

3.9. Acronyms are defined.

3.10. Personnel costs are consistent with the Manpower Estimate Report, or deviations are properly explained.

3.11. Sensitivity analysis and risk/opportunity/uncertainty analysis is documented.

3.12. Wrap rates and Forward Pricing Rate Agreement / Forward Pricing Rate Recommendation assumptions are included.

APPENDIX I GAO AUDIT PREPARATION

GAO routinely conducts audits of DoD cost estimates. The following table provides GAO best practices for DoD cost estimates and questions for assessing if a particular estimate achieves the best practice. These questions can help DoD analysts to determine if their cost estimate is complete, credible, defendable, and well documented.

Best practice	Auditor question
The cost estimate includes all life cycle costs.	Does the cost estimate include both government and contractor costs of the program over its full life cycle, from inception of the program through design, development, deployment, and operation and maintenance to retirement of the program? Have items excluded from the estimate been documented and justified?
The technical baseline description completely defines the program, reflects the current schedule, and is technically reasonable.	Is there a documented technical baseline description that resides in one location?
	Has the technical baseline description been developed by qualified personnel such as system engineers?
	Is the technical baseline description updated with technical, program, and schedule changes?
	Does the technical baseline description contain sufficient detail of the technical characteristics, risk, and the like, based on the best available information at the time?
	Has the technical baseline description been approved by management?
The cost estimate WBS is product-oriented, traceable to the statement of work, and at an appropriate level of detail to ensure that cost elements are neither omitted nor double-counted.	Does the WBS clearly outline the end product and major work of the program?
	In addition to hardware and software elements, does the WBS contain program management and other common elements to ensure that all work is covered?
	Does the WBS contain at least 3 levels of indenture and does the sum of the children equal the parent?
	Is the WBS standardized so that cost data can be collected and used for estimating future programs?
	Does the cost estimate WBS match the schedule and earned value management (EVM) WBSs, if applicable?
	Is the WBS updated as the program becomes better defined and to reflect changes as they occur?
	Is there a WBS dictionary that defines what is included in each element and how it relates to others in the hierarchy?
The estimate documents all cost-influencing ground rules and assumptions.	Are there defined ground rules and assumptions, and are the rationale and historical data to support them documented?
	Have the ground rules and assumptions been developed by estimators with input from the technical community?
	Have risks associated with assumptions been identified and traced to specific WBS elements? For example, have effects related to budget constraints, delayed program content, dependency on other agencies, and technology maturity been identified?
	Are cost-influencing assumptions used as inputs to the sensitivity and uncertainty analyses?
The documentation shows the source data used, the reliability of the data, and the estimating methodology used to derive each element's cost.	Does the documentation identify what methods were used such as analogy, expert opinion, engineering build up, parametric, or extrapolation from actual cost data?
	Have the supporting data been documented? For example, are sources, content, time, and units documented, along with an assessment of the accuracy of the data and reliability and circumstances affecting the data?
	Does the documentation describe how the data were normalized, and does the documentation include the inflation indexes that were used?
	Are the inflation indexes used to convert constant year dollars to budget year dollars documented?

Best practice	Auditor question
The documentation describes how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it.	Are data adequate for easily updating the estimate to reflect actual costs or program changes so that they can be used for future estimates?
	Did the documentation describe the estimate with narrative and cost tables and did it contain an executive summary, introduction, and descriptions of methods, with data broken out by WBS cost elements, sensitivity analysis, risk and uncertainty analysis, management approval, and updates that reflect actual costs and changes?
	What guidance is used to govern the creation, maintenance, structure, and status of the cost estimate?
	Does the documentation completely describe the risk and uncertainty analysis? For example, does the documentation discuss contingency reserves and how they were derived, the cumulative probability of the point estimate, correlation, and the derivation of risk distributions?
	Does the documentation include access to an electronic copy of the cost model and are both the documentation and the cost model stored so that authorized personnel can easily find and use them for other cost estimates?
The documentation discusses the technical baseline description and the data in the technical baseline are consistent with the cost estimate.	Are the technical data and assumptions in the cost estimate documentation consistent with the technical baseline description?
The documentation provides evidence that the cost estimate is reviewed and accepted by management.	Was management presented with a clear explanation of the cost estimate so as to convey its level of competence?
	For instance, did management receive an overview of the program's technical foundation, were the life cycle costs presented in time-phased and constant year dollars, were ground rules and assumptions discussed, were the estimating method and data sources discussed for each WBS cost element, were the results of sensitivity analysis and cost drivers identified, were the results of risk and uncertainty analysis including S curve cumulative probabilities and risk distributions discussed, was the point estimate compared to an independent cost estimate and any differences explained, was an affordability analysis discussed based on funding and contingency reserves, were conclusions and recommendations provided, and were any other concerns or challenges addressed?
	Is there documentation showing management's acceptance of the cost estimate including recommendations for changes, feedback, and the level of contingency reserves decided upon to reach a desired level of confidence?
The cost model is developed by estimating each WBS element using the best methodology from the data collected.	If analogy is used, are adjustments reasonable and based on program information, physical and performance characteristics, and the like?
	If expert opinion is used, are quantitative historical data available to enable the estimate to be adjusted for optimism and bias?
	If the build-up method is used, is the work scope well defined, the WBS sufficiently detailed, a detailed and accurate materials and parts list available, estimate based on specific quantities, and an auditable source provided for labor rates?
	If the parametric method is used, is the size of the data set sufficient and homogeneous data available for developing the cost estimating relationship (CER)? Are parametric models calibrated and validated using historical data?
	If CERs are used, are the statistics provided and are they reasonable? Are the CER inputs within the valid dataset range?
	If learning curves are used do they represent manual, complex, and repetitive labor effort? Is production continuous and, if not, are production breaks incorporated?

Best practice	Auditor question
The estimate is adjusted properly for inflation.	Are the cost data adjusted for inflation so that they could be described in like terms and to ensure that comparisons and projections are valid?
	Is the final estimate converted to then-year (budget) dollars?
The estimate contains few, if any, minor mistakes.	Does the estimate contain any mistakes, such as numbers that do not sum properly, costs that do not match between documents, and the like?
	What quality control process does the program use to ensure the cost estimates contains few, if any, mistakes?
The cost estimate is regularly updated to ensure it reflects program changes and actual costs.	Is the estimate updated to reflect changes in technical or program assumptions and does documentation reflect how these changes affect the cost estimate?
	Are the cost estimates replaced with actual costs? If so, what is the source of the actual costs?
Variances between planned and actual costs are documented, explained, and reviewed.	Does the estimate document variances and any lessons learned for elements whose actual costs or schedules differ from the estimate?
The estimate is based on a historical record of cost estimating and actual experiences from other comparable programs.	Is the estimate based on historical data and are the data applicable to the program?
	How reliable are the data? For example, how old are the data?
	Is there enough knowledge about the data source to determine if the data can be used to estimate accurate costs for the new program?
	If EVM data are used, has the EVM system been validated against the EIA-748 guidelines?
The cost estimate includes a sensitivity analysis that identifies a range of possible costs based on varying major assumptions, parameters, and data inputs.	Were the following steps taken: key cost drivers, ground rules, and assumptions were identified as factors;
	Cost elements representing the highest percentage of cost were determined and their assumptions were examined;
	The total cost was re-estimated by varying each factor;
	Results were documented and outcomes were evaluated for factors most sensitive to change.
A risk and uncertainty analysis is conducted that quantifies the imperfectly understood risks and identifies the effects of changing key cost driver assumptions and factors.	Were the following steps performed: were probability distributions modeled based on data availability, reliability, and variability?
	Was the correlation between cost elements captured?
	Was a Monte Carlo simulation model (or other modeling technique) used to develop a distribution of total possible costs and an S curve showing alternative cost estimate probabilities?
	Was the cumulative probability associated with the point estimate identified?
	Were contingency reserves recommended for achieving the desired confidence level?
	Was the risk-adjusted cost estimate allocated to WBS elements, as necessary?
	Was the risk-adjusted cost estimate phased and converted to budget year dollars?
	Was a risk management plan implemented to identify and analyze cost related risk so that risks could be treated and continually tracked during program execution?
	Was a risk and uncertainty analysis performed periodically as the cost estimate was updated to reflect progress and changes occurred to risks?
Major cost elements are crossed checked to see if results are similar.	Were major cost elements cross-checked to see if results are similar?
An independent cost estimate is conducted by a group outside the acquiring organization to determine whether other estimating methods produce similar results.	Was an ICE performed by an organization outside of the program office's influence?
	Was the depth of the ICE analysis sufficient to allow reconciliation between the ICE and the program office estimate?
	Is the ICE based on the same technical baseline and ground rules as the program office estimate?
	Are differences between the ICE and the program office estimate documented and justified?

APPENDIX J RECOMMENDED READING LIST

Inclusion of a book in this list does not indicate endorsement from the DoD. Rather, this is a list of books that cost estimators have found interesting or useful to learning the cost estimating and acquisition trade.

- Cost Estimating/Operations Research
  - Block, Arthur. "Murphy's Law (Complete): All the Reasons Why Everything Goes Wrong." Arrow/Children S (a Division of Random House), July 1, 2008.
  - Butler, Don. "A Guide to Ship Repair Estimates in Man-hours." 2nd Edition, Elsevier Ltd, 2012.
  - Fox, Bernard and et. al. "Guidelines and Metrics for Assessing Space System Cost Estimates." RAND Corporation, January 21, 2008.
  - Goldberg, Matthew S. and Anduin E. Touw. "Statistical Methods for Learning Curves and Cost Analysis." The CNA Corporation, March 2003.
  - Goldratt, Eliyahu. "The Goal: A Process of Ongoing Improvement – 30th Anniversary Edition." North River Press, June 1, 2012.
  - Goldratt, Eliyahu. "Critical Chain." North River Press, April 1, 1997.
  - Knaflic, Cole Nussbaumer. "Storytelling with Data: A Data Visualization Guide for Business Professionals." Wiley, November 2, 2015.
  - Lee, David. "The Cost Analyst's Companion." Logistics Management Institute, December 1, 1997.
  - Melese, Francois (Editor), et. al. "Military Cost-Benefit Analysis: Theory and Practice." Routledge, June 8, 2015.
  - Mislick, Gregory K. and Daniel A. Nussbaum. "Cost Estimation: Methods and Tools." Wiley, May 4, 2015.
  - Savage, Sam L. "The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainty." Wiley, 26 March 2012.
  - Silver, Nate. "The Signal and the Noise: Why So Many Predictions Fail--but Some Don't." Penguin Group, September 27, 2012.
  - Stewart, James (Editor), et. al. "Cost Estimator's Reference Manual." Wiley-Interscience, 2020.
  - Stewart, Rodney D., "Cost Estimating." 2nd Edition, Wiley-Interscience, January 2, 1991.
  - Tetlock, Philip E. and Dan Gardner. "Superforecasting: The Art and Science of Prediction." Crown Publishers, September 29, 2015.
  - The Standish Group International. "CHAOS Manifesto: The Laws of CHAOS and the CHAOS 100 Best PM Practices." The Standish Group International, 2011.
  - Younossi, Obaid, and et. al. "Military Jet Engine Acquisition: Technology Basics and Cost-Estimating Methodology." RAND Corporation, 2003.

- Risk and Uncertainty
  - Garvey, Paul R. and et. al. "Probability Methods for Cost Uncertainty Analysis: A Systems Engineering Perspective." 2nd Edition, Chapman and Hall/CRC, December 22, 2015.
  - Morgan, Millett G. and et. al. "Uncertainty – A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis." 6th Edition, Cambridge University Press, August 31, 1990.

  - Pinto, Cesar A. and Paul R. Garvey. “Advanced Risk Analysis in Engineering Enterprise Systems.” CRC Press, October 8, 2012.
  - Smart, Christian. “Solving for Project Risk Management: Understanding the Critical Role of Uncertainty in Project Management.” McGraw Hill Education, October 23, 2020.
  - Taleb, Nassim Nicholas. “The Black Swan: Second Edition: The Impact of the Highly Improbable: With a new section: "On Robustness and Fragility”." Random House, May 11, 2010.

- Software Cost Estimating
  - Brooks, Frederick Jr. “The Mythical Man-Month: Essays on Software Engineering, Anniversary Edition.” Addison-Wesley Professional, August 2, 1995.
  - Cohn, Mike. “Agile Estimating and Planning.” Pearson, November 1, 2005.
  - Cohn, Mike. “User Stories Applied: For Agile Software Development.” Addison-Wesley Professional, March 1, 2004.
  - Jones, Capers. “Estimating Software Costs: Bringing Realism to Estimating.” 2nd Edition, McGraw-Hill Education, May 10, 2007.
  - Kan, Stephen H. “Metrics and Models in Software Quality Engineering.” 2nd Edition, Addison Wesley Professional, September 26, 2002.
  - McConnell, Steve. “Software Estimation: Demystifying the Black Art (Developer Best Practices).” Microsoft Press, March 1, 2006.
  - Pigoski, Thomas M. “Practical Software Maintenance: Best Practices for Managing Your Software Investment.” Wiley, November 1, 1996.
  - Putnam, Lawrence H. and Ware Myers. “Measures for Excellence: Reliable Software on Time, Within Budget.” Prentice Hall, 1992.
  - Reifer, Donald J. “Software Maintenance Success Recipes.” Auerbach Publications, November 11, 2011.
  - Stutzke, Richard D. “Estimating Software-Intensive Systems: Projects, Products, and Processes.” Addison-Wesley Professional, December 10, 2012.

- Acquisition
  - Augustine, Norman R. “Augustine’s Laws.” Penguin Books, January 6, 1987.
  - Burton, James G. “The Pentagon Wars: Reformers Challenge the Old Guard.” Naval Institute Press, February 15, 2014.
  - Enthoven, Alain C. and K. Wayne Smith. “How Much is Enough? Shaping the Defense Program 1961 – 1969.” RAND Corporation, October 28, 2005.
  - Fox, Ronald J. “Defense Acquisition Reform, 1960 – 2009: An Elusive Goal.” Center of Military History, December 11, 2014.
  - Rendon, Rene G. “Management of Defense Acquisition Projects.” American Institute of Aeronautics and Ast, September 24, 2008.
  - Sorenson, David S. “The Process and Politics of Defense Acquisition: A Reference Handbook.” Praeger, December 30, 2008.

- Acquisition Context for Various Commodities
  - Aircraft

  - Coram, Robert. "Boyd: The Fighter Pilot Who Changed the Art of War." Little, Brown and Company, November 21, 2002.
  - Kelly, Orr. "Hornet: The Inside Story of the F/A-18." Presidio Press, October 1, 1990.
  - Olsen, John Andreas. "Airpower Applied: U.S., NATO, and Israeli Combat Experience (History of Military Aviation)." Naval Institute Press, May 30, 2017.
  - Rich, Ben R. and Leo Janos. "Skunk Works: A Personal Memoir of My Years at Lockheed." Little, Brown and Company, February 1, 1996.
  - Stevenson, James P. "The $5 Billion Misunderstanding: The Collapse of the Navy's A-12 Stealth Bomber Program." Naval Institute Press, January 1, 2001.
  - Whittle, Richard. "The Dream Machine: The Untold Story of the Notorious V-22 Osprey." Simon & Schuster, May 17, 2011.
- Marine Corps
  - Krulak, Victor H. "First to Fight: An Inside View of the U.S. Marine Corps." Naval Institute Press, February 22, 1999.
- Ships/Submarines
  - Oliver, Dave RADM (Ret). "Against the Tide: Rickover's Leadership and the Rise of the Nuclear Navy." Naval Institute Press, September 1, 2018.
  - Pugh, Philip. "The Cost of Seapower: The Influence of Money on Naval Affairs from 1815 to the Present Day." Conway Maritime Press, January 1, 1986.
- Space
  - Davenport, Christian. "The Space Barons: Elon Musk, Jeff Bezos, and the Quest to Colonize the Cosmos." PublicAffairs, April 30, 2019.
- Technology
  - Ackerman, Elliot and James Stavridis, "2034: A Novel of the Next World War." Penguin Press, March 9, 2021.
  - Brose, Christian, "The Kill Chain: Defending America in the Future of High-Tech Warfare." Hachette B and Blackstone Publishing, April 21, 2020.
  - Singer, P.W. "Wired for War: The Robotics Revolution and Conflict in the 21st Century." Penguin Books, December 29, 2009.
  - Singer, P.W. and August Cole. "Ghost Fleet: A Novel of the Next World War." Eamon Dolan/Mariner Books, May 24, 2016.

- Government Periodicals and Annual Reports
  - CAPE Annual Reports on Cost Assessment Activities (https://www.cape.osd.mil/)
  - Defense Acquisition Magazine (https://www.dau.edu/library/defense-atl/)
  - Defense Acquisition Research Journal (https://www.dau.edu/library/arj/)
  - DOT&E Annual Reports (https://www.dote.osd.mil/annualreport/)

- Professional Cost Estimating and Operations Research organizations
  - Association for the Advancement of Cost Engineering (https://web.aacei.org/)
  - International Cost Estimating and Analysis Association (https://www.iceaaonline.com/)
  - Military Operations Research Society (https://www.mors.org/)

APPENDIX K COST ESTIMATING CASE STUDY

Introduction

This case study follows the efforts of Ava, a newly hired Air and Space Cost Analysis Agency (ASCAA) cost analyst, and her team, colleagues, and leadership through the cost estimating process for a major weapon system estimate. It follows the cost estimating process laid out in the DoD Cost Estimating Guide and highlights the efforts and thinking analysts should put into each stage of the process, while also demonstrating the cyclical nature of the process itself. Since it is impossible to cover every scenario, the case study provides additional "critical thinking" items in blue boxes at the end of each section to highlight additional topics or concerns of the process steps that may apply in other scenarios. The authors have intentionally simplified the estimate described in this case from a full-scale cost estimate.

Critical Thinking Questions Boxes

To facilitate the critical thinking required for a successful cost estimate, this case study includes "Critical Thinking Questions" at the end of each section, which are designed to illustrate additional areas of thought that may be required. While these questions are not all inclusive, they are important to a comprehensive, accurate, useable, and repeatable cost estimate. The case study does not include answers to these questions, since in most cases there is not a single "correct" solution. Experienced cost estimators may have different opinions on the answers to these questions, illustrating how important critical thinking is to the art and science of the cost estimating profession. Every question posed is not necessary in every cost estimating scenario. They are intended to be thought provoking and not necessarily answered directly in a cost estimate or its documentation.

CACEG Programmatic Summary

The AH-21 CACEG (pronounced Kay-Sig) Attack Helicopter is a key asset within the defense inventory and is the first heavy attack helicopter for the Air Force. It is a modified Vexis AH-65 with a twin-engine, four-bladed, and tandem seat (crew of two) attack helicopter with 30-millimeter ammunition, 2.75-inch rockets, and Hellfire missiles. The AH-21 CACEG is a network-centric, multi-role weapon system within the future modular force providing the capability to simultaneously conduct close combat, mobile strike, armed reconnaissance, and security missions. The AH-21 CACEG effort will enhance Air Force ground operations and other service missions including real-time Intelligence, Surveillance and Reconnaissance (ISR) information, and conduct responsive precision fires.

The AH-65E Vexis is an active Army acquisition program. The Army's current active production line will produce the AH-21 CACEG airframe and deliver it to the United States Air Force (USAF) as a fully-functional Vexis. The USAF will provide the Vexis helicopter as Government Furnished Equipment (GFE) to Vandalay Industries for modification to the AH-21 CACEG technical specifications.

Since the early 1980s, Incom Corporation has solely designed, developed, manufactured, and integrated the AH-65 Vexis platform. The AH-65E program is the fourth generation of upgrades to the Vexis, which encompasses a limited number of design and component changes from the base configuration. The Army incrementally developed the current AH-65E variant between 2005 and 2019; the current Version 6 capability will continue through all future Army Production lots, with any upgrades planned for integration as incremental block modifications. The USAF intends to procure the current AH-65E Version 6 capability, with inclusion of any and all subsequent updates in order to maximize production efficiencies of the shared product line. The Vexis Helicopter Project Office conducts market research on an ongoing basis for sources of supply that could fulfill the Government's requirements. Currently, Incom alone possesses the personnel, facilities, special test equipment, and exclusive corporate knowledge to manufacture and perform special tests required by the Government. The USAF procured two AH-65E helicopters in support of AH-21 Engineering & Manufacturing Development (EMD) work scope. The Firm Fixed Price (FFP) EMD contract was awarded sole-source to Incom Corporation on 30 June 2016, with a Period of Performance (POP) that concluded on 30 June 2019. The USAF plans to award a sole-source FFP contract to Incom Corporation, consistent with the Army contracting strategy and current Army contract terms and conditions, in support of AH-21 Low-Rate Initial Production (LRIP) and Full Rate Production (FRP) lots. Plans for the FRP 1 initial contract include award of twenty-five aircraft with options for two follow-on orders of twenty-five aircraft in FRP 2 and FRP 3.

Upon delivery as GFE by the USAF, Vandalay Industries modifies the AH-65E with new mission hardware/software and stealth technologies to improve mechanical, communications, radar, and stealth technologies. The Air Force awarded a sole-source Cost Plus Incentive Fee (CPIF) contract on 14 April 2015 to Vandalay Industries for aircraft configuration development and integration of GFE components. The work scope required upgrades to mission hardware and software, implementation of new security protocols, and new tooling requirements. The USAF placed orders with Vandalay for two AH-21 Engineering Development Model (EDM) units on 13 June 2018 and 8 October 2019, with the POP concluding on 30 September 2021 upon planned delivery of EDM 2. Currently Vandalay Industries alone possess the personnel, facilities, and corporate knowledge of new critical technologies required to meet Government specifications for the AH-21 helicopter. Upon a successful Milestone C decision, the USAF plans to award a sole-source FFP contract to Vandalay for LRIP 1 production units. The USAF plans for the second LRIP lot contract and three FRP lot contracts to be sole-source, FFP awarded between 1QFY2024 and 1QFY2027.

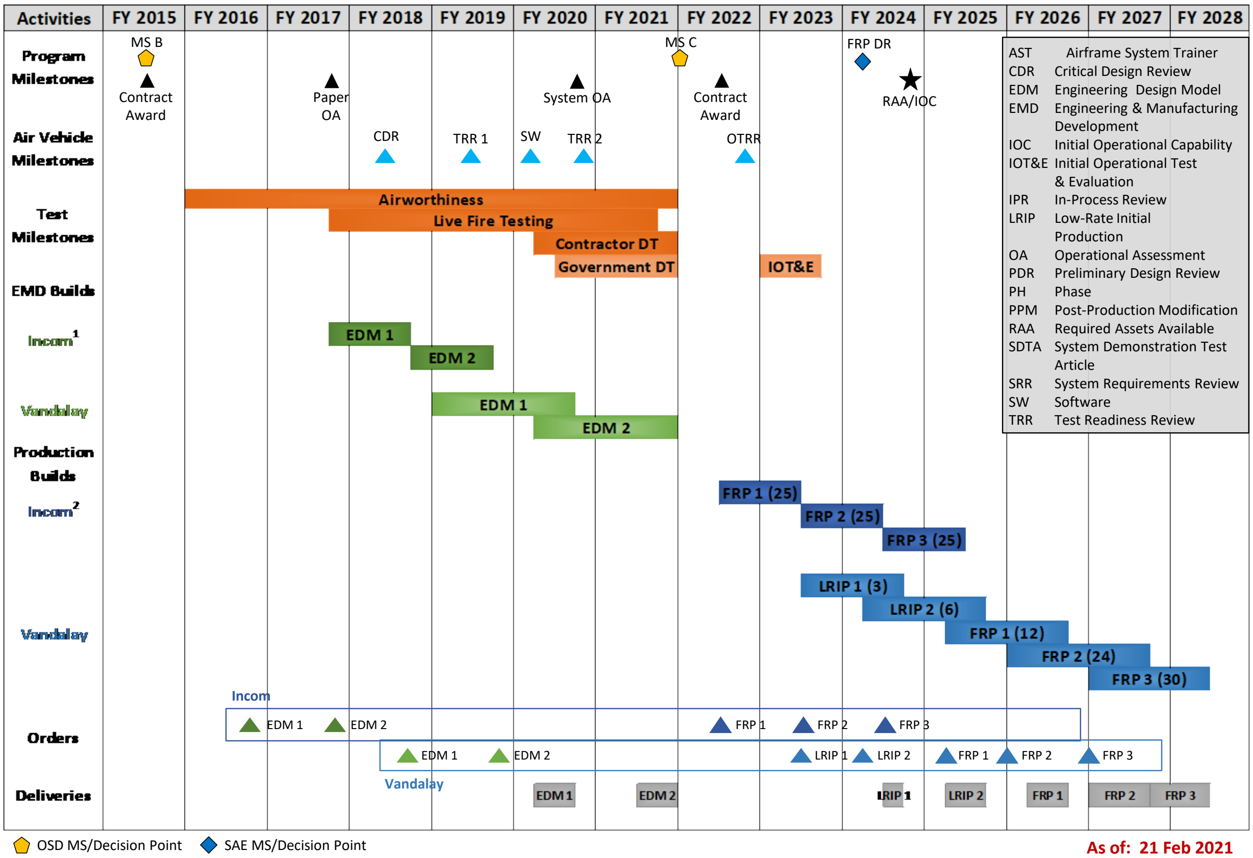
Table 15 provides a summary of the AH-21 CACEG system production and delivery quantities and schedule by contractor. The planned production schedule begins in FY2022 with the first FFP LRIP contract award to Incom Corporation and completes in late 2QFY2028 upon conclusion of FRP 3 production by Vandalay Industries. The AH-21 delivery schedule to the Air Force begins in 3QFY2024 and completes in 2QFY2028. The USAF will maintain the two EDM units as test units with no intention for their modification to production units at any future date. There is a one-year period between Incom start of production and delivery to the USAF; an average fourteen month period exists between the Vandalay start of production and final delivery of the helicopter. **Figure 29** shows a snapshot of the current program schedule.

Cast of Characters (alphabetically)

- Ava – ASCAA Procurement analyst
- Eduardo - CAPE Analyst
- Jasmine -- ASCAA AH-21 Team Lead for Helicopter programs
- Jay -- ASCAA Director
- Joanna -- AH-65 Vexis Program Office Lead Estimator
- Liam -- ASCAA O&S Estimator
- Marta -- ASCAA Division Director for Aircraft and Weapons
- Reggie -- Vandalay Industries Contractor Lead
- Tamara -- AH-21 CACEG SPO Lead Estimator
- Tim -- ASCAA Sunk Cost and EMD To-Go Estimator

Table 15: Time-Phased System Quantity Requirements

Contract	Phase	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	Total
Incom	Production	25	25	25	0	0	0	0	0	75
	Delivery	0	25	25	25	0	0	0	0	75
Vandalay	Production	0	3	6	12	24	30	0	0	75
	Delivery	0	0	3	6	12	24	30	0	75



Note 1: Phasing for Incom AH-65E EMD builds labeled according to corresponding AH-21 EMD Builds by Vandalay
Note 2: Phasing for Incom AH-65E Production builds labeled independent of AH-21 Production Builds by Vandalay

Figure 29: AH-21 CACEG Program Schedule (as of 21 February 2021)

Getting Started

Just over a month into her new job at ASCAA, Ava's boss Jasmine assigned her to develop the Production & Deployment estimate for a new Air Force helicopter, the AH-21 CACEG. The helicopter was well into the EMD acquisition phase and scheduled for a Milestone (MS) C decision approximately nine months down the road. Along with a quick overview of the requirement, Jasmine provided Ava the proposed event timeline in **Table 16**, based on the standard timeframes for estimates provided in the DoDI 5000.73 and an automated ASCAA organizational template that built to reflect those timelines. Jasmine pointed out that although the schedule centered on the Cost Review Board meeting, the Overarching Integrated Product Team (OIPT) meeting provided another key date for the timing of all of the supporting cost estimating effort. If the estimates were not ready for senior leadership to see at the OIPT, then they became irrelevant to the decision-making process.

Table 16: AH-21 CACEG Cost Estimating Timeline

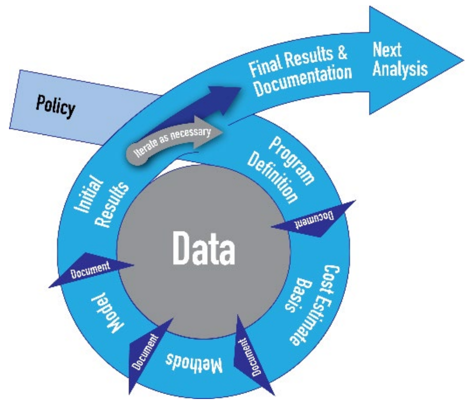
Event	ACAT ID Days from CRB	CACEG Dates
Notify CAPE of Upcoming Milestone	-210	January 27, 2021
Draft CARD to CAPE and CIPT/ICE Kickoff : Estimating Plan to ASCAA Director	-180	February 26, 2021
CAPE and ASCAA CARD Sufficiency Review to Program Office	-135	April 12, 2021
ASCAA Midterm Review with ASCAA Director	-99	May 18, 2021
Midterm Reconciliation – Program Office and ASCAA	-85	June 1, 2021
Draft Final CARD To CAPE & ASCAA / Draft POE and Draft ASCAA Estimate to CAPE	-45	July 11, 2021
ASCAA Final with ASCAA Director	-37	July 19, 2021
Final Reconciliation - Program Office and ASCAA	-30	July 26, 2021
Draft Reconciled CCP to ASCAA Director	-9	August 16, 2021
ICE/CCP Comparison Meeting	-7	August 18, 2021
Pre-CRB Meeting	-3	August 22, 2021
CRB Meeting	**0**	**August 25, 2021**
Formal ICE/CCP Meeting	2	August 27, 2021
Draft CCP Memo to Service Director, coordinate Full Funding language in ADM	4	August 29, 2021
CCP Memo meeting	10	September 4, 2021
Final CCP & Signed Full Funding to CAPE	11	September 5, 2021
OSD CAPE ICE Report/Brief (5 days after receipt of CCP & Full Funding)	16	September 10, 2021
OIPT	**21**	**September 15, 2021**
DAB	35	September 29, 2021

Jasmine tasked two other team members to provide a sunk cost review up to MS C (i.e., CACEG program funding expended to date), an estimate of remaining EMD costs (i.e., “To-Go” costs), and an estimate of Operating & Support (O&S) costs for this Major Capability Acquisition (MCA) Program Life-Cycle Cost Estimate (PLCCE). While Ava had a strong background in data analysis and possessed statistical expertise, her cost estimating experience was limited. As a result, Jasmine asked the rest of the team to help Ava as much as possible over the next few months.

During her first month, Ava had attended in-house cost estimating training and reviewed documentation of several recent cost estimates by ASCAA coworkers. Some of that training had been an introduction to the Department of Defense (DoD) and all of its jargon and nomenclature. Ava had learned that what a civilian would refer to as a helicopter the DoD called a helo or a rotary wing aircraft. The DOD gave each aircraft both a programmatic name (like Vexis or CACEG) and an alphanumeric designation (like AH-65 or AH-21). Jasmine had also shared a series of notes that experienced cost estimators had written on the cost estimating process. (Jasmine called these “white papers.”) In her review of these notes, Ava found references to the Government Accountability Office (GAO) Cost Estimating and Assessment Guide, the Army Cost Analysis Manual, and a number of other documents she thought could be extremely helpful. She had taken note of the titles, found several available online, and skimmed through a few before saving them for reference. Now, with an estimate assignment and limited time available before the estimate kickoff meeting at the end of February, Jasmine suggested that Ava focus her review on the DoD Cost Estimating Guide and use that as the basis for her development of the Production & Deployment estimate, which Jasmine tended to reference simply as “Production” in working-level discussions. Jasmine encouraged her to consult other documents as questions that are more specific arose.

Policy

As Ava began to read and understand the DoD Cost Estimating Guide, she was somewhat puzzled to see a discussion of policy. She began asking a few coworkers about its inclusion in the guide and the role of policy in cost estimating, and Liam jumped in to clarify right away that a guide was different from policy. He explained that guides helped to clarify policies; they did not prescribe required processes themselves. However, the cost-estimating guides did represent established standards or best practices that had worked well for other cost estimators, and adherence to those standards would help a reader fulfill policy requirements.



Liam continued to explain more about the role of policy in cost estimating. As Liam explained the different levels of policy – statute, directives/instructions, and guides to Ava, he drew the sketch in **Figure 30** so that she could visualize what he was saying. In the sketch, Liam differentiated between Acquisition and Cost Estimating, but explained that both were equally important since they provided cost estimates for acquisition programs.

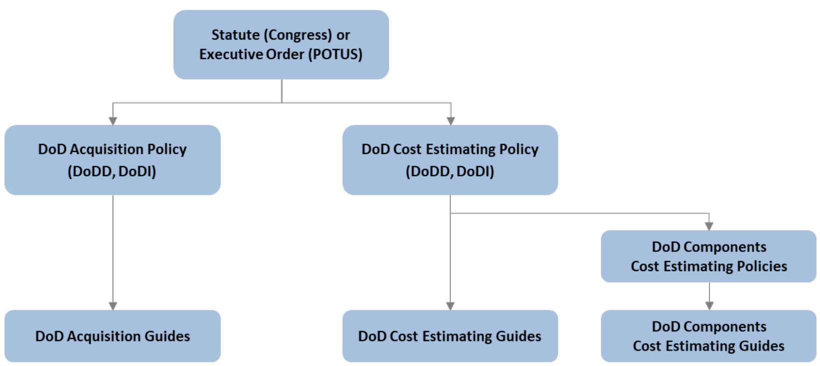


Figure 30: Relationships Among Policy and Guidance

After her discussion with Liam, Ava was grateful for her newfound understanding of the relationships between statutes, the DoD Instruction (DoDI) 5000.73 as an instruction, and the manuals and guides that she had initially begun reviewing. As she looked up the DoDI 5000.73 specifically, its constant reference within the manuals and guides she had seen now made sense. Liam's comment about regulatory policies existing at both the DoD and Component level had gotten her thinking about what Air Force instructions might go hand-in-hand with the DoDI 5000.73. She did not have to look far before identifying the Air Force Instruction (AFI) 65-508, titled Cost Analysis Guidance and Procedures. At the bottom of the title block in the current 2018 version that she found, big bold letters highlighted what Liam had explained the day before about instructions: "COMPLIANCE WITH THIS PUBLICATION IS MANDATORY."

Before proceeding any further in her research, Ava printed out a copy of the MCA process (**Figure 31**), which had been included in introductory material on the DoD acquisition process during her recent in-house training. This was apparently a significant process figure included in the DoDI 5000.85, which established specific policy for MCAs like the CACEG program. As she printed it out, a passing teammate commented on its usefulness to a new analyst, which enthused Ava. She knew that it would be a helpful reference to keep at her desk as she considered the estimating roles assigned to Tim, Liam, and herself.

Ava took a few hours to review the DoDI 5000.73 and AFI 65-508 documents. She started out by comparing the two tables of contents; several of the sections seemed to overlap. As she skimmed through similar content on responsibilities, timelines, and cost estimate requirements or expectations (for different types of estimates), her teammates' explanation of the relationship between the two instructions made even more sense. Liam had explained that statutory policy from Congress typically leads to regulatory policy at the DoD level, which was further expanded down to the Component level. Each lower level was an effort to implement, or explain how to implement, the policies of the higher organizational level. With this in mind, Ava decided to spend more time focusing on the AFI 65-508 content. She learned more about the specific roles and responsibilities that the ASCAA team, the SPO team, and the Cost Assessment and Program Evaluation (CAPE) would be fulfilling and the expectations for all three of their estimates (within the section on Life Cycle Cost Estimate (LCCE) Requirements).

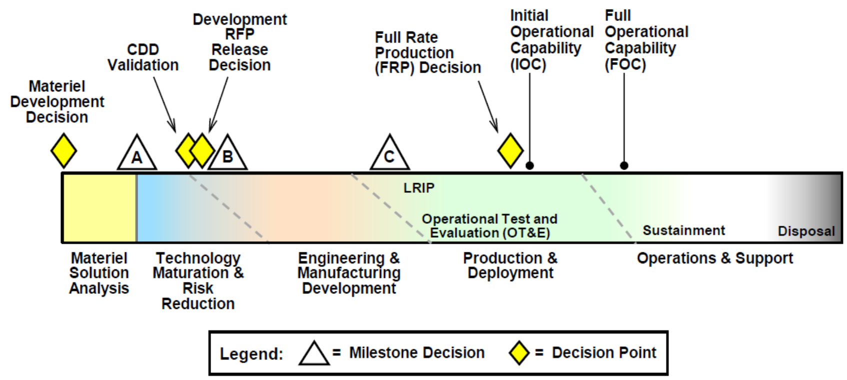


Figure 31: Major Capability Acquisition Model (DoDI 5000.85)

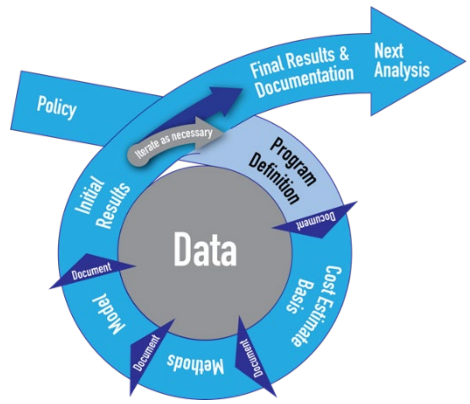
During the team meeting the next morning, Ava asked about the rigorous deliverables and process steps that she saw in the DoD and Air Force policies. Jasmine and her teammates acknowledged the lengthy process and explained that there would be considerable communication along the way between the SPO, Component cost agency, and CAPE. This communication would be critical to the cost estimating process and deliverables.

Before their discussion ended, Tim asked Jasmine about the status of the CACEG Cost Analysis Requirements Description (CARD). Apparently, the System Program Office (SPO) had yet to send a copy of their CARD, and the ASCAA analysts were hoping to have a copy earlier than required for submission to the CAPE. While Ava remembered several of the policy documents she had been reviewing mentioned the CARD, she told Jasmine and the team that she was unfamiliar with it. Tim explained that the CARD contains the technical, schedule, and programmatic information they would need to complete their estimates, and he recommended that she start out by circling back to look at the CARD information included within the DoDI 5000.73, the AFI 65-508, and the DoD Cost Estimating Guide.

Critical Thinking Questions – Policy

- Which policy and guidance documents are most important to stay current on?
- As a cost estimator, how important is it to have a good understanding of acquisition policy? Why?
- How does the chosen acquisition pathway affect the cost estimating requirements for a program?
- Is there a difference between operations and sustainment, operating and support, and operations and support?
- If my Component has a related, but slightly different policy from OSD, which policy should be followed?
- Where can I find out if Congress has changed cost estimating requirements?

Program Definition



During Ava's review of both the AFI 65-508 and DoDI 5000.73, it became apparent that these policy documents lacked specific details on CARD requirements. While they mentioned draft and final CARD delivery timelines, some things about insufficiency, and CARD feedback to the program office, they did not tell Ava what should be included in a CARD. The DoD Cost Estimating Guide offered a helpful overview of what the CARD would include and how an analyst would use it; an appendix even included a list of questions related to sufficiency of CARD contents like GFE, programmatic plans, quantities, and sustainment plans. It offered a much better idea of what to expect in the MS C CARD, but Ava was still uncertain of what the actual document and supporting tables might look like.

CARD Help from Liam

Since Liam was at his desk, Ava decided to ask him about her observations. Liam reminded Ava that policy has many layers and referred her to the CARD guidance section of the Cost Assessment Data Enterprise (CADE) website. He explained that she could actually download the detailed templates for CARD tables by commodity; a helicopter program, like the one they would be estimating, would follow the template for aircraft systems. However, Liam warned Ava that the templates represented a wide range of possible inputs for an aircraft system. In reality, their CARD would likely use only a subset of the many rows of technical parameters, and it was possible that entire tables (or worksheets within the template) might not be applicable to their helicopter program. He also explained that CARDs evolve over time as their subject program and system matured. For example, the draft MS C CARD for CACEG should have more detailed information than the MS B CARD, since the Original Equipment Manufacturers (OEMs) had fabricated the EMD units and begun testing efforts. By the MS C CARD, very few elements should remain "To Be Determined."

Liam asked whether Ava had reviewed the MS B CARD for the CACEG. Looking at CARD versions from prior milestones was an idea that Ava had not considered, but Liam assured her that it would be time well spent as they waited for the draft of the MS C CARD. After taking a moment to find and email a copy to Ava, he reminded her of a few notes that she had read within the DoD Cost Estimating Guide. First, the program office was responsible for developing the CARD, often with some help and initial feedback from cost estimators within the program office; and second, because the CARD evolved over time, the MS C CARD would likely not match the old MS B document. Understanding the MS B version would, however, offer her valuable insight into the ASCAA MS B estimate and highlight the differences that she needed to capture within the updated estimate.

After thanking Liam for his help, Ava began to review the MS B CARD and the CARD guidance on the CADE website over the next few days. On the CADE website, she found guidelines for the CARD narrative[65] and CARD tables[66], various CARD table templates by commodity, and CARD training. She was thankful to have a copy of the MS B CARD in hand as she read through guidelines and content on the CAPE website.

Reviewing the Draft CARD

The SPO provided their draft MS C CARD for the AH-21 CACEG Attack Helicopter to ASCAA a few weeks early, on February 1st, hoping for some feedback before providing the official draft to the CAPE later in the month. Jasmine forwarded the document to the team alongside a meeting invite for discussion on it the following Tuesday. Ava spent the rest of her day reviewing the draft narrative and CARD tables. While Ava was excited to finally be working on her estimate, she was not exactly sure where to begin her review in preparation for the team discussion. With the MS B CARD and Liam's mention of the CARD as a living document fresh in her mind, Ava decided to take notes as she compared the draft MS C CARD narrative (and its CARD tables) with the MS B versions and the CARD guidance that she had reviewed. By Monday morning, Ava's notes had become a lengthy list of questions and quick thoughts, and Tim noticed her difficulty. He mentioned that this would be a great time to begin formalizing her questions for the SPO within a Comment Resolution Matrix (CRM). Tim explained that a CRM would organize comments and questions about the document and ensure enough detail to drive actionable review by the owner of the document under review. He pointed her to the DD Form 818 template and explained that it would be a way to begin formalizing her notes and help Jasmine get a head-start on preparing their CARD feedback, which was incidentally the next event on their **Table 16** formal schedule. Ava began documenting all missing or inconsistent information, as shown in **Table 17**.

First, she noticed that there was no signature block for the Program Executive Officer (PEO), and the document was missing two topics from the "Program and System Description" section (specifically the requirements for "System Performance Parameters & Characteristics" and "Critical Technologies"). Next, she found that the Time Phased Requirements section of the narrative and the corresponding Excel table showed the same quantities in slightly different fiscal years. Additionally, within the Excel tables, Ava discovered that the top-level software sizing metrics did not sum correctly, and the fielding associated with time-phased quantities procured seemed misaligned. Interestingly, she saw a few "To Be Determined" phrases in the Production & Deployment section, but overall, the MS C draft demonstrated more detail than the final MS B CARD, just as Liam suggested that it should.

During the CARD review meeting with the rest of the team, Ava conveyed all of these differences. After complimenting Ava on her thorough review, Jasmine took an action to combine all of the team's comments on the MS C CARD within a new consolidated CRM workbook and send them to the SPO (well ahead of the official April 12th deadline). In the meantime, she asked the team to continue their review and follow up with any updates needed. She would copy the team on her final delivery to the SPO, and she also planned to copy the SPO lead cost estimator, Tamara, for her situational awareness. Hopefully the SPO would resolve at least a few of their comments prior to CARD delivery to the CAPE on

[65] "Guidelines for the Preparation and Maintenance of the Cost Analysis Requirements Description Narrative," March 28, 2019.

[66] "Guidelines for the Preparation and Maintenance of CARD Tables," March 28, 2019.

February 26th. At that point, Jasmine planned to update the CRM file and share it with their CAPE analyst, Eduardo. Based on the team's planned schedule, Ava wondered whether they would wait on a SPO response to the CARD comments before continuing with the estimate development. However, it was soon evident that there would be no need to wait; many actions could be done concurrently while waiting on inputs (from other groups) during the cost estimating process.

As soon as Jasmine finished recording the action to consolidate their CARD CRM, she pivoted discussion to their new cost model. While ASCAA had an AH-21 cost model on the shelf, no one had updated it in the six years since the MS B decision. In a flurry of discussion, Jasmine mentioned that the SPO actually maintained their cost model continuously in order to provide budget estimates and other requests from the SPO staff. She also mentioned an Army program office and quite a bit about multiple cost models and integration problems. This confused Ava a bit. After a few minutes, both Tim and Liam clearly sat comfortably with a sense of direction and handful of notes jotted on their respective paths forward, and Jasmine turned to Ava. She graciously addressed Ava's obvious look of confusion and assured her that there was no expectation that she would fully understand their last few minutes of planning. Jasmine put a meeting on the calendar for the next day. She asked Ava to begin reviewing the MS B model before the meeting.

Table 17: Ava's CARD CRM Excerpt

CONSOLIDATED DoD ISSUANCE COMMENT MATRIX						
AH-21 CACEG MS C CARD (dated Feb 17, 2021)						
CLASS	#	PAGE	PARA	BASIS FOR NON-CONCUR?	COMMENTS, JUSTIFCATION, AND ORIGINATOR JUSTIFICATION FOR RESOLUTION	COMPONENT AND POC NAME, PHONE, AND E-MAIL
U	1			☐	**Coordinator Comment and Justification:** Missing PEO signature block **Coordinator Recommended Change:** Add signature block **Originator Response:** Choose an item. **Originator Reasoning:**	ASCAA Ava Smith 703-555-2298 ava.smith@ascaa.mil
U	2			☐	**Coordinator Comment and Justification:** Missing "System Performance Parameters and Characteristics" section **Coordinator Recommended Change:** Add section narrative or describe why section is not applicable to CACEG MS C **Originator Response:** Choose an item. **Originator Reasoning:**	ASCAA Ava Smith 703-555-2298 ava.smith@ascaa.mil
U	3			☐	**Coordinator Comment and Justification:** Missing "Critical Technologies" section **Coordinator Recommended Change:** Add section narrative or describe why section is not applicable to CACEG MS C **Originator Response:** Choose an item. **Originator Reasoning:**	ASCAA Ava Smith 703-555-2298 ava.smith@ascaa.mil
U	4	8	1.6	☐	**Coordinator Comment and Justification:** Time phased requirements quantities are inconsistent between narrative and spreadsheet **Coordinator Recommended Change:** Correct quantities between documents **Originator Response:** Choose an item. **Originator Reasoning:**	ASCAA Ava Smith 703-555-2298 ava.smith@ascaa.mil
U	5	9	1.7.2	☐	**Coordinator Comment and Justification:** Top-level software sizing metrics not summing correctly **Coordinator Recommended Change:** Correct totals **Originator Response:** Choose an item. **Originator Reasoning:**	ASCAA Ava Smith 703-555-2298 ava.smith@ascaa.mil

Beginning with the MS B Cost Model

As Jasmine directed, Ava began to review the ASCAA MS B cost model. The model opened to a summary worksheet (**Figure 32**), and she noticed right away that it clearly delineated between the various MCA phases of the life cycle (i.e., Technology Maturation & Risk Reduction (TMRR), EMD, Production &

Deployment (P&D), and O&S). Already, she appreciated the MCA process printout (from **Figure 31**) posted on her cube wall. Each phase had its own worksheet (i.e., tab) marked with a different color.

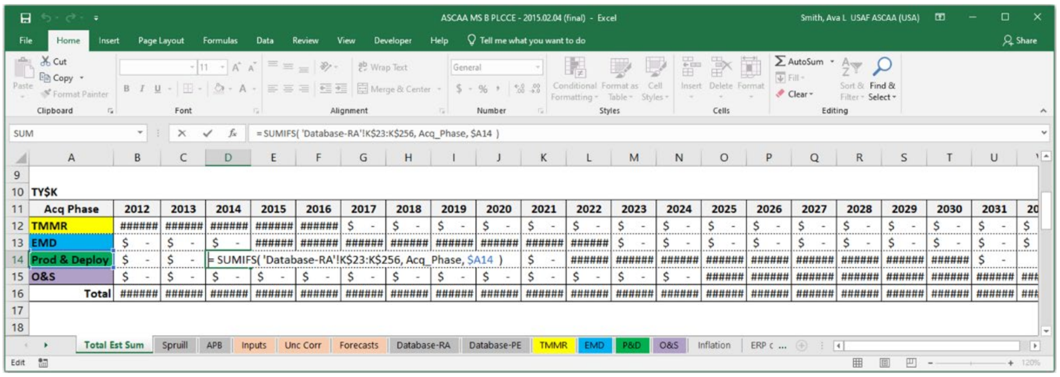


Figure 32: MS B CACEG Cost Model Sample

The "Total Est Sum" worksheet appeared to be a time-phased total cost summary by MCA phase. Each phase had its own row and was identically colored with a series of individual worksheets. Right away, Ava noticed the correspondence between the phased Fiscal Year (FY) results and the MS B CARD schedule. She observed the delay between the LRIP initial order assumption in FY2022, which would begin her Production phase estimate, and the beginning of Deployment activities three years later (completed as the helos delivered to various air wings beginning in FY2025). Both the estimate phasing and overall model seemed intuitively built, based on her experience in the internal ASCAA introductory training she had completed. The MCA phase worksheets likely contained individual estimates by lifecycle phase, and the "Total Est Sum" likely aggregated their results. Ava guessed that the other similarly colored grey tabs probably included summary results as well, but their labels were diverse. She skimmed through all of the worksheets and made a list of questions to ask Jasmine during their next meeting.

MS C Modeling Plan

When Ava sat down with Jasmine the next day, she excitedly began to inquire about the new functions, styles, and methods that she had encountered while reviewing the MS B model. Jasmine launched into a tutorial of more advanced Excel features and formulas. After covering all of Ava's questions (and then some), Jasmine reminded Ava that Excel-based models are not the only option available, especially with the recent emergence of so many data science tools. Jasmine ultimately recommended that Ava continue with Excel for MS C, since she knew the historic data available for the estimate would be in formats that are not ideal for the newest tools. Jasmine and Ava were both hopeful that estimates after MS C would be able to utilize some of the data science techniques. Jasmine returned the discussion to the MS B model architecture itself and gave Ava an overview of how information flowed through the model.

During MS B estimate development, each analyst had created their own mini-model, which had a similar flow to the integrated ASCAA MS B PLCCE model that Ava had reviewed. Each analyst separated their general input variables (eventually combined on the orange "Inputs" worksheet) from their estimate build-up worksheet. This build-up worksheet might leverage data in other "backup" or reference worksheets, but all of the equations and estimating methods used to build-up the EMD estimate were contained within the blue "EMD" worksheet that Ava had observed. (The same was true of the other MCA life cycle phases.) The workbook contained some of the larger data sources and intermediate data normalization steps as well, but the modeler had hidden a few of these worksheets from view so Ava had not seen all of them when she perused the model earlier. Jasmine asked Ava to build her MS C

Production estimate similarly, ensuring that significant backup sources were visible and well labeled. Jasmine took a few extra moments to explain that her summary table at the top of the worksheet needed to contain all of the fiscal years of the life cycle, not just those pertinent to the Production phase, so make the final consolidation of the estimate pieces easier.

Jasmine told Ava not to worry about the other orange-colored worksheets' content within the MS B model just yet. Their first focus was to develop the total PLCCE point estimate, captured within individual MCA phase build-up worksheets and the "Database-PE" results table. Once the point estimate was complete, the team would apply uncertainty using a simulation tool, capture the uncertainty simulation results on the "Forecasts" worksheet), and finally use those uncertainty results to report a statistical selection (e.g., the mean). Before moving on, Jasmine explained that another guide – the Joint Agency Cost Schedule Risk and Uncertainty Handbook (JA CSRUH) – would serve as a helpful resource when the time came to develop the uncertainty estimate.

Jasmine took a few minutes to show Ava the "Spruill" chart and "APB" table, on their respective grey worksheets; both reported estimate results in a specific format required for oversight of the program. She encouraged Ava to look up the Acquisition Program Baseline (APB) within the DoDI 5000.73 and 5000.85. The APB served as the primary cost, schedule, and performance baseline against which the Air Force tracked the CACEG program. Ultimately, at the end of the process outlined within their **Table 16** schedule, the Milestone Decision Authority (MDA) would select either the Air Force Component Cost Position (CCP) or the CAPE's Independent Cost Estimate (ICE) to serve as the new APB cost baseline.

Finally, Jasmine pointed to the "Inflation" worksheet within the MS B model and asked Ava to plan on referencing the inflation tables as the MS B model already formatted them. Obviously, the tables themselves would need to be updated with current inflation guidance, but the analysts' use of the same MS B format and inflation formula would allow Ava, Tim, and Liam to integrate their respective estimates more easily in a few months' time. The MS B model referred to a FY2015 constant year in its "Inflation" worksheet documentation; Jasmine explained that this meant that the model's Constant Year (CY) results always reflected CY2015. Returning to the "APB" worksheet, Jasmine explained that a program's initial APB reflected then-current CY results, and that year became the program's Base Year (BY). In order to compare future estimates accurately over time, subsequent cost reporting for the program always included results in the same CY as the established baseline. Therefore, the CACEG MS C model would report the program's results in CY2015, consistent with both the MS B model's architecture and the program's successful MS B decision in FY2015. As they had seen, the MS B cost model's "Inflation" worksheet and standardized inflation functions reflected the CY2015 assumption, so Ava needed only to use the architecture and formulas already in place while building her Production mini-model.

Jasmine's overview of the MS B PLCCE model had filled in many of Ava's gaps from the team's modeling conversation during CARD review the day before (all that she knew of and more). Ava now understood better what Jasmine had meant while talking with Tim and Liam about model "architecture," integration of multiple models (per life cycle phase), and specific guidance to make that integration process easier. She was grateful for the clarity, but she suddenly remembered one part that still did not make sense. Why had Jasmine mentioned an Army program office?

Making Sense of Production Contracts & the Overall Estimate

When Ava asked Jasmine about the Army program office, Jasmine started with the simple reminder that the CACEG program was building off of the current Army AH-65 helicopter. Jasmine took this opportunity to discuss the high-level plan for collaboration with the AH-65E program office. Ava would need to include elements of this plan within the Process & Approach sections of her cost estimate plan for Production. Jasmine grabbed a blank sheet of paper started sketching an outline for Ava (**Figure 33**). She began with the simple reminder that the CACEG program would build off of the current Army AH-65 helicopter. Incom was still in FRP for the Army's AH-65E helicopters. They were nearing the end of planned remanufacturing work (modifying existing AH-65Ds to become AH-65Es via extensive upgrades), but the AH-21 SPO knew that the Army planned to continue adding "new build" helos to the Program of Record (POR). The POR referred to the approved and funded baseline for cost and quantities across the Future Years Defense Program (FYDP) of the current budget. If a significant acquisition change superseded the current budget, POR also instead referred to the updated baseline within approved program documentation (e.g., a new APB, acquisition strategy, or Selected Acquisition Report (SAR)). Jasmine further explained that the FYDP summarized DoD resources and force structure information for the next five years; those five years consisted of the current budget year and the four subsequent years. Thus, Jasmine's statement meant that the Army planned to continue adding AH-65E helicopters to their current plan. Both quantities added by the Army AH-65E program and the Air Force CACEG program would significantly impact cost improvement curves associated with the shared production line, but the CACEG helos would not be included in the Army AH-65 POR since the Air Force would have its own CACEG POR.

From working-level discussions over the last few years, Jasmine knew that Tamara, the CACEG SPO cost analyst, had been coordinating closely with the Army program office. As a result, she would bring a robust estimate for the Incom aircraft to the table during AH-21 MS C estimate reconciliation. Via coordination with their sister Army agency, the Army Cost Estimating Center (ACEC), ASCAA leadership knew that the Army AH-65E POE was a mature estimate, which had been approved as the CCP at the Vexis MS C decision. Thus, instead of focusing their efforts on duplication of both Army and USAF program office estimating efforts, ASCAA leadership had agreed to focus Ava's time and effort on the Vandalay modification efforts since the Vandalay modification efforts represented a higher risk area than the mature Incom production portion of the estimate.

Hence, Jasmine and ASCAA leadership had planned to coordinate with the Army program office analyst, Joanna, and request Joanna's estimate for the USAF units projected to impact her own AH-65E new build costs. The ASCAA division director, Marta, had already laid plans for Jasmine and the team to meet with Joanna in late May. Joanna would provide a deep-dive of the current Vexis cost model and methods. She had already incorporated the AH-21 aircraft quantities within the Vexis model's cost improvement curves. Ahead of the scheduled meeting with ASCAA, the Army would modify their architecture to actually output aircraft estimates for use within the ASCAA estimate. The estimating tool that Army mandated for use in all their program cost estimates made it fairly easy to produce those results without actually adding the USAF aircraft costs within their own POE results. Ava was impressed and relieved. Tackling the estimate for Vandalay's modification contract seemed like a significant effort without also needing to estimate the Incom portion; the more she had learned about the AH-65E program, the more she had grasped the challenges presented in the estimating schedule and the tight timeline available to tackle her piece of the estimate.

Jasmine reminded Ava not to forget about the SPO operating costs that were outside of the Incom and Vandalay contract costs they had focused on thus far. Operation of a large program like CACEG required a great deal of planning and execution in areas like: management, engineering, cybersecurity, logistics, contracting, and finance. Ava needed only to look at the Manpower CARD table to see how many people were in the SPO and get a sense for the magnitude of the effort of their various management and support functions. The Manpower CARD table reflected a SPO team comprised of multiple personnel types; there were Government civilians, uniformed military airmen, Government civilians labeled as Other Government Agencies (OGA), and a large number of service contractors. Jasmine explained that the operational costs of the SPO management and support team fell outside of their standard aircraft WBS. As a result, an analyst may easily overlook these costs if focused solely on a product-oriented WBS or Contract WBS (CWBS). Jasmine warned Ava not to confuse the government efforts (by both civilian personnel and service contractors working alongside within the SPO) with the industry contract efforts by Vandalay and Incom. Even when meeting to support the same test event, the teams were performing different functions.

Before concluding their meeting, Jasmine spent a bit of time explaining the concept and utility of a WBS. As Ava listened and asked questions, she began to comprehend the nuances of the overall program WBS as a means to capture all of the program costs via the various WBS elements. Ava remembered reading about the concept of a CWBS during her review of the DoD Cost Estimating Guide; a CWBS was a means to capture and partition the costs of an individual contract. Jasmine reviewed the relationship between a CWBS and program WBS, clarifying that the CWBS contained only a portion of the program WBS. Although the CWBS that Ava would review should align generally with their CACEG WBS, Jasmine warned her that there could be differences between lower level Incom and Vandalay CWBS elements and their overall program WBS, as defined within the CARD. Ava would need to review these instances carefully when handling their data or building cost estimating methods. Since Ava was responsible for the Production estimate, Jasmine did not spend a lot of time explaining the Cost Element Structure (CES) for O&S. However, gaining a better understanding of the WBS for her Production cost estimate, the overarching acquisition strategy, and the planned separation of Incom and Vandalay costs was an immense help to Ava. She left with a new understanding of the layout and setup of the MS B cost model and a much clearer vision of how to approach her MS C Production estimate.

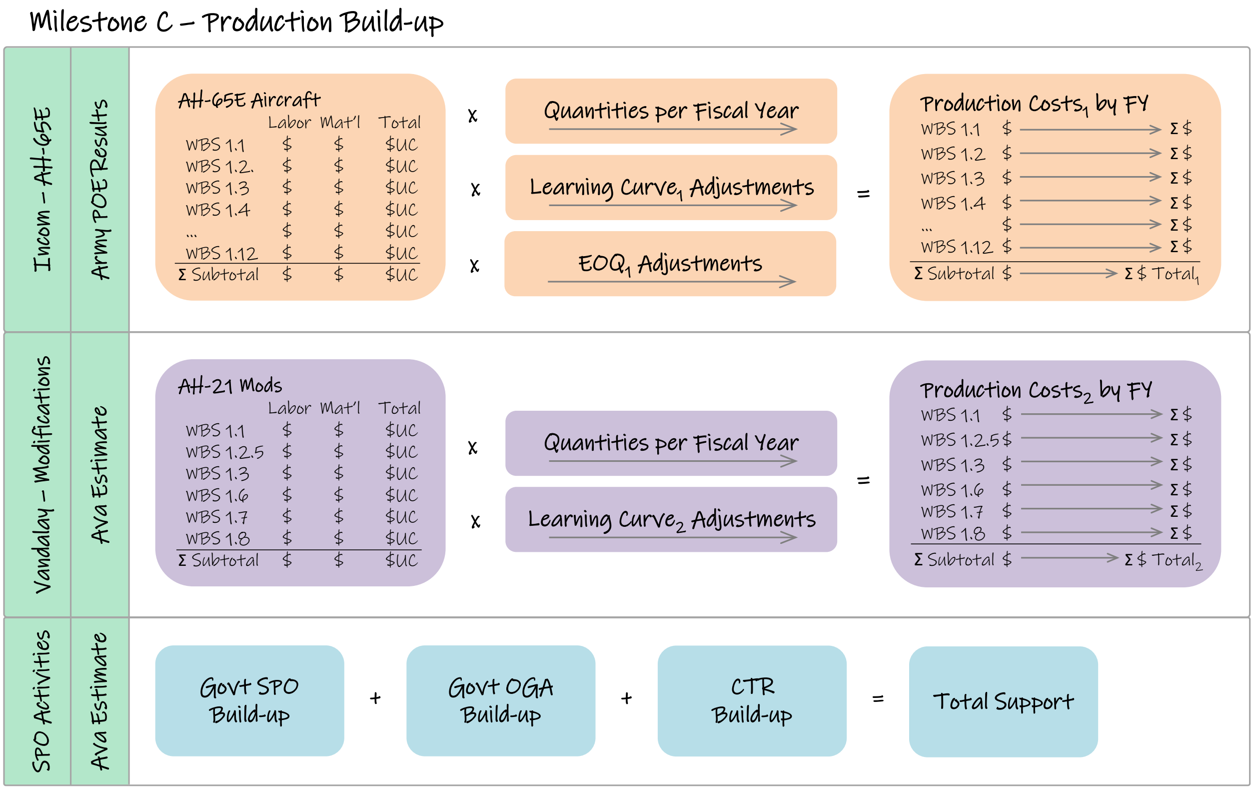
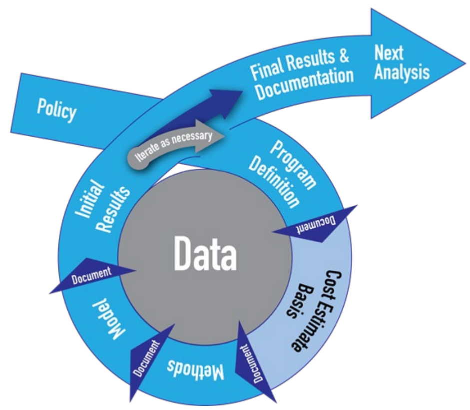


Figure 33: Outline of MS C Production Estimate

Critical Thinking Questions – Program Definition

- What should be done if the CARD content does not match other program office documents? Is it sufficient if it closely matches?
- Is a CARD the only document that conveys the program definition?
- What can be done if the program office is not timely in its reply to CARD submission and/or comments?
- Why is the WBS in the CSDR Standard Plans more detailed than the WBS found in the latest version of the MIL-STD 881?
- Who can I talk to in the program office to understand the program or technical parameters of the system?
- Are there any discrepancies in the procurement profile across data sources?
- Other than by program phase, how else could an estimate be grouped/displayed? What are the advantages and disadvantages of each way?
- Should I build my whole estimate in a single file or are there reasons to have multiple files?

Cost Estimate Basis



Following discussion of the overarching approach to her Production estimate with Jasmine, Ava began to realize the amount of work required to finish the Production portion of the cost estimate. She left their meeting with an action item to develop a cost estimate plan to help compartmentalize, prioritize, and track the tasks she needed to address in her portion of the cost estimate. While some of these tasks were included in her formal documentation, Ava realized that she should expand it to include the lower level details. The plan should also incorporate the estimate schedule so that the estimating timeline would remain clear. The team would actually aggregate their respective plans for each portion of the PLCCE and present the overall ASCAA plan during the Cost Integrated Product Team (CIPT) / ICE Kickoff meeting scheduled for February 26th.

Developing a Cost Estimate Plan

Unfortunately, the MS B cost estimate timeline had been compressed (i.e., rushed), and the ASCAA team did not develop a formal cost estimate plan to support their 2015 estimate. To develop their MS C plans, Ava and the team needed to start from a nearly blank document. Jasmine sent her the ASCAA AH-21 MS B final cost estimate briefing since the first few slides in the deck covered the team's purpose and scope, their Ground Rules & Assumptions (GR&A), and the program schedule; each of these portions of the brief helped Ava to understand elements needed in her plan. The availability of the MS B brief itself was especially helpful since it reflected the same basic AH-21 CACEG program that Ava would be estimating.

Ava recalled that the DoD Cost Estimating Guide included a dedicated section covering cost estimate plans. With the resources available within the guide, MS B brief, and draft MS C CARD, Ava was able to add detailed task information to her estimate schedule (**Table 18**). The exercise helped Ava to think through the work required to support Jasmine's original schedule, including: the important meeting dates required in terms of estimate deliverables, the timing of data collection and initial analysis, due dates for draft versions, preparation for review cycles and final estimate delivery, and overall estimate documentation needed to support the process.

Alongside the detailed schedule, Ava gathered information on the applicable policy documents, purpose and scope of their estimate, estimate structure, and team members (**Table 19**). Ava was unsure of how much contact information to include for the ASCAA team, whether or not to list the Army program office analyst who she would work with, or whether to list any trips within the travel section. She decided to bring these questions up at their next weekly team meeting.

During the next team meeting, Tim, Liam, and Ava compared notes on their draft cost estimate plans. Liam complimented the thought that had gone into Ava's detailed alignment of tasks to the schedule, and Jasmine was pleased with the summary description of her estimating approach. She asked that Ava spend some time to develop a slide or two with next level details based on their last one-on-one meeting and suggested that they add some detail regarding analogous systems that they would target during data collection.

When the question of team members and travel arose, Jasmine told the team that she would take care of content for both sections. Apparently, Eduardo, their CAPE analyst, had called her just the day before their team meeting to discuss trip requirements ahead of their kickoff meeting. Together they had decided to prioritize a trip to Vandalay's facilities. With Incom's mature production line already in place and "hot" because of the FRP phase of the Vexis AH-65E contracts, Eduardo and Jasmine decided to skip an additional trip to the Incom facility; they decided that time would be better spent on discussions about the programmatic plans and mitigation of schedule risk with the AH-21 SPO. Eduardo had actually worked on the CAPE ICE supporting the Vexis's FRP decision, and as a result he was already familiar with the program, the facility, and the Incom management team.

Table 18: Task & Schedule Subset of Cost Estimate Plan

Event	ACAT ID Days from CRB	AH-21 CACEG Dates	Duration Days	ASCAA Preceeding Activities
Notify CAPE of Upcoming Milestone	-210	January 27, 2021		▪ Cost team and assignments (complete) ▪ Policy review (ongoing)
ASCAA CARD Feedback Kickoff Announcement	-195	February 11, 2021	15	▪ Review CARD (complete) ▪ WBS review (MS B and MS C CARD - problems) ▪ Comments to System Program Office (complete)
Draft CARD to CAPE and CIPT/ICE Kickoff : Estimating Plan to ASCAA Director	-180	February 26, 2021	15	▪ Gather stakeholder information (talk with Tamara) ▪ Document cost estimate purpose & scope ▪ Process Approach - Identify ground rules and assumptions – use MS B as starting point - Determine if MS B cost model is still viable for MS C estimate - Outline estimate structure – highlight modifications from MS B - Preliminary estimating methodologies ◦ Identifify potentially analogous data ◦ Program actuals ◦ Determine need and schedule for contractor visits
CAPE and ASCAA CARD Sufficiency Review to Program Office	-135	April 12, 2021	45	▪ Coordination with CAPE analyst on outstanding CARD issues ▪ Final comments to System Program Office ▪ Gather, review, and validate data - Gather and review data ◦ Analogous data (Apache & other Vandalay helo programs?) ◦ Program actuals (EMD units) ◦ Program office CDRLs & acquisition documents - Contractor visits - Vandalay (& Boeing?) - Normalize & analyze data – Identify major gaps by WBS ▪ Develop estimating methods
ASCAA Midterm with ASCAA Director	-99	May 18, 2021	36	▪ Continue to develop estimating methods ▪ Begin mapping methods to cost model structure ▪ Prepare working documentation of estimating methods - PPT slides
Midterm Reconciliation – Program Office and ASCAA	-85	~~June 1, 2021~~ June 7, 2021	21	▪ Continue to develop estimating methods ▪ Continue mapping methods to cost model structure ▪ Update to ASCAA Director working documentation
Final CARD to CAPE & ASCAA Draft POE and Draft ASCAA Estimate to CAPE	-45	July 11, 2021	34	▪ Individual modeling of Sunk Cost & EMD, Production and O&S estimates ▪ Complete crosschecks & Finalize estimate ▪ Integrate Sunk Cost & EMD, Production and O&S working models ▪ Finalize integrated PLCCE model
ASCAA Final with ASCAA Director	-37	July 19, 2021	8	▪ Prepare Documentation - PPT slides ▪ Update Documentation (limited) & provide to CAPE

Table 19: Draft Production Subset of Cost Estimate Plan

Policy	DoD	DoDI 5000.73 - Cost Analysis Guidance and Procedures (dated 13 Mar 2020)
	USAF	AFI 65-508 - Cost Analysis Guidance and Procedures (dated 6 Dec 2018)
Purpose and Scope	Purpose	Program Life-Cycle Cost Estimate (PLCCE) supporting Milestone C decision and Low-Rate Initial Production (LRIP) decision
	Scope	Program life-cycle costs from TMMR through O&S Disposal excluded per draft MS C CARD dated 16 Mar 2021
Estimate Structure	Structure	Production Estimate to be divided into separate efforts for Boeing production (labor, material, etc.) and Vandalay modification (labor, material, etc.)
	WBS	WBS as defined within draft MS C CARD dated 16 Mar 2021 (*include copy to Level 3 in slide backup)*
Process / Approach	Summary	ASCAA Production Estimate focuses on Vandalay modification estimate (per AFI 65-508 Section 3.3.3.5); plan to leverage Army AH-64E POE for Boeing production estimate
Team Members	ASCAA	Jasmine - Team Lead Tim - Sunk Cost & EMD To Go Ava - Production & Deployment Liam - O&S
Travel		

Considering Analogous Data

Before the team meeting wrapped up, Ava asked to circle back to Jasmine's action to update the Process & Approach portion of her estimating plan with notes on analogous systems. Ava knew that the AH-21 helo would be a modified version of the Army AH-65E Vexis, so she suspected that the AH-65E itself would be an analogous system. However, she was not sure where to look from there. Tim and Liam offered to continue the discussion with Ava since Jasmine had another afternoon meeting.

From her review of the DoD Cost Estimating Guide, Ava knew that an analogous system should be "similar" to the program being estimated and appropriately represent the system being estimated. Her confusion lay in whether an analogous system needed to be similar to all schedule, technical, and programmatic characteristics of the system being estimated. Did an analogy need to be a legacy version of the new system (a suggested source included during her internal ASCAA cost training)? Did it matter whether a different contractor produced an analogous system? How would one know how to accurately estimate adjustments to an analogous program? Tim and Liam both smiled and assured her that she was asking the right questions. Liam actually overheard a fair amount of Jasmine and Ava's one-on-one discussion on the MS B model, the team's modeling approach for MS C, and the Production estimating approach. He also knew the AH-21 CACEG program well enough at this point to assure Ava that she would not need to fully rely on an analogy as her primary estimating method for Production. He pointed to Jasmine's **Figure 33** drawing in Ava's notebook and pulled out another blank sheet to help clarify some of Jasmine's passing comments on the MS B Production methodologies. As he continued, he began to sketch out the comparable MS B Production methodology (**Figure 34**).

As Jasmine had mentioned during their model discussion, the MS B estimate relied on analogy to the AH-65D program as its primary Production method. Although the Army's changes between the AH-65D and AH-65E were considerable, both variants were twin-turbo shaft attack helicopters with tail wheel-type landing gear, with a similar technical configuration, as well as a cockpit configuration for a crew of two. The AH-65E variant included several upgrades, including digital connectivity improvements, more powerful engines (with higher speeds and planning for increased range), and composite rotor blades. However, even with these upgrades, and among programs already well past Initial Operating Capability (IOC) at the time of CACEG's MS B decision, the AH-65D variant was the closest match to the AH-65E and AH-21 airframe's technical parameters and performance characteristics. Thus, the ASCAA team used

AH-65D cost data and adjusted various portions of the labor and material estimate to account for the AH-65E variant upgrades as well as the planned Vandalay modifications.

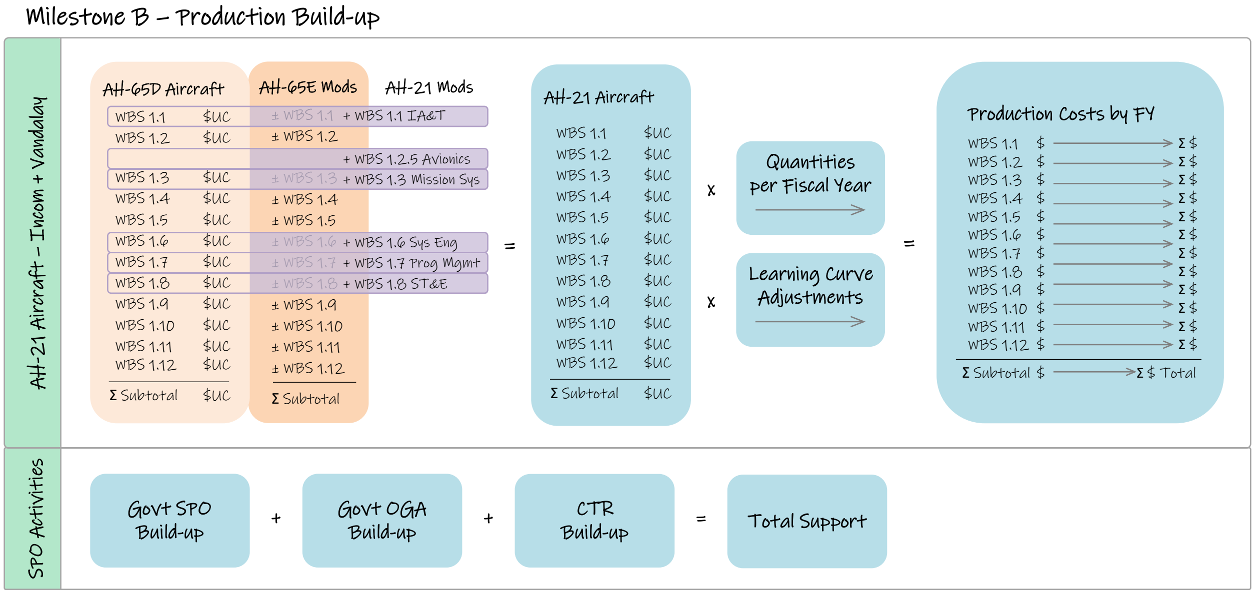


Figure 34: Outline of MS B Production Estimate

Now that AH-65E new build production was underway, Ava could leverage the best available resource in the form of the Army's AH-65E POE for the Incom portion of her AH-21 estimate. Since she would be estimating the cost of Vandalay modifications discretely (and extrapolating from the EDM actuals), as Jasmine's MS C outline made clear (**Figure 33**), Ava would need analogous data to develop and crosscheck specific assumptions within her labor and material estimate, but it would be impossible to find a perfectly analogous modification program (in terms of technical scope and programmatic assumptions) because of the GFE airframe being provided to Vandalay. She should focus her questions of similarity and appropriateness of individual assumptions before selecting analogous program data. For example, the modification work by Vandalay, within a specific set of WBS elements, would still be constrained by many of the same limitations on the production line that other heavy attack helicopter production lines experienced. With the space, assembly, and other physical constraints of the production process, another AH- program learning curve would likely be a good analogy for the program. Ava knew that a learning curve was a representation of the relationship between proficiency at a task and experience in performing that task. In her estimate, the task would be production of a helicopter and workers should become more efficient at their specific tasking as they gained experience from performing the task multiple times. Since learning curves were also dependent on a contractor's individual production processes, similar helo or modification programs that Vandalay may have completed in the past might provide a better analogy.

In short, Liam said that Ava should look for available AH-65D and AH-65E variant data, since those systems aligned most closely with the technical parameters of the AH-21 airframe. She should also look for available Vandalay helo program data, since it might provide a closer analogy to actual production practices and capabilities at the facility that would modify the Incom airframe. Tim reiterated that Vandalay-specific programs might also provide more accurate assumptions on lower level details within cost data since differences in accounting systems could sometimes make a significant difference in metrics measured on individual CWBS elements (like the ones Ava would focus on for the modification work scope). Ava was grateful for her teammate's time and valuable insight. She returned to her desk, yet again with much to consider, and she took a few minutes to translate her written notes into a high-level summary of possible analogous programs for her cost estimate plan. After a bit of research on Vandalay's prior helicopter programs, Ava found a few older utility helicopter (UH-) programs, two more recent fixed-wing transport aircraft (C-) with operating ranges three-to-four-times larger than the AH-21, and one recent attack helicopter program (AH-) with similar speed, weight, and operating range to the AH-21. Ava saved these search results within her working documentation and made a note to return to them later on in the estimating process.

Updating the Cost Estimate Plan

As she began to work through her actions on the cost estimate plan, Ava considered a comment that Jasmine had made during one of their chats that the best cost estimators she had met were those that clearly and succinctly documented their cost estimates. Liam had taken this line of thinking a step further and stated that the analyst should sufficiently document the cost estimate so that another cost estimator could reproduce the entire cost estimate from the documentation. With this and the importance of coordinating their GR&A in mind, Ava decided to continue updating portions of the cost estimate plan during development of her Production estimate. From the schedule, she knew that they would meet with Jay, their ASCAA director, periodically. She hoped to be able to accurately highlight changes and modifications to their GR&A, estimating assumptions, and proposed estimating methodologies during those reviews. Even if the high-level estimating methods in their plan stayed the same, the team's later reviews would require more detail, and the estimate plan working file, alongside their proposed model structure, seemed like a good place to aggregate and document summary information. Ava also knew herself pretty well; she tended to take lots of notes and iterate within working files. Although maintenance of her cost estimate plan would require a fair amount of effort, she knew that this aggregate snapshot of her GR&A, overarching notes, and working-level analyses and methodologies should make it far easier to prepare for final reviews and reconciliation with the SPO and CAPE analysts.

Considering Ground Rules & Assumptions

Ahead of their kickoff meeting, Ava turned her attention to the GR&A associated with her Production estimate. This was an area less straightforward to her, so she went to Jasmine for help. Jasmine indicated that the SPO had established many of the framing assumptions for their estimate years earlier. Prime examples were the SPO's plan to award the AH-21 airframe contract sole-source to Incom and the modification contract sole-source to Vandalay. As the TMMR and EMD phases had progressed, other framing assumptions matured alongside the CACEG's technical baseline. Jasmine pointed out that ground rules like the phasing of production quantities and planned IOC date had changed (but not drastically) since MS B, as Ava had seen in her comparison of the MS B and MS C CARDs. Based on her review of the DoD Cost Estimating Guide and careful review of the CARD, Ava felt that she had a decent understanding of many of the framing assumptions and ground rules, and she understood why many would be unlikely to change at MS C (or beyond). As the CACEG CARD outlined, Vandalay had progressed fairly smoothly through integration of critical technologies during EMD; this is what had caused the MS C decision to shift one year earlier than originally expected. Other aircraft had already demonstrated three of the CACEG critical technologies, and the remaining two represented the majority of overall program risk. However, the program had traded schedule against these requirements by incorporating a slower ramp-up to production during LRIP 1-2. In other words, because the program had decided to take longer to build the LRIP 1 and LRIP 2 aircraft so that CACEG engineers had more time to demonstrate and incorporate the final two critical technologies. The AH-65E Vexis program represented the single significant interdependency with another program, but both their program office and prime contractor (Incom) had proven themselves effective throughout recent program history.

Ava was, however, having some trouble identifying what additional information within the CARD to highlight within the GR&A (specifically, the cost assumptions). She sighed as she told Jasmine that she wished that the CARD narrative could just summarize the most important ground rules and cost estimate assumptions in a separate section. Recognizing the opportunity for a teaching moment, Jasmine told Ava that no specific section of any CARD ever contains or summarizes all of the concepts considered as part of an analyst's GR&A. In fact, many cost estimators struggled with defining, establishing, and verifying these foundational elements of their estimates. She assured Ava that her recognition of several of the framing assumptions and ground rules already discussed gave her a great start with respect to the cost estimate plan. As a next step, Jasmine advised Ava to pull the GR&A from the MS B final cost estimate briefing and to search the CARD for any changes that she could identify. The team would schedule a meeting with the POE analyst Tamara to discuss the unclear or undefined ground rules and their respective assumptions.

CIPT/ICE Kickoff Meeting

Finally, the day of their CIPT/ICE Kickoff meeting arrived. As the ASCAA Director, the head of their office (Jay) would serve as the CIPT lead. Ava had read a bit about this within the AFI 65-508 during her policy review. The ASCAA team met with Eduardo, the CAPE analyst, various members of the AH-21 SPO (including the program manager, acquisition lead, and the POE analyst Tamara), a representative from the Air Force PEO, and another representative from the Office of the Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics) (SAF/AQ). The meeting started with a program overview from the acquisition lead, describing the weapon system itself, and the acquisition, sustainment, and contracting strategies. Then, the ASCAA team presented their cost estimate plan and highlighted the schedule that Jasmine had created. Because several meeting dates or deadlines fell on a weekend (due to the team's use of the standard, automated schedule template), the group agreed to adjust working-level dates according the same rules for observation of federal holidays falling on a weekend. They would leave the official schedule as-was. This seemed like a minor detail to Ava, but Tim whispered to her that setting expectations among all of the participants was very important. One additional adjustment was made based on the CAPE's availability and the Memorial Day holiday; the midterm reconciliation meeting between the POE and ASCAA estimates would be delayed until the following week (with June 7th as a target date). The group discussed the CAPE and ASCAA desire to visit the Vandalay facilities, and the AH-21 acquisition lead took an action to coordinate the visit. The AH-21 SPO team suggested that the best scheduling option would correspond to an upcoming EDM 2 test event, which Vandalay had scheduled to occur in mid-April. Jasmine and Eduardo both agreed and seemed grateful for the opportunity to see the CACEG EDMs in action. Before the kickoff meeting, Jasmine had aggregated all known contact information and passed it around the room alongside a sign-in sheet to document attendance. She took an action to forward all CIPT members the contact information (and any updates recorded on the sign-in sheet). The whole meeting impressed Ava, and she finally had a face to put with the name for both Tamara and Eduardo. Jay officially approved their cost estimate plan and schedule, just as Jasmine suggested that he would. (In internal reviews prior to the kickoff meeting, Jay had tentatively approved of ASCAA team's plan, pending CAPE concurrence with the schedule.)

After the meeting, Jasmine paused to speak with Tamara about setting up a GR&A meeting the following week. They set a time and planned for Tamara to visit them in the ASCAA office; Jasmine also invited Eduardo to attend since the GR&A could significantly alter the results of a cost estimate. The CIPT team had made it clear that the ASCAA and SPO teams should communicate closely with one another and with CAPE during the overall CCP process. As they stood listening, Liam mentioned to Ava that it was critical that the teams address any gaps or disconnects on the ground rules, and that any disagreement on them needed to be resolved because of their impact on each organization's cost estimate. However, each organization's assumptions might vary; in truth, everyone expected them to vary. The strength of the CCP process and purpose of the ICE lay in their independent analyses of the same program and ground rules. Thus, they would communicate and even potentially collaborate regarding estimating assumptions, but apart from the eventual reconciliation process of the POE and ASCAA estimates, there was no need that their assumptions match completely.

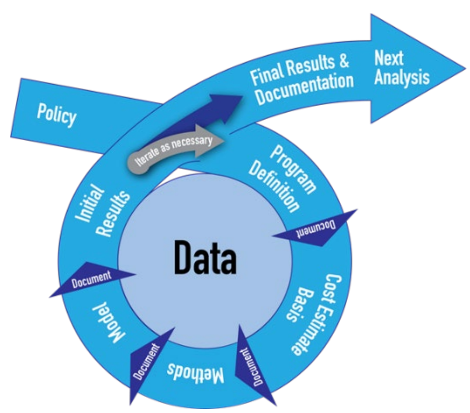
Back in the ASCAA office, Ava updated her cost estimate plan to reflect the modifications to their **Table 16** schedule. She picked up with GR&A documentation where she left off ahead of the kickoff meeting, and she began translating her notes on GR&A changes since MS B into her working-level electronic documentation. As Ava made these updates, she realized that her next step was data collection. That seemed somewhat generic to her since this section in her estimating plan did not contain too many details about specific data sources or how to use them. For her Production portion of the estimate, the team had mostly discussed use of the EMD contract actuals and leverage of Vexis data. Although Jay seemed satisfied with the overall process approach during review of their plan, Ava was unsure of where to begin. However, she remembered that all of the cost estimating guides had sections devoted to data, so Ava returned to the data section, "Identify, Collect, Validate, Normalize, and Analyze Data," in the DoD Cost Estimating Guide.

Critical Thinking Questions – Cost Estimate Basis

- Is a visit to the prime contractor always required? What is the latest that program office and contractor visits should be scheduled? Is more than one visit needed? What information/knowledge can be gained from conducting site visits?
- Are subcontractor visits necessary?
- What are the possible repercussions if a cost estimate plan is not developed?
- How do I determine which systems are analogous? Is a legacy system different than an analogous system?
- Are there possibly analogous systems in another Military Service or in the commercial sector?
- Can a ground rule ever become an assumption? Can an assumption ever become a ground rule? Does it matter?

Data – Identify, Collect, Validate, Normalize, and Analyze

Ava reexamined the data section in the DoD Cost Estimating Guide, and she realized that the process graphic used throughout the document did not contain an actual step for data collection; instead, "Data" appeared as a circle at the center of the rotating arrow. Obviously, the authors of this document thought data was very important in the cost estimating process.



As she studied the graphic, Ava initially wondered if she had missed something since data was somehow associated with the program definition and cost estimate basis, which she thought she had already "completed." While Ava intended to consistently update her plan, it was not clear to her how this plan related to data. She understood that both the AH-21 program definition and her cost estimate basis would influence the data needed to prepare the estimate. Why was data not the next step in the process? Eventually, after discussions with Jasmine and the cost estimating team, Ava realized that data was more than a single step within the estimating process. Data collection actually began early-on in the process with identification of programmatic data during Program Definition; GR&A identified within the Cost Estimate basis significantly shaped data needs. To consider Data as a "next step" would overlook those important activities. Furthermore, due to the iterative nature of cost estimating and evolving nature of DoD programs, data could actually exert influence on the early estimating process steps as well. Jasmine explained that data-driven cost estimates (particularly early in a program's life-cycle) could actually force change to the program definition – most often because of affordability. Hopefully that was not a likely scenario as the AH-21 approached MS C. However, Jasmine highlighted a portion of the DoD Cost Estimating Guide that stated that iteration of the cost estimating process could actually happen at any step in the process. The DoD Cost Estimating Guide listed a change to the cost estimate basis among the possible reasons for iteration in the cost estimate process, and Jasmine explained that portions of the program definition – from production quantities to readiness of a new technology – could change as she developed a cost estimate. Depending upon the programmatic or materiel impact, a shift could send program managers and engineers in search of a suitable solution, which could significantly impact a cost analyst's data requirements. These types of changes were not held in a back pocket and pulled out at just the right time to torture program managers and cost estimators; typically, they came as a result of changing threats, emerging technology, Congressional direction, or budget decisions. Until the program office, service cost agency, or CAPE established a point near the end of the process to lock the framing assumptions and ground rules of a required estimate, almost any programmatic, technical, or schedule input could change. Thus, data was an aspect of the cost estimating process that could both influence and be influenced by all steps in the process.

With this new, higher level understanding of cost estimate data, Ava felt as if she had crossed a threshold. She sensed that the challenge associated with identifying data for her estimate would be significant. Her cost estimating team had warned her that it was not necessarily the identification of data, but the identification and collection of "good" and defendable data, that would require most of her time and energy. They had warned her that spending some additional time to identify "good" data, or at least the best available data, early on would save time later. Ava internalized this concept. As she turned her thoughts to her Production estimate for the AH-21 CACEG, she wondered, "What is good, or defendable, data?"

Reviewing Historical Estimates

Ava decided to dive in and begin with the list of data leads that Jasmine had given to her. Jasmine had been an intern during the MS B decision for AH-21 and actually worked alongside another analyst on the MS B estimate. Since she knew that the technical scope had remained stable since selection in the Analysis of Alternatives (AoA) phase, Jasmine encouraged Ava to skim through both the original AoA estimate documentation and MS B estimate documentation with careful attention to the technical scope sections, program data leveraged, and the estimating methodologies. Ava searched the network drive for both documents.

While looking for the AoA in the AH-21 program folders, Ava spotted a few other files that looked helpful. There was a folder with backup files for the Vandalay labor rates used in the previous Production estimate and another with Vexis AH-65D Earned Value Management (EVM) data used to develop the MS B learning curve. Having read a number of articles about the AH-65E on the Incom website, Ava knew it would be the foundation for the AH-21. She remembered that the SPO had discussed the AH-65E FRP contract award during the kickoff meeting and wondered if she might be able to update the old learning curve analysis using LRIP data for the AH-65E. Ava copied both files to her desktop in order to look more closely at the workbook architecture and how prior analysts had normalized the data.

Exploring DoD Data Repositories

Jasmine had also suggested that Ava request access to two of the DoD-level data repositories mentioned in the DoD Cost Estimating Guide, specifically CADE and the Defense Acquisition Visibility Environment (DAVE). She explained that CADE was a web-based application providing comprehensive cost, software, and technical data to facilitate efficient and effective analysis. Contractor Cost Data Reports (CCDRs), CARDs, and Software Resource Data Reports (SRDRs) were all available, as well as access to several libraries of cost and technical studies on DoD acquisition programs. DAVE included tools for statutory and regulatory reporting, data and capabilities for program and portfolio analysis, and technical resources for data consumption. Ava decided to see what reports were available for the Vexis program and for the Vandalay Corporation and determine from there which cost information would be most applicable.

Within just a few hours, Ava received an automated email that the CADE team had established her CADE account. In the CADE portal, Ava was quickly able to find a summary of Vexis program Cost and Software Data Report (CSDR = CCDR + SRDR) submissions using the drop-down on the Data & Analytics page. She was excited when the initial Dashboard results to her search turned up dozens of results organized by program phase and prime contractor. The challenge now lay in knowing which row(s) to pick, or what data line items actually offered the 1921 (Cost Data Summary Report) that she was interested in. Exploring further, Ava found a CSDR Browse tool under the Data menu. Using it, she was able to filter down to Incom's Army aircraft production submissions, where she quickly found several contract tasks related to their AH-65D work. Based on her conversation with Tim and Liam, she knew that AH-65D may not provide the best analogy to the upgraded AH-21 helo, but the reports could be helpful (at a minimum) in crosschecking her total helo estimate after she combined the Vandalay and Incom estimates. She decided to download the AH-65D submissions and continued to look through the submissions in search of AH-65E. Eventually the addition of a keyword for "65E" in her search criteria (**Figure 35**) enabled her to hone in on the program. Several submissions appeared, corresponding to the first seven lots, but CADE had them all saved under the AH-65E Remanufacture program, which Ava thought was separate from the "new build" program she had read about. Since one of the FRP Lot 3 & 4 task submission events was labeled "New Build Final Delivery," she decided to download all of the available CSDR submissions and search for more details on the contract later. Only after downloading all of the files did Ava realize that she had a mix of file types – PDF, XLS, DOC, and XML. She knew that some of these file types would make it easier to process large amounts of data, but unfortunately historical reporting from Incom for the AH-65 was not in the modern FlexFile format. Ava made a mental note to talk to Jasmine about how to make sure that any CACEG reporting aligned to the FlexFile format.

As Liam had pointed out, Vandalay-specific contract data would be helpful to Ava's estimate for their AH-21 modifications, so she decided to modify her CSDR search to look for available data on past Vandalay helicopter programs. She returned to her working-level documentation and the list she had compiled about analogous programs. After modifying her query within the CSDR Browse interface several times (casting a wide net with her search criteria), submission data for the older utility transport (UH-) programs appeared non-existent. She turned her attention to the AH-51, the one heavy attack program that she had identified in Vandalay's production history, and hoped for better search results. Right away, 1921 and 1921-1 (Functional Cost-Hour Report) submissions popped into view, and Ava was able to download final submission data for the six lots of the AH-51 program, which had recently ended production. Ava felt confident that these reports would come in handy as they provided insight into the Vandalay CWBS, the split between recurring and nonrecurring costs, allocation of the contractor's accounting system across an aircraft CWBS, General & Administrative rates, performance history, and related profit/loss/fee data. Further down in the AH-51 submission list, Ava noticed a Vandalay submission labeled 1921-3 (Contractor Business Data Report). She remembered seeing that report name during her reading and had also noticed it under the Data menu in CADE. Exploring further, she found pages of 1921-3 reports labeled Business Base Data. Ava quickly drew the correlation between the CADE menu title and the MS B Forward Pricing Rate Agreement (FPRA) working file she had found on the network drive to support labor rates utilized within the estimate, so she saved several recent 1921-3 submission files for Vandalay's production location. Based on her prior reading and research, she hoped that these would provide further insight into the direct, indirect, and overhead rates for the individual business unit associated with the AH-51 (and now the AH-21 as well).

Before leaving CADE, Ava shifted gears to access the Selected Acquisition Report (SAR) Database application. Tim had mentioned this annual report when Jasmine encouraged her to sign up for the CADE and DAVE accounts. While CSDRs were built with cost estimators in mind and for their use, the SARs were program reports to Congress that contained an annual snapshot of helpful information like total program cost, schedule assumptions, performance information, and unit costs. DAVE housed the full SAR reports, published in narrative form, but CADE contained a useful snapshot of information most readily transferable within a database format (e.g., unit cost table data, performance characteristics, and standard narrative sections like "mission" or "executive summary"). At the top of her CADE aircraft search, Ava spotted the AH-65E new build program. SAR extracts back to FY2010 were visible within the browser, but she focused on the most current submission for the previous fiscal year. Under the executive summary section, she found a point of contact for the Vexis new build program office; and within the unit cost section, the original and current quantities and unit costs were broken down by acquisition phase. Ava exported the table to Excel and made note of the breakdown between recurring and non-recurring procurement costs.

Once the DAVE administrators activated her account a few days later, she utilized the Defense Acquisition Management Information Retrieval (DAMIR) system to pull the full SAR submissions. The DoD Cost Estimating Guide had highlighted the difference between primary and secondary data sources. Although the SAR Excel table saved from CADE gave her a visual representation of some of the SAR information (most notably the AH-65E baseline and current unit costs), they were secondary data and she wanted to look through the latest report in its entirety in order to get a better understanding of the current status of the AH-65E new build program. By downloading and comparing the last few years of SAR submissions, Ava was also able to get a feel for how the Army's quantity increases had occurred over the last several years; she observed a drop in the recurring unit cost as the program office added production units, so she made note of the changes.

In the EVM Central Repository (EVM-CR), accessed through DAVE or via CADE, Ava found numerous AH-65E EMD and LRIP contract submissions. (The EVM-CR was a data repository for EVM and Integrated Program Management (IPM) data.) Like the 1921 data from CADE, the reports were specific to contractor-only scope for the airframes, but Ava noticed that Incom uploaded submissions on a monthly basis. From the peer review for another recent ASCAA estimate, Ava remembered that another analyst had used EVM data to phase a longer production schedule according to the monthly actuals for labor hours instead of their program office's planned duration information. Ava decided that she should review the Vandalay EMD contract similarly, if she could manage, in order to validate the CARD delivery schedule against the EVM schedule metrics. She downloaded what looked to be the final Integrated Program Manager's Report (IPMR) submission for the last AH-65E LRIP contract and turned her attention to Vandalay's reports. She knew that the CARD had mentioned that integration of the mission system modifications was going well on the CACEG EDM units, but she wanted to see how well, if she could. Jasmine had mentioned that the EVM submissions were the quickest way to assess current status and that Ava should be familiar with the basic EVM metrics for Cost Performance Index (CPI) and

Schedule Performance Index (SPI) before talking with the AH-21 SPO or visiting Vandalay on their site visit. She quickly found the Vandalay IPMRs and downloaded all submissions for the EMD contract.

Ava was excited. She had managed to collect many reports, and she had learned about the current AH-65E program's production schedule, milestone and contract history, and unit cost changes over time. The Vandalay EVM data had initially given her some trouble; however, after some work with a calculator, she started understanding how the columns and rows of the report added up, and she remembered that Contract WBS structures could be somewhat different than the MIL-STD 881 structure found in the CARD tables and the estimating structure inherent to the old MS B estimate. She noted specifically that the Vandalay EMD contract reports were missing a number of the Level 2 elements of their estimate WBS under 1.2 Airframe. This made sense because Vandalay was receiving most of the air vehicle (apart from the avionics upgrades) as GFE, but this discovery also concerned Ava a bit relative to her plans for the Vandalay Production learning curve. The same AH-65D learning curve that she had found from MS B might not be as applicable and useful as she originally hoped since the MS B cost team had derived it from a fully-delivered helicopter, not the same technical scope that Vandalay would perform for CACEG. Her thoughts had drifted back to the earlier question, "What is good, or defendable, data?"

Course Correction with Jasmine

At her next weekly meeting with Jasmine and the team, Ava happily reported her progress. Before the meeting, she had decided that she ought to acknowledge her confusion about various source's applicability to her learning curve. To her surprise, when she brought it up, Jasmine apologized. Apparently, she had intended to give Ava a tutorial of both CADE and DAVE, but she and Tim had been caught up working through some confusion in the AH-21 sunk cost history with the SPO. In order to accurately update the APB tables to reflect their MS C estimate, Tim needed to allocate sunk costs between Acquisition and O&S categories, which was not always straightforward. Total Acquisition included requirements for multiple appropriations, including: RDT&E, procurement, military construction (MILCON), and acquisition-related Operations & Maintenance (O&M). However, parsing DoD accounting data for O&M funding and efforts like SPO management and support labor sometimes presented problems.

Jasmine was pleased with the research that Ava had done in CADE and DAVE, and she set a time to meet with Ava the next day to review a few additional capabilities. Jasmine then announced that she had set up a second meeting with the AH-21 acquisition lead and lead engineer. Prior to an opportunity to meet with the SPO, Ava wanted to ensure that she clearly understood the relevance of data already in-hand and any potential gaps. The SPO meeting offered an excellent opportunity to ask clarifying questions about the program, and potentially about applicability of certain data sources, so Ava wanted to ensure that she made the most of it.

The next day, Jasmine confirmed Ava's suspicions that some of the reports she had pulled were more useful for some purposes than others within her estimating approach. For example, Jasmine said that the 1921-3 would be good for analyzing overhead, but not as useful for determining labor hours and material information that would be more detailed in the 1921-1 reports. Jasmine was pleased with the advice that Tim and Liam had passed on to Ava, and she encouraged Ava to return to her notes on analogous systems within the cost estimate plan. Overall, Ava had come up far from empty-handed,

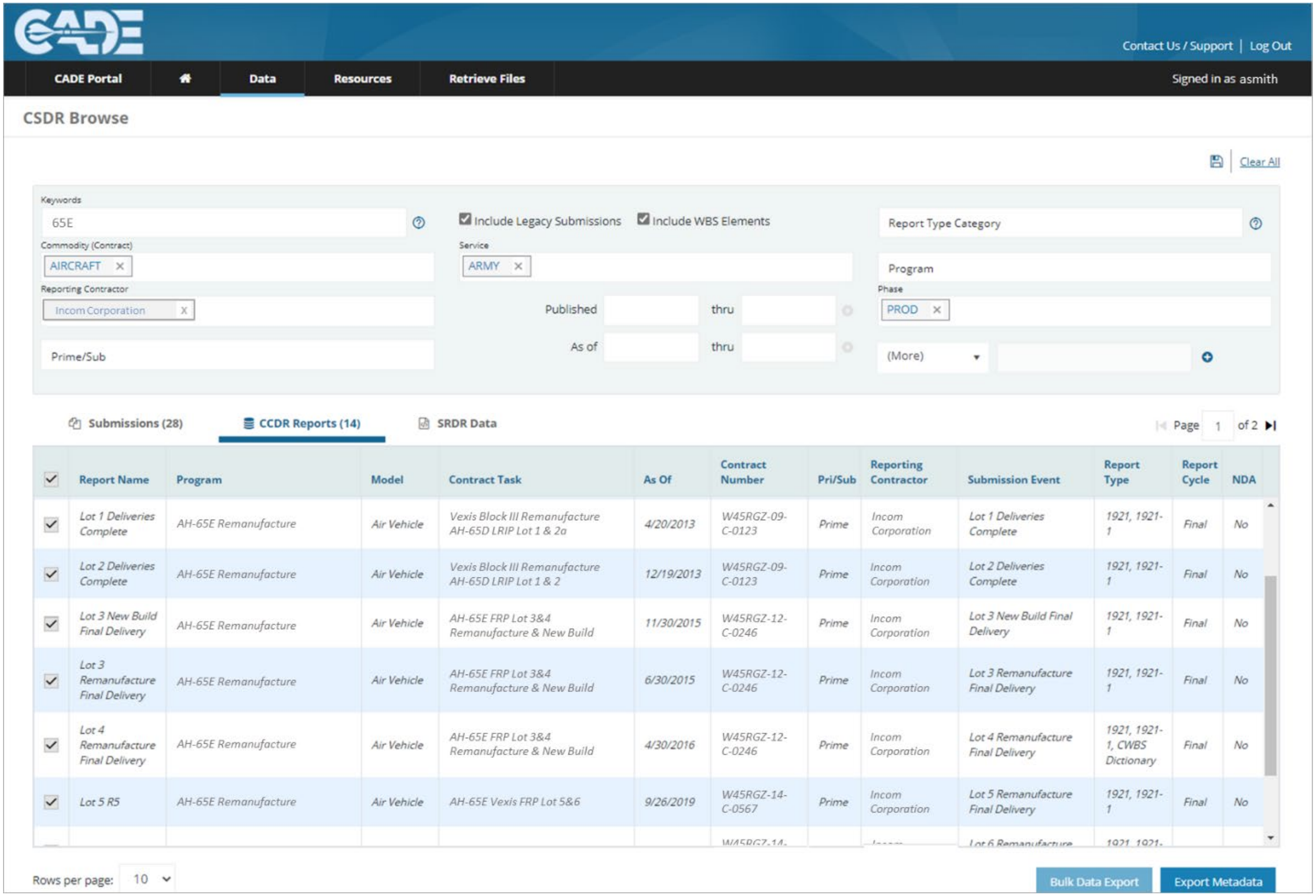


Figure 35: CADE Data & Analytics Screenshot of CSDR Browse

with quite a bit of usable data to leverage in her Production estimate, and Jasmine encouraged her to keep researching independently to some extent, whenever she had a question. She explained that a simple web search for acronyms and specific contract or contractor information never hurt, as long as she was careful what websites she clicked on. Usually, Jasmine explained, the veracity of any publicly-available data on a program of interest could be checked via some government resource, but taking the initiative to learn "what was out there" could clue Ava in to the applicability of resources she already had access to via databases like DAVE or CADE. Likewise, a few minutes of web research on a program like Vexis could save Ava a lot of time digging through database records that were not analogous.

Jasmine had Ava open the production cost estimate plan, the MS B and MS C build-ups (**Figure 33** and **Figure 34**), and the MS B cost model. Together they reviewed the plan for the initial modeling structure, the estimate WBS for Production, and the MS B cost contributors. Jasmine highlighted the largest cost contributors to Ava's Production estimate – labor and material – but she pointed Ava to the separation in their estimating plan between the GFE aircraft (from Incom) and the Vandalay modifications. This separation had been made intentionally because Jasmine, their division chief Marta, and the ASCAA director Jay all knew that additional data sources for Vandalay's modifications were now available (unlike during the MS B timeframe). At MS B, there wasn't any EDM data for the Vandalay scope, so the team used a whole AH-65D helo as the basis for their estimate with a few adjustments at lower-levels. Now that they had two sources for actual/contract data, Incom and Vandalay, they would estimate the two Production efforts separately. Within the Vandalay portion of Ava's MS C outline (**Figure 33**), Jasmine pointed to the first box – representing a Vandalay AH-21 first production unit (T1). On the reverse side of the paper, she added notes on the AH-21 proposal and EVM data now available for EMD efforts (**Figure 36**). This EMD contract data would enable full-division of the two work scopes within their Production estimate and associated methodologies.

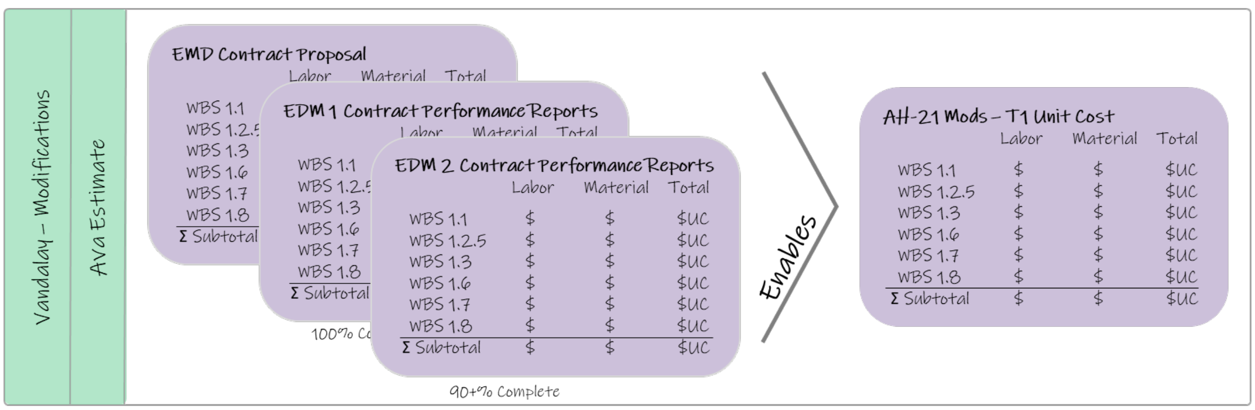


Figure 36: Examples of EMD Contract Data Available at MS C

Jasmine clarified that Ava had not wasted her time by downloading so much Vexis cost data. The GFE aircraft would likely be the top cost contributor in Ava's overall Production estimate (i.e., combined Incom, Vandalay, and SPO efforts), which made crosschecking the estimate data that Jasmine hoped to receive from the Army program office (and the total AH-21 unit costs) important. She further explained that it wasn't that AH-65 program data was *not* applicable to the Vandalay modification estimate at all; Ava just needed to be careful to utilize the Vexis data at the applicable level of detail when she applied it to the Vandalay work scope. At MS B, the ASCAA team had estimated AH-21 based on AH-65D total production labor, plus several high-level adjustments for the AH-65E variant and Vandalay modifications; hence, they calculated their learning curve based on total labor hours for the aircraft (all CWBS elements). Now that the Air Force had EVM return data from EMD for the Vandalay work scope, Ava could estimate the labor associated with the CACEG modifications at a more granular level.

Likewise, she should review the AH-65 data at a more granular level to fit a curve to learning improvements in just the Avionics (WBS 1.2.5) and Mission System (WBS 1.3) elements over the course of the early AH-65D production lots and the AH-65E LRIP lots. The cost reporting data just needed to be normalized for technical scope comparable to its use within the estimate.

Getting Organized & Moving Forward

Jasmine suggested that they request a copy of the Acquisition Strategy and Systems Engineering Plan (SEP) from the AH-21 SPO team. These two acquisition documents would have greater detail than their respective CARD summaries, and skimming them (even just introductory sections) would be well worth Ava's time to gain a clearer understanding of the technical interface between the GFE aircraft and the Vandalay modifications as well as the schedule and business interfaces during production.

In the meantime, to help Ava keep track of her data requirements, she and Jasmine subdivided the AH-21 into two major contracting efforts: the Incom GFE aircraft and the Vandalay modification work scope. As shown in **Table 20**, Jasmine and Ava systematically reviewed the estimate WBS and marked the applicability for each contracted effort (as a cost contributor to the overall program).

Table 20: Partial Outline of Cost Contributors by Contracting Effort

WBS		GFE - Incom	Vandalay	Notes / Acq Document References
1.0	Aircraft System	Buildup	Buildup	
1.1	Aircraft System, Integration, Assembly, Test, a	X	X	
1.2	Air Vehicle	Buildup	Buildup	
1.2.1	Air Vehicle Integration, Assembly, Test, and	X		
1.2.2	Airframe	X		
1.2.3	Propulsion	X		
1.2.4	Vehicle Subsystems	X		
1.2.5	Avionics	X	X	CARD narrative 4.0
1.2.6	Armament/Weapons Delivery	X		
1.2.7	Auxiliary Equipment	X		
1.2.8	Furnishings and Equipment	X		
1.3	Payload/Mission System	X	X	CARD narrative 1.12 and 2.0
1.4	Ground/Host Segment	X		
1.5	Aircraft System Software Release 1...n (Specif	X		CARD narrative 3.0 (for Dev/EMD and O&S)
1.6	Systems Engineering	X	X	SEP
1.7	Program Management	X	X	CARD table data - NonHW Technical
1.8	System Test and Evaluation	X	X	CARD narrative 3.0 TEMP
1.9	Training	X	X	CARD narrative 5.5.5

Then they worked to subdivide her Vandalay estimate, in the middle column of **Table 20**, into three major cost contributors: labor for WBS 1.1, 1.2.5, and 1.3, material for WBS 1.1, 1.2.5, and 1.3, and below-the-line contractor efforts like System Engineering & Program Management (SEPM) and System Test & Evaluation (ST&E). (Tim had taught Ava that "below-the-line" was another term for the WBS elements captured within the Non-Hardware Technical WBS table of the CARD. As opposed to "touch labor" production activities directly related to physical production of a helo, these "below-the-line" efforts included support activities still directly attributable to delivery of an end unit.)

In addition to the contractor efforts, SPO management and support labor costs added a fourth major cost contributor to Ava's Production estimate. (Jasmine had taken a moment to point out the delineation between the SPO and contractor efforts within the **Figure 33** drawing still prominently pinned to Ava's cube wall.)

Ava would need to capture additional cost elements in her Production estimate (omitted in this case study), and she would need to incorporate the Incom estimate coming from the Army AH-65 program office. However, these four cost contributors comprised the largest portion of her overall estimate and represented the portions of the Production estimate that Ava should focus on while reviewing data (and later developing estimating methods). In **Table 21**, Jasmine helped Ava to align her current data sources with applicable portions of the estimate. They captured sources pertaining to the high-level estimating methodologies included within the approach of their estimating plan and identified potential sources for data that Ava was currently lacking (highlighted in pink).

Following their meeting, Ava felt much more confident in her progress and ability to seek out remaining resources. It was not long before she had collected the applicable General Schedule (GS) pay scale; alongside contractor labor rate and travel information from the SPO, this would comprise the bulk of her additional input data for SPO support. Jasmine had mentioned a General Services Administration (GSA) website (i.e. CALC or Contract-Awarded Labor Category) that Ava might be able to use for program office support labor rates, but she recommended that Ava hold off on more research until they discussed the CARD manpower table and the specific breakdown of contractor personnel to functional areas, with the SPO. Anticipating the need for careful normalization of cost data, Ava also tracked down a copy of the latest inflation tables for USAF appropriations; another ASCAA analyst had updated the tables to reflect updated outlay rates released by USD (Comptroller) in their annual OSD Inflation Guidance memo. She carefully reviewed the updated actuals for the prior fiscal year as well as changes to the current and out-year raw inflation projections. Tim had asked her to confirm that the MS B appropriations were all consistent thus far with the sunk cost actuals that he had expected.

Finally, consistent with Jasmine's mention of their missing contractor personnel breakdown in the CARD manpower tables, Ava looped back to the team's working copy of the CARD CRM and added an action item for the missing information. Up until her discussion with Jasmine, she had not recognized any omission of detail. During their conversation, Jasmine had taken a moment to open the current draft CARD manpower table and explain that the counts included actually reflected a unit called Full Time Equivalents (FTE). She pointed to two of the current government civilian rows that reflected partial FTE assumptions, and she noted that Ava could expect that the missing breakdown of SPO contractor manning would likely reflect even more partial FTEs. One FTE reflected a full year of work according to some set metric (commonly for hours per year); thus fractional FTEs could represent one person supporting full-time for only a portion of a year (e.g., 100% for three months equating to 0.25 FTE), one person working part time for a whole year (e.g., 50% for twelve months equating to 0.5 FTE), or some combination of both scenarios.

Meeting with the AH-21 SPO

Ahead of the meeting with the AH-21 SPO team, Ava carefully re-read the CACEG draft CARD, specifically the acquisition strategy and technical description sections. She also printed a copy of the division of WBS elements that she and Jasmine had created for quick reference. Jasmine had been in touch with Eduardo as they continued to track the SPO's adjudication of CARD issues highlighted in the CRM, and she invited him to join the ASCAA team's meeting. With many of their CAPE and ASCAA CARD comments still outstanding with the SPO, their discussion to clarify technical scope and GFE business interfaces would be helpful to him as well. With the CARD Sufficiency Review fast-approaching next month, the cost team wanted to capitalize on the opportunity of a working-level discussion with the acquisition manager and engineering lead. During the meeting, Jasmine was pleased with the progress made relative to their CARD issues. As she had said multiple times to Ava and her teammates, a face-to-face informal discussion was often much more efficient (and usually more informative) than more official communication via e-mail. One well-executed meeting could save the trouble, and potential miscommunication, of a dozen email exchanges (especially if one followed best practice to begin meetings with a distinct agenda, stated goals and outcomes, and read-ahead material to make the most of the team's time).

Table 21: Ava's Production Cost Contributors and Identified Data

WBS by Effort		Applicable Cost?	Labor	Material	Other	Data Sources
1.0	Aircraft System - Vandalay Unclass	Buildup	Buildup	Buildup	Buildup	
1.1	Aircraft System, Integration, Assembly, Test, an	X	X	n/a	n/a	Vandalay EMD Proposal
1.2.5	Avionics	X	X	X	n/a	EMD CPRs
1.3	Payload/Mission System	X	X	X	n/a	Vandalay FPRA
1.6	Systems Engineering	X	X	X	n/a	Vandalay EMD Proposal
1.7	Program Management	X	X	X	n/a	EMD CPRs
1.8	System Test and Evaluation	X	X	X	n/a	Vandalay FPRA
2.0	System Program Office (SPO)	Buildup	Buildup	Buildup	Buildup	
2.1	Government Pay	Buildup	Buildup	Buildup	Buildup	
2.1.1	Military Personnel	Buildup	Buildup	Buildup	Buildup	
2.1.1.1	Systems Engineering	X	X	n/a	n/a	CARD table FTEs by Grade
2.1.1.2	Program Management	X	X	n/a	n/a	*Military Basic Pay rates*
2.1.1.3	Test & Evaluation	X	X	n/a	n/a	*Military Composite rates*
2.1.2	Civilian Personnel	Buildup	Buildup	Buildup	Buildup	
2.1.2.1	Systems Engineering	X	X	n/a	n/a	CARD table FTEs by GS scale *GS labor rates*
2.1.2.2	Program Management	X	X	n/a	n/a	
2.1.2.3	Test & Evaluation	X	X	n/a	n/a	
2.1.3	Other Govt Agencies (OGA)	Buildup	Buildup	Buildup	Buildup	
2.1.3.1	Systems Engineering	X	X	n/a	n/a	CARD table FTEs by GS scale *GS labor rates*
2.1.3.2	Test & Evaluation	X	X	n/a	X	*OT&E independent agency test*
2.1.4	Travel	X	n/a	n/a	X	*Request current year requirements from BFM*
2.2	Contractor Support	Buildup	Buildup	Buildup	Buildup	
2.2.1	Program Management Administration (PMA)	Buildup	Buildup	Buildup	Buildup	
2.2.1.1	Fed. Funded Research & Dev Center (FFRDC)	n/a	n/a	n/a	n/a	n/a
2.2.1.2	Advisory and Assistance Services (A&AS)	Buildup	Buildup	Buildup	Buildup	
2.2.1.2	Professional Services Schedule (PSS)	X	X	X	n/a	CARD table FTEs
2.2.1.2	Systems Engineering & Technical Assistance	X	X	X	n/a	*Request SPO FTE allocation*
2.2.2	Travel	X	n/a	n/a	X	*Request current year requirements from BFM*

During their meeting, Ava was able to ask the AH-21 lead engineer for more detail on the Vandalay modifications. The SPO team fielded all of Ava's specific questions and took actions to follow up with a copy of the SEP and the Acquisition Strategy. The SPO team discussed EMD production performance, the handful of minor production adjustments planned ahead of LRIP award, and changes that the SPO team expected to see within the LRIP proposal from Vandalay. Lastly, Jasmine brought up a specific Operational Test & Evaluation (OT&E) event scheduled for next year. She had pulled a recent DoD aircraft study, which included historical cost data on the OT&E event that the AH-21 required. Thankfully, the lead engineer was able to highlight specific programs within the data set that were most analogous to the scope and scale of the tests AH-21 would undergo. Tim would utilize this information in his EMD To-Go estimate.

Before departing, Eduardo, Tamara, and Jasmine discussed specific agenda items to bring up during their upcoming visit to Vandalay. The SPO was coordinating their meetings with a Vandalay program manager named Reggie, but the three cost team leads were collaborating on a single agenda of discussion topics. Many of the topics overlapped with the items that they had just discussed regarding engagement and coordination with Incom and technical interfaces.

Reviewing Acquisition Documents

True to his word, the AH-21 acquisition lead sent Ava copies of the Acquisition Strategy, SEP, and Test and Evaluation Master Plan (TEMP). He also included a copy of the EMD proposal and Vandalay's associated pricing model, alongside a backup workbook that Vandalay provided monthly with their Contract Performance Report (CPR). This internal working document was not technically in the Contract Data Requirements List (CDRL), but the company provided it to the SPO in order to track progress at a lower-level than the CWBS utilized within the CPR. The workbook tracked progress by cost account and work package, related to Vandalay's internal accounting system and standard cost breakdowns. Often contractors' accounting systems tracked work at a far more granular level than the MIL-STD 881 breakdowns, and they organized their structure by both work processes and who accomplished it. While common CWBS structures (tied to MIL-STD 881) were largely product-oriented (i.e., what the work would produce), the internal working document offered ways to track how that work was accomplished (i.e., the aggregation of many processes within "cost center" locations or teams) and who was accomplishing the associated work. The "who" aspect inherent within Vandalay's accounting system tied to the labor pool categories that Ava had observed within the FPRA. Ava was surprised at how much detail was available to substantiate the CPR data she had been reviewing. She noted that the same workbook (labeled as the final report for AH-51) had been included as the starting point for the AH-21 EMD proposal (in the supporting files for their labor estimate), lending credit to her rationale that AH-51 could be an appropriate analogous system in her estimate.

Jasmine's explanations made it much easier to make sense of both the EMD proposal and its relationship to the CWBS within the CPR and 1921 CWBS. However, the backup details were highly complex. Even after using pivot tables to try to organize and make sense of the labor pool and cost center information, Ava had some questions about how the puzzle of who, how, and what, came together. For example, why were some functions labeled "quality" allocated to the Systems Engineering portion of the CWBS rollup while others were spread into the Avionics and Mission System CWBS values? If Vandalay's overhead rates captured indirect costs, including the "cost of doing business," then why did some of the cost centers mapped to Program Management seem to be business-related? (Ava suspected that the nuances of "below-the-line" elements might explain this.) Ava took notes on these seemingly inconsistent aspects of the CPR backup files and asked Jasmine to add a discussion on cost accounting to their agenda for the Vandalay visit.

Comparing Data Sources

One final question nagged Ava: If there was that much detail and nuanced information behind the monthly EVM values she had been reviewing, what detail did the annual reports like the 1921s and SARs she had collected contain? Thankfully, an opportunity soon presented itself to talk with Jasmine about this. A ten-minute stop by Ava's desk to check-in turned into an hour-long discussion on various aspects of cost data and why it was important to understand key aspects of the programmatic, schedule, and performance changes that might have occurred between particular points in time. Jasmine assured Ava that the multitude of non-recurring issue resolution and re-planning details of program execution that were buried within her 1921 and SAR reports did not render them completely useless. At a high level, each type of report offered a different insight into the program costs, and each report type had some specific limitations. They began mapping out some of the pros and cons of the primary three reports that Ava had collected and reviewed (**Figure 37**). Jasmine explained to Ava that it was important to consider the value added by each report relative to the cost estimating methodologies they might be used to support. Ava internalized this concept and considered the high-level breakdown they had already created. Within her Vandalay Production estimate, the most important cost contributors required estimation of total labor hours, the anticipated learning curve, and direct materials. She began to consider how to utilize the EMD proposal, the EDM 2 EVM data, and Vexis and AH-51 reports to fill in her estimating structure.

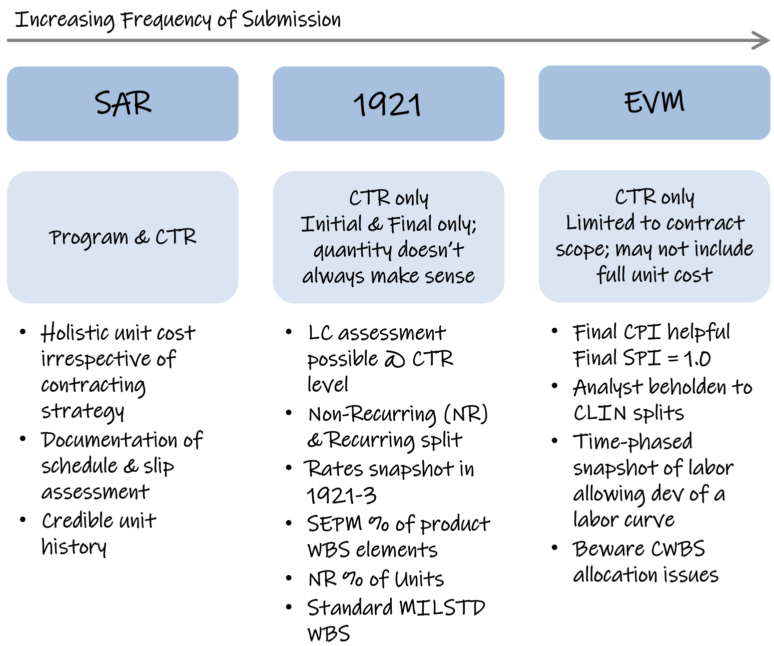


Figure 37: Comparison of Cost Data Sources

Vandalay Site Visit

Finally, the week of their site visit had arrived, and the team flew to the Vandalay production facility. As expected, Vandalay held several days of meetings to discuss their perspective on the AH-21 work split with Incom, the new production line for the aircraft modifications, and how EDM 2 work was progressing. They had aligned their visit with one of the EDM 2 test events, which gave Ava better insight into the ST&E activities she had read about in the program TEMP and allowed her to finally see the physical aircraft. As Jasmine had requested, the Vandalay program manager had set up a special breakout meeting with some of their cost reporting leads. During the meeting, Ava was able to gain valuable insights on the accounting system, and several cost account managers even joined them in order to relate specific performance topics to Ava's questions about the EMD proposal and CPR. Later in the week, Reggie took them on a tour of their engineering and production facilities; throughout the production tour he pointed out minor modifications and new tooling requirements added to their pre-existing production line. As they walked the line, he explained the non-recurring issues that they had resolved thus far during the EDM 1 and EDM 2 modification and pointed out new security protocols in place to accommodate the AH-21 product line. Finally, he showed them the storage facility intended to house the Incom aircraft after GFE delivery and walked them through Vandalay's procedures for operational testing upon receipt. Ava had never seen a helicopter at ground level, much less envisioned a facility where manufacturers assembled these giant birds. The cleanliness and intricate attention to detail amazed her; they had orchestrated every movement of the GFE aircraft from arrival and delivery receipt to facility departure. The production process influenced every piece of equipment and the layout of the overall facility to optimize movement and efficiency.

Ava was extremely grateful for the opportunity to see the AH-21 EDM units and Reggie's tour of Vandalay's production/modification facility. Having seen the product and the manufacturing process, Ava found it so much easier to envision the nuances of the contract performance data and technical descriptions that she had reviewed over the last several months. The icing on the cake was touring the facility alongside the SPO team. During the trip, Ava had gotten to know Tamara, the SPO cost estimator, more informally. They had shaken hands and spoken briefly during the CIPT / ICE Kickoff meeting, but the trip had given them a chance to confer on the EDM units and performance data, challenges to the program, and data limitations associated with such a unique program.

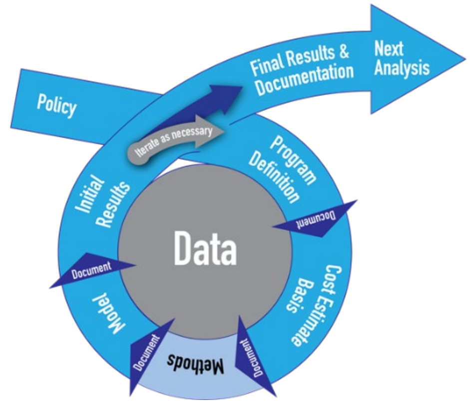
Ava really appreciated the insights that Tamara had shared. She had joined Jasmine and Ava for the breakout meeting regarding accounting data, and it sounded like she had experience working through some of the CWBS mapping details that had challenged Ava. Beyond discussions with the Vandalay team, Tamara had been able and willing to explain the Contract Line Item Number (CLIN) structure captured within the CPR reports. Tamara described how EDM 2 was on a separate CLIN from EDM 1, but Vandalay had charged some of the shared impacts of retooling as non-recurring engineering on CLIN 1 only. Tamara had worked through some of the overhead and indirect allocations specific to Vandalay's accounting system (e.g., indirect business labor expenses captured within the overhead rates; quality assurance functions spread across the product portion of the CWBS vice those reported in Systems Engineering) and highlighted the nuances specific to SEPM and ST&E values in the CPR. These were items that she was mindful of when comparing below-the-line elements between cost data for Vandalay and other contractors. Lastly, because Tamara knew the AH-21 lead engineer so well, she arranged for the lead engineer to hang back with Jasmine and Ava at certain points during the tour; he pointed out two minor areas of the production process causing a difference between the current Estimate at Completion (EAC) reported in Vandalay's CPR and the SPO's in-house EAC.

Ava paused throughout their facilities tour to take detailed notes on all that she was hearing – from both Reggie and the SPO engineering lead. She looked forward to reviewing her notes and comparing the specifics of the CPR data in order to validate some of the non-recurring issues that Reggie's team had mentioned. Before returning home, Ava and Tim agreed to collaborate on the EDM 2 EAC and CPR data. Tim had been carefully considering the interface of his EMD estimate (sunk cost data and the to-go estimate) with Ava's Production estimate, which made him the perfect person to consult with about the production details and non-recurring issues affecting the EDM 2 EAC, which should ultimately impact the first unit costs (or T1) of Ava's Production estimate.

Critical Thinking Questions – Identify, Collect, Validate, Normalize, and Analyze Data

- What is good, or defendable, data? Who gets to decide that?
- How can gaps in CSDR data be handled?
- Were there any Over Target Baseline (OTBs) or Over Target Schedule (OTSs) in the EVM data?
- What type of contract (FFP, CPFF) were used across your data sources? What are the different considerations that accompany each different contract type?
- Is my data representative of cost or price? Why does it matter?
- Where the reference programs competitive procurements or sole-sourced? Why does it matter?
- Are you able to map between Contractor WBS and the MIL-STD 881?
- Were there any major modifications to the Contractor's Accounting System within CWBS items between contracts, but in support of the same program?
- What industrial base considerations are important? Have there been any major contractor consolidations that are relevant to the data being used?

Methods – Select Cost/Schedule Estimating Methods



Back in the office, Ava reflected on her trip and all that she had learned and accomplished over the last few weeks. Her new firsthand experience walking the Vandalay production line and seeing EDM aircraft was invigorating. She had examined so many of her data sources, explored the lower level details of Vandalay's own EMD cost estimate, and now she understood better than before how the entire AH-21 program would be coming together, literally, after the benefit of their site visit.

Translating Data into Planned Estimating Methods

In just a few months, she had gone from a limited understanding of the AH-21 program and a high-level estimating plan to feeling fairly knowledgeable and swimming in data. Her thoughts returned to her data sources and the team's upcoming review with Jay. After her last discussion on data with Jasmine, she had begun to align different data sources to the matrix of cost contributors that she and Jasmine created (**Table 20**). Ahead of the meeting with Jay, she needed to update her working-level documentation with their data sources and add some details about how she planned to utilize them developing her estimate. Ultimately, she would probably need to take a break from estimate development in order to prepare additional slides for that review, but for now, Ava decided to continue organizing her thoughts within the same working level WBS table that she and Jasmine had created. She began with the GFE portion (**Table 22**). Since the Army would provide the entirety of their GFE estimate based on the Army POE estimating results, Ava was able to roll up her data and methodology notes onto the Level 1 Aircraft row of the WBS. Alongside the WBS and data sources, Ava listed her plans for estimating methodology and a crosscheck that might be helpful in determining whether the primary methodology was realistic.

Next to this, she added several notes adding detail to her original cost estimate plan. Alongside her original note on coordination with the SPO lead cost estimator, Ava needed to integrate the Army POE results table within their AH-21 cost model and hopefully validate their delivery schedule assumptions using the AH-65E new build CPR data.

Table 22: GFE Estimating Methodology

WBS		GFE Incom	GFE - Incom Data Sources	Primary Method	Crosscheck
1.0	Aircraft System	Throughput	AH-65E Army POE AH-65E Incom CPRs AH-65D CSDRs AH-65E CSDRs AH-65E SARs	Throughput and integration of Army POE results for AH-65E units delivering to USAF	AH-65D FRP unit costs AH-65E New Build unit costs

Continuing on to the Vandalay modification portion of her estimate, Ava realized that she had overlooked one of the smaller below-the-line WBS elements for Training. She also struggled to come up with a crosscheck method for the specific set of aircraft modifications captured in WBS 1.1, 1.2.5, and 1.3. This was the Air Force's first attack helicopter, and they had never procured any helo program this way (by essentially splitting off from an existing production line and transferring the aircraft as GFE to a different, specialized primary contractor). Ava decided to highlight these areas of her table (**Table 23**) for discussion during the next weekly meeting with Jasmine and the estimating team.

As she began to add details to her estimating plan for the Vandalay contract costs, she realized that her notes read almost like a to-do list. Much of the time that she had spent to normalize and understand lower level details during data collection efforts had either positioned her well to complete this or allowed her to mark some items as already complete.

Table 23: Vandalay Production Estimating Methodology

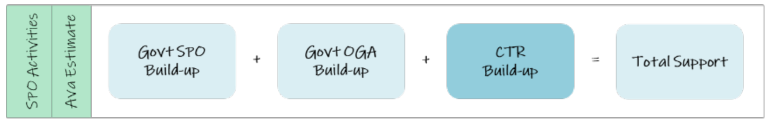
WBS		Vandalay	Vandalay Data Sources	Primary Method	Crosscheck
1.0	Aircraft System	Buildup		Subtotal of Level 2 (& 3)	
1.1	Aircraft System, Integration, Assembly, Test, and Checkout	X	Vandalay EMD Proposal EMD CPRs Vandalay FRPA Vandalay AH-51 CCDRs	Labor Buildup = (Proposal x EDM CLIN 2 EAC x EDM Step-Down) x (LC Adj) x Labor Rate Material Buildup = Proposal BoM	*No analogous program for comparison*
1.2.5	Avionics	X			
1.3	Payload/Mission System	X			
1.6	Systems Engineering	X	Vandalay EMD Proposal EMD CPRs Vandalay FRPA Vandalay AH-51 CCDRs	Labor = Factor of Σ (WBS 1.1, 1.2.5, and 1.3) (AH-51 1921) Material = Factor of Σ (WBS 1.1, 1.2.5, and 1.3) (AH-51 1921)	Comparable factors of Σ (WBS 1.1, 1.2.5, and 1.3) (AH-65D & AH-65E 1921s)
1.7	Program Management	X			
1.8	System Test and Evaluation	X			
1.9	Training	Buildup		Subtotal of Level 3	
1.9.1	Equipment	n/a	n/a	n/a	n/a
1.9.2	Services	X	*No Training scope included in EMD proposal or CPRs*	*Same as SE, PM and ST&E ?*	

She completed her methodology preparation by adding planned methodologies to the SPO management and support costs portion of her workbook (**Table 24)**. Ava added it to the matrix now and updated highlighting associated with a few areas where she still lacked data or a method for crosschecking her estimate.

Table 24: SPO Estimating Methodology

WBS - SPO		Applicable Cost?	SPO Data Sources	Primary Method	Crosscheck
2.0	System Program Office (SPO)	Buildup		Subtotal of Level 2	
2.1	Government Pay	Buildup		Subtotal of Level 3	
2.1.1	Military Personnel	Buildup		Subtotal of Level 4	
2.1.1.1	Systems Engineering	X	CARD table FTEs by Grade Military Basic Pay rates Military Composite rates	(CARD table FTEs allocation) x Military DoD Composite Rate by Grade	*FY2021 manning from BFM*
2.1.1.2	Program Management	X			
2.1.1.3	Test & Evaluation	X			
2.1.2	Civilian Personnel	Buildup		Subtotal of Level 4	
2.1.2.1	Systems Engineering	X	CARD table FTEs by GS scale GS labor rates	(CARD table FTEs allocation) x GS rates x Civilian Fringe Benefit Factor	*FY2021 manning from BFM*
2.1.2.2	Program Management	X			
2.1.2.3	Test & Evaluation	X			
2.1.3	Other Govt Agencies (OGA)	Buildup		Subtotal of Level 4	
2.1.3.1	Systems Engineering	X	CARD table FTEs by GS scale GS labor rates	(CARD table FTEs allocation) x GS rates x Civilian Fringe Benefit Factor	
2.1.3.2	Test & Evaluation	X	OT&E independent agency test	Average of analogous OT&E events	
2.1.4	Travel	X	*Request current year requirements from BFM*	Extrapolate Current Year Requirements	
2.2	Contractor Support	Buildup		Subtotal of Level 3	
2.2.1	Program Management Administration (PMA)	Buildup		Subtotal of Level 4	
2.2.1.1	Fed. Funded Research & Dev Center (FFRDC)	n/a	n/a	n/a	n/a
2.2.1.2	Advisory and Assistance Services (A&AS)	Buildup			
2.2.1.2.1	Professional Services Schedule (PSS)	X	CARD table FTEs SPO FTE allocation (PSS) CTR rates by contract	(CARD table FTEs allocation) x CTR rates	*FY2021 manning from BFM*
2.2.1.2.2	Systems Engineering and Technical Assistance (SETA)	X	CARD table FTEs SPO FTE allocation (SETA) CTR rates by contract	(CARD table FTEs allocation) x CTR rates	*FY2021 manning from BFM*
2.2.2	Travel		*Request current year requirements from BFM*	*Review Other Direct Charges (ODCs) by contract*	

Developing SPO Estimating Methods



During their trip to Vandalay, Ava had spoken to the SPO's acquisition lead about the CARD manpower tables and requested both a lower-level allocation of their SPO contractor personnel and current rate information for their contracts. From research in the MS B cost model, she knew that all or most of the SPO's contractor personnel worked under contracts categorized as Advisory & Assistance Services (A&AS). (The CACEG SPO did not require any support from Federally Funded Research & Development Centers (FFRDC) personnel during the Production phase, although the SPO had utilized this support during TMRR.) Within the MS B model, Ava found the A&AS type contractors subdivided into Professional Services Schedule (PSS) and Systems Engineering and Technical Assistance (SETA) contracts and functional areas (e.g., Program Management and Logistics support). She could see that this breakdown would allow her to better align SPO contractor costs with specific WBS elements from the SPO portion in the MS C model; it would also allow for a more granular estimate if she could also obtain current rate information for those A&AS contracts. After their trip to Vandalay, the Business Financial Management (BFM) analyst had followed up to provide both the rates and manning budgeted for FY2021; **Table 25** shows these organized by functional area. The FTE counts would be helpful in validating the steady-state manning that the SPO had included through FRP within the Manpower CARD table. (The acquisition lead had apparently not taken the action to provide the ASCAA team with an equivalent breakdown of their CARD total contractor FTEs, so Ava had added the request to their CRM for the CARD. She hoped to receive the information at some point prior to the final CARD delivery.) As she began her analysis of SPO contractor labor costs, Ava paused to reach out to the BFM analyst again in order to request information on the SPO personnel recent travel activities, which she had overlooked in her initial programmatic data requests.

Table 25: FY2021 Vandalay SPO Manning Plan

SPO FY2021 CTR Manning		FTEs	Avg Rate (TY$K)
PSS	Acquisition	10.0	$ 161.9
PSS	BFM - Finance	2.5	$ 127.2
PSS	Contracts Support	3.0	$ 200.8
PSS	Program Management	10.0	$ 187.5
SETA	Cyber Awareness	5.5	$ 166.7
SETA	Engineering	1.5	$ 186.0
SETA	Configuration Mgmt	5.5	$ 154.5
SETA	Logistics	4.0	$ 186.8
	Total	*42.0*	

With her newly available PSS and SETA contract data, Ava created a working file to house her SPO contract labor build-up estimate. She took note that the rates provided by the BFM for the relevant contractor staff were labeled as proprietary data (since the rates came out of their current contract proposals); she followed suite to annotate her own workbook with a similar note. Comparing the rates year-over-year, Ava observed approximately 2% inflation applied each year (**Table 26**). She assumed that the rates reflected FY2019 rate assumptions (or calculations) for the first year of contract execution; the three contractor teams had likely inflated that assumption at exactly 2%.

Next, Ava prepared a comparison of the FY2021 proposed rates against the **Table 25** executed rates (**Table 27**). She found that some of the personnel categories (like Contracts Support) had increased quite a bit according to the BFM's execution rates. Others showed small increases of 0-3%, and one was even slightly lower in execution relative to the proposed rate. Tim was able to explain that the SPO had probably ramped up staffing of more experienced contracting support personnel during development of their Request for Proposal (RFP) from Vandalay. He explained that Ava should expect some deviation relative to the proposal rates. She could hope that the SPO would actually execute with a similar skill mix relative to their initial proposals (and corresponding similar average rates per functional area), but it was not uncommon for any SPO to deviate from their plans once programs were in the heat of battle awarding (and managing) industry contracts.

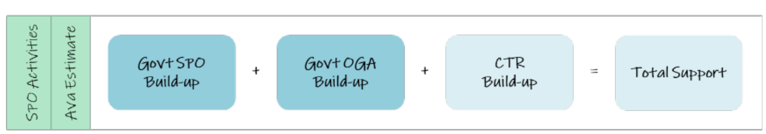
Table 26: SPO Contract Proposal Rates FY2019 to FY2023 (TY$K)

SPO Contract Proposal Rates (TY$K)		2019	2020	2021	2022	2023
Contract A						
PSS	Acquisition Support	$ 147.3	$ 150.3	$ 153.3	$ 156.4	$ 159.5
PSS	BFM - Finance	$ 124.5	$ 127.0	$ 129.5	$ 132.1	$ 134.7
PSS	Contracts Support	$ 176.8	$ 180.3	$ 183.9	$ 187.6	$ 191.3
PSS	Program Management	$ 177.5	$ 181.1	$ 184.7	$ 188.4	$ 192.2
Contract B						
SETA	Cyber Awareness	$ 159.3	$ 162.5	$ 165.7	$ 169.0	$ 172.4
SETA	Engineering	$ 170.4	$ 173.8	$ 177.3	$ 180.8	$ 184.5
Contract C						
SETA	Configuration Mgmt	$ 144.1	$ 147.0	$ 149.9	$ 152.9	$ 156.0
SETA	Logistics	$ 175.1	$ 178.6	$ 182.2	$ 185.8	$ 189.6
	Average Annual Escalation		*2.0%*	*2.0%*	*2.0%*	*2.0%*

Table 27: FY2021 SPO Labor Rate Comparison (TY$K)

SPO FY2021 Rates (TY$K)		FY2021 Execution	FY2021 Proposal	% Inc from Proposal
PSS	Acquisition	$ 161.9	$ 153.3	5.6%
PSS	BFM - Finance	$ 127.2	$ 129.5	-1.8%
PSS	Contracts	$ 200.8	$ 183.9	9.2%
PSS	Programmatic Supt	$ 187.5	$ 184.7	1.5%
SETA	Cyber Awareness	$ 166.7	$ 165.7	0.6%
SETA	Engineering	$ 186.0	$ 177.3	4.9%
SETA	Configuration Mgt	$ 154.5	$ 149.9	3.1%
SETA	Logistics	$ 186.8	$ 182.2	2.5%

Ava noted that each contract ended in a few years' time, so it seemed more likely that the skill mix embedded within the SPO's execution rates was closer to reality over the next few years of Production than their corresponding rates from the proposals. She decided to maintain the FY2021 average execution rates (for each contract and functional area) and extrapolated these out to the end of the Production period. Tim affirmed Ava's decision and agreed that the SPO's current rates likely served as the better reflection of near-term SPO needs, as far as contractor skill mix and average labor rates were concerned. However, outside the build-up of labor costs, she calculated and saved the recent percent deviation by functional area for reference. Finally, Ava combined her selected rates with a placeholder for the lower-level FTE counts missing within the current draft CARD. For the time being she substituted the FY2021 execution counts for each fiscal year within the Production estimate and added a subtotal to capture total labor costs for each fiscal year.



Moving on to her build-ups for SPO personnel and Other Government Agencies (OGA), Ava utilized a similar format to the contractor build-up she had just created for contract support labor. During review and comment resolution of the CARD, Ava had asked Jasmine about the OGA FTEs and why they were broken out separately from the other Program Office Civilian FTEs within the CARD tables. Jasmine explained that unlike the Military and

Program Office FTEs, these OGA personnel were personnel matrixed (or "loaned") to the program office specifically to support the AH-21 CACEG program. They were typically specialized Air Force acquisition workforce personnel who were able to move between programs and assist in milestone preparation where the need was the greatest. Their home organization required reimbursement of associated labor (and travel) costs by the CACEG SPO. Within her build-up, Ava was careful to separate the OGA labor cost build-up from the corresponding build-up for SPO Military and SPO Civilians.

Based on further conversation with Tim, she utilized the average of each GS pay grade's multi-step scale (**Table 28**), and she noted this assumption within her workbook. During this follow-up, Tim warned her to be sure to apply the civilian personnel fringe benefit rate so that her labor estimate reflected the fully-burdened cost of labor. This confused Ava; even as a relatively new DoD civilian employee, she was familiar with the GS pay tables, but no one had mentioned any additional compensation rate (beyond the pay scale) during her hiring process. Tim explained further that the fringe benefit rate reflected the GS equivalent of the contractor billing rates that she had received from the BFM. (Contractor salary did not reflect the full amount of the rates the BFM had provided Ava; in reality, their salary was only a portion of the rate billed to the SPO contract.) The civilian fringe benefit rate covered additional costs associated with DoD civilian employee benefits like health insurance and educational assistance, plus additional burdens to cover additional costs like retirement benefits. In a quick internet search, Tim helped her to find DoD Comptroller's guidance memo for FY2021, and together they pulled the appropriate Civilian Fringe Benefit USAF personnel with "billings to other DoD Components and Federal agencies."

Just as Tim had instructed, Ava carefully applied the appropriate locality multiplier to burden these average direct rates from the GS pay tables, then she applied the civilian fringe benefit rate to calculate fully-burdened labor rates by GS grade (**Table 28**).

Table 28: CY2021 GS Labor Rates

GS Grade	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Avg	Avg + Locality (19.18%)	Avg + Locality + Fringe (32.8%)
GS-7	$ 37,674	$ 38,930	$ 40,186	$ 41,442	$ 42,698	$ 43,954	$ 45,210	$ 46,466	$ 47,722	$ 48,978	$ 43,326	$ 51,636	$ 68,573
GS-8	$ 41,723	$ 43,114	$ 44,505	$ 45,896	$ 47,287	$ 48,678	$ 50,069	$ 51,460	$ 52,851	$ 54,242	$ 47,983	$ 57,186	$ 75,942
GS-9	$ 46,083	$ 47,619	$ 49,155	$ 50,691	$ 52,227	$ 53,763	$ 55,299	$ 56,835	$ 58,371	$ 59,907	$ 52,995	$ 63,159	$ 83,876
GS-10	$ 50,748	$ 52,440	$ 54,132	$ 55,824	$ 57,516	$ 59,208	$ 60,900	$ 62,592	$ 64,284	$ 65,976	$ 58,362	$ 69,556	$ 92,370
GS-11	$ 55,756	$ 57,615	$ 59,474	$ 61,333	$ 63,192	$ 65,051	$ 66,910	$ 68,769	$ 70,628	$ 72,487	$ 64,122	$ 76,420	$ 101,486
GS-12	$ 66,829	$ 69,057	$ 71,285	$ 73,513	$ 75,741	$ 77,969	$ 80,197	$ 82,425	$ 84,653	$ 86,881	$ 76,855	$ 91,596	$ 121,639
GS-13	$ 79,468	$ 82,117	$ 84,766	$ 87,415	$ 90,064	$ 92,713	$ 95,362	$ 98,011	$ 100,660	$ 103,309	$ 91,389	$ 108,917	$ 144,642
GS-14	$ 93,907	$ 97,037	$ 100,167	$ 103,297	$ 106,427	$ 109,557	$ 112,687	$ 115,817	$ 118,947	$ 122,077	$ 107,992	$ 128,705	$ 170,920
GS-15	$ 110,460	$ 114,142	$ 117,824	$ 121,506	$ 125,188	$ 128,870	$ 132,552	$ 136,234	$ 139,916	$ 143,598	$ 127,029	$ 151,393	$ 201,050

Ava then applied the fully-burdened rates to the appropriate OGA and SPO civilian FTE counts from the CARD table in order to calculate her labor costs by fiscal year (**Table 29**).

Shortly after Ava had finished creating her manpower labor build-up, the BFM responded to her request for travel expenditure data, so Ava incorporated a travel estimate within the same workbook. Based on her meeting with the acquisition lead and discussion during the team's site visit to Vandalay, Ava knew that the SPO team had been traveling to Vandalay for quarterly progress reviews during EMD 1 and 2 production. Both the contractor and government teams had indicated that these quarterly meetings would continue as they progressed into LRIP and FRP. Therefore, she converted both the FY2019 and FY2020 expenditure data to the model base year, calculated the average, and applied it across all fiscal years of the Production schedule (FY2022-28).

Table 29: SPO Labor Cost Build-Up (FY2022-26)

SPO Cat	Grade	Avg + Locality + Fringe	FTEs by FY					Fully Burdened Labor Cost (CY2021 $K)				
			2022	2023	2024	2025	2026	2022	2023	2024	2025	2026
SPO Civilian	GS-15	$ 201,050	2.00	2.00	2.00	2.00	2.00	$ 303	$ 303	$ 303	$ 303	$ 303
	GS-14	$ 170,920	20.00	20.00	20.00	20.00	20.00	$ 2,574	$ 2,574	$ 2,574	$ 2,574	$ 2,574
	GS-13	$ 144,642	30.00	30.00	30.00	30.00	30.00	$ 3,268	$ 3,268	$ 3,268	$ 3,268	$ 3,268
	GS-11	$ 121,639	40.00	40.00	40.00	40.00	40.00	$ 3,664	$ 3,664	$ 3,664	$ 3,664	$ 3,664
	GS-9	$ 92,370	20.00	13.33	13.33	13.33	13.33	$ 1,391	$ 927	$ 927	$ 927	$ 927
	GS-7	$ 68,573	13.33	6.67	6.67	6.67	6.67	$ 688	$ 344	$ 344	$ 344	$ 344
	Total	**n/a**	**125.33**	**112.00**	**112.00**	**112.00**	**112.00**	**$ 11,888**	**$ 11,080**	**$ 11,080**	**$ 11,080**	**$ 11,080**
Other Govt Agencies	GS-15	$ 201,050	1.00	1.00	1.00	1.00	1.00	$ 151	$ 151	$ 151	$ 151	$ 151
	GS-14	$ 170,920	10.00	10.00	10.00	10.00	10.00	$ 1,287	$ 1,287	$ 1,287	$ 1,287	$ 1,287
	GS-13	$ 144,642	15.00	15.00	15.00	15.00	15.00	$ 1,634	$ 1,634	$ 1,634	$ 1,634	$ 1,634
	GS-11	$ 121,639	20.00	20.00	20.00	20.00	20.00	$ 1,832	$ 1,832	$ 1,832	$ 1,832	$ 1,832
	GS-9	$ 92,370	10.00	6.67	6.67	6.67	6.67	$ 696	$ 464	$ 464	$ 464	$ 464
	GS-7	$ 68,573	6.67	3.33	3.33	3.33	3.33	$ 344	$ 172	$ 172	$ 172	$ 172
	Total	**n/a**	**62.67**	**56.00**	**56.00**	**56.00**	**56.00**	**$ 5,944**	**$ 5,540**	**$ 5,540**	**$ 5,540**	**$ 5,540**

Ava worked through a nearly identical process in order to calculate the cost of SPO military personnel for Production. She utilized the FY2021 guidance memo for Military Composite Standard Pay and Reimbursement Rates (from the same DoD Comptroller website) to find the applicable Annual DoD Composite rates of Air Force personnel.

Begin Preparing for ASCAA Midterm Review

When Jasmine saw Ava's working plan at the weekly meeting, she was enthused. She encouraged Ava to use the same framework to prepare her slides for their midterm review with Jay and asked Tim and Liam to further develop their portions of the plan similarly. Ava translated her working tables into a few PowerPoint slides to integrate into the team's brief (**Figure 38**).

Ava turned her working slides over to Jasmine for configuration control and returned to her running to-do list, which so much of her slide content had been based upon. As she and Jasmine had noted, production labor was likely to be Ava's largest cost contributor to the Vandalay portion of the estimate (and second largest overall), so she decided to tackle as much of this portion of her to-do list as possible ahead of their midterm review with Jay, which was a little less than two weeks away on May 18th.

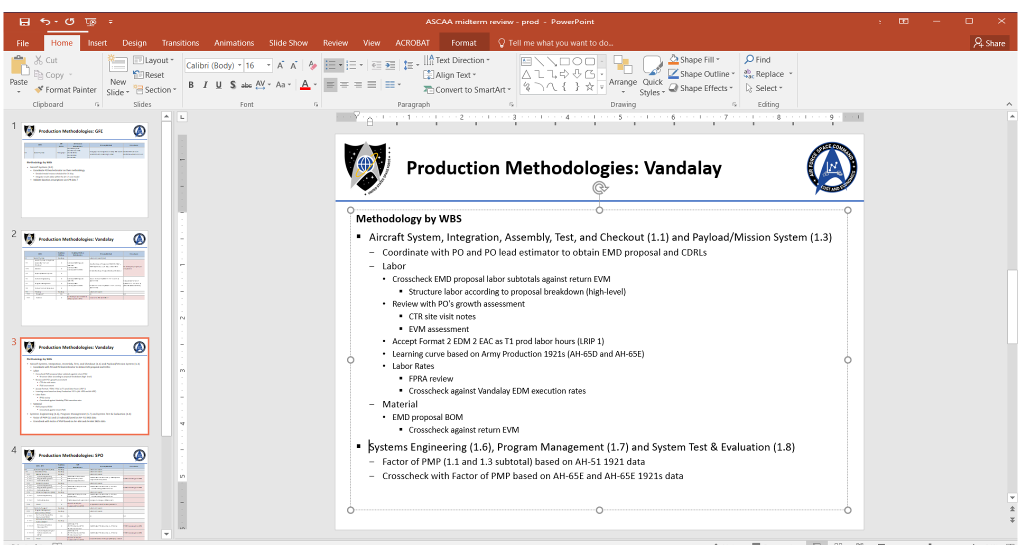
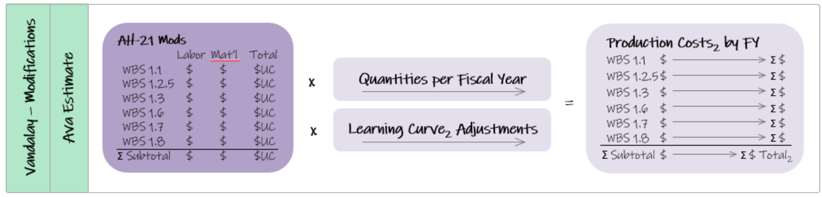


Figure 38: ASCAA Midterm Review Slides

Developing Vandalay Labor Hours Estimating Methods



Prior to their site visit to Vandalay, Ava had reviewed the EMD proposal carefully. During the trip, either the Vandalay team or Tamara had answered many of her outstanding questions on cost accounting nuances. She returned to the copy of the EMD labor build-up where she had previously highlighted questions and taken notes. Vandalay had submitted Excel workbooks as backup to their written proposal, and Ava had been grateful for the ease it afforded during her review and comparisons to the CWBS summaries within the most current EMD CPR. Looking back at her questions and the notes she had taken during their visit, Ava was able to reconcile her few outstanding questions about mapping and cost increases between the two files. Time with the SPO leadership and the Vandalay meetings had been very helpful in understanding the labor increases that she had observed within the EDM 2 CLIN labor EAC. Within her file, she highlighted the specific cost centers that Tamara and the AH-21 lead engineer had pointed out as sources of non-recurring issues during EDM 2 production. Like Ava, Tamara was planning to base her LRIP 1 production hours on the latest CPR labor hours EAC, but she had also shared her plans to reduce particular portions of the Avionics (WBS 1.2.5) and Mission Systems (WBS 1.3) data in order to account for these EDM 2 production issues. Ava understood Tamara's thought process, but she did not feel comfortable reducing her own EAC in the same way. Although Vandalay had already acted to correct the issues and did not intend to repeat them during LRIP or FRP, there would inevitably be other non-recurring issues and production hiccups during the Production & Deployment phase. Ava decided to hold off on making any adjustments, and she copied the lower-level proposal breakdown into a new worksheet; she aligned the proposal details according to the added CWBS subtotals each mapped to. Next to each CWBS Level 3 subtotal, she calculated the percentage increase between proposal value and the corresponding EAC value from the CPR. She then "peanut-butter spread" these percentages evenly amidst the lower level details – assuming that the Level 3 increases had adjusted each Level 4 element in equal proportion (**Figure 39**). Along the way, she again highlighted the specific cost accounts which Tamara planned to adjust, and she hoped that the notes might come in handy later when they reconciled their estimates.

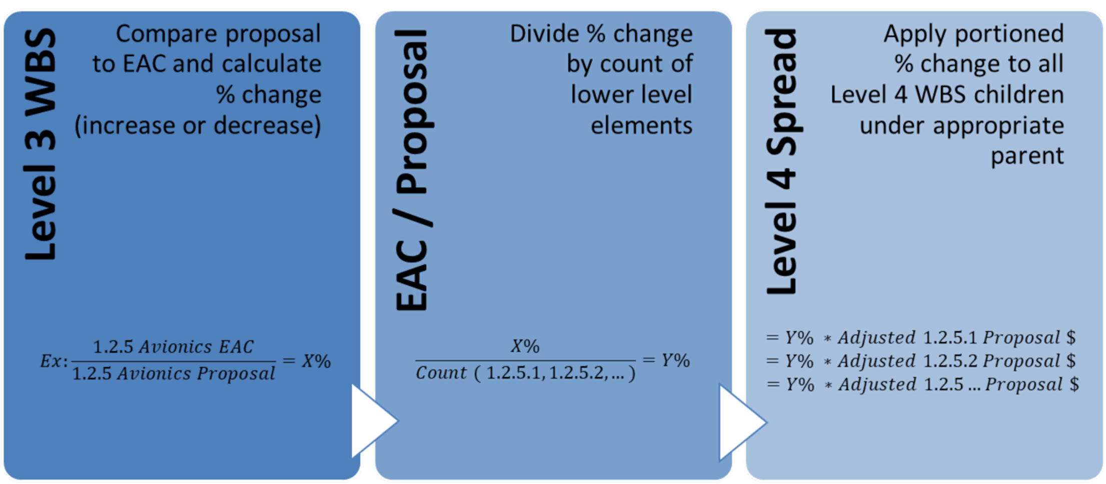
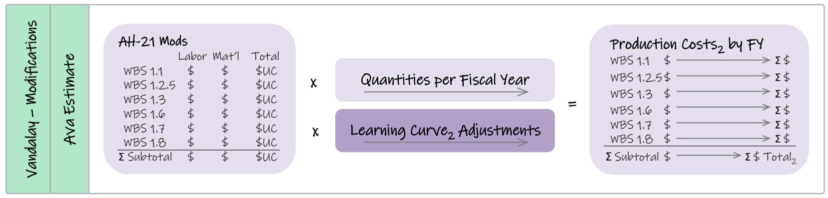


Figure 39: Proposal and CPR EAC Comparison



With her T1 labor hours estimate in hand, Ava turned her attention to the learning curve that she wanted to apply within her Production labor estimate. She had a copy of the CACEG MS B learning curve documentation to review (based upon AH-65D data), and Jasmine had sent her a few training resources from an internal ASCAA file and a Defense Acquisition University (DAU) course she had yet to review. The MS B learning curve was calculated using unit learning curve theory. This made sense to Ava when she read the backup documentation and more about the concept of a Lot Midpoint (LMP). Like the MS B estimating team, Ava would be relying on CCDR data from the 1921, which summarized total costs for a specific quantity, or lot, of production units. She knew that lot sizes often reflected the quantity purchased within a single fiscal year; however, the CACEG program had based lots sizes on the phases of Production (i.e., LRIP 1 & 2, FRP 1, FRP 2, and FRP 3). Within her CCDR data, the reports themselves clearly delineated between lots and recorded the associated quantities per lot. Even for lots procured on the same contract, Ava found that the manufacturers had provided separate 1921 and 1921-1 submissions for each respective lot.

Like the MS B analysis, Ava would apply unit learning curve theory to regress the Average Unit Cost (AUC) of each lot against the calculated LMP. She decided to use the same iterative LMP calculation employed within the MS B file, which began with a heuristic approximation based upon the count of first (F) and last (L) units of each lot.

$$LMP \approx \frac{F + L + 2\sqrt{FL}}{4}$$

Ava began with AH-65E and the "new build" report data she had for the first three lots. A separate 1921-1 submission for each lot contained detailed worksheets for each element of the CWBS; these detailed worksheets contained summary costs (for both the "cost incurred to date" and "costs incurred at completion") that aligned with each parent 1921 report. However, the 1921-1 detailed worksheets also offered labor hours associated with these costs. In a new workbook, Ava carefully aggregated 1921-1 reported labor hours associated with CWBS elements aligning to 1.2.5 Avionics and 1.3 Mission Systems. These WBS elements were the same subset that she and Jasmine had discussed before creating their matrix of cost contributors by contract (**Table 20**), which were applicable to Vandalay's particular work scope. By focusing on just these elements, Ava's learning curve analysis would capture trends in the source data that were most relevant to her Vandalay labor estimate.

Within her summary table (**Table 30**), Ava noted lot numbers and the quantity of units associated with the lot. She used the quantities per lot to convert her lot subtotal hours to an AUC for each of the three "new build" lots.

Table 30: AH-65E New Build Labor Hours by Lot (1921-1)

	1921-1 Data				
Lot #	Lot Qty	WBS 1.2.5 Avionics (Hrs)	WBS 1.3 Mission Sys (Hrs)	Lot Subtotal Cost (Hrs)	AUC (Hrs)
1	8	633	449	1,082	135
2	10	739	524	1,264	126
3	10	688	488	1,176	118

In two additional columns, she added the first unit (F) and last unit (L) of each lot. Using these and the LMP heuristic equation, Ava calculated an approximate lot midpoint for each of the three production lots (x_1) (**Table 31**). Finally, she transformed her data: taking the natural log of each AUC (ln(y)) and the natural log of each LMP value (ln(x)).

Table 31: Starting Data for AH-65E Learning Curve

	1921-1 Data					1 - LMP Heuristic		
Lot#	First Unit (F)	Last Unit (L)	Lot Qty (N)	Lot Subtotal Cost (Hrs)	AUC (Hrs)	LMP_1 Heuristic	$LN(LMP_1)$	LN(AUC)
1	1	8	8	1,082	135.2	3.7	1.30	4.91
2	9	18	10	1,264	126.4	13.1	2.57	4.84
3	19	28	10	1,176	117.6	23.3	3.15	4.77
					y	x_1	$ln(x_1)$	ln(y)

In **Figure 40**, Ava plotted her LMP values (x_1) against the AUC labor hours she had calculated. In the resulting "unit-space" graph, the traditional decreasing power function of the learning curve was clearly visible ($y = a \cdot x^b$). Plotting her log-space parameters (or ln(x) vs ln(y)), she observed a linear trend line ($y = a + b \cdot x$).

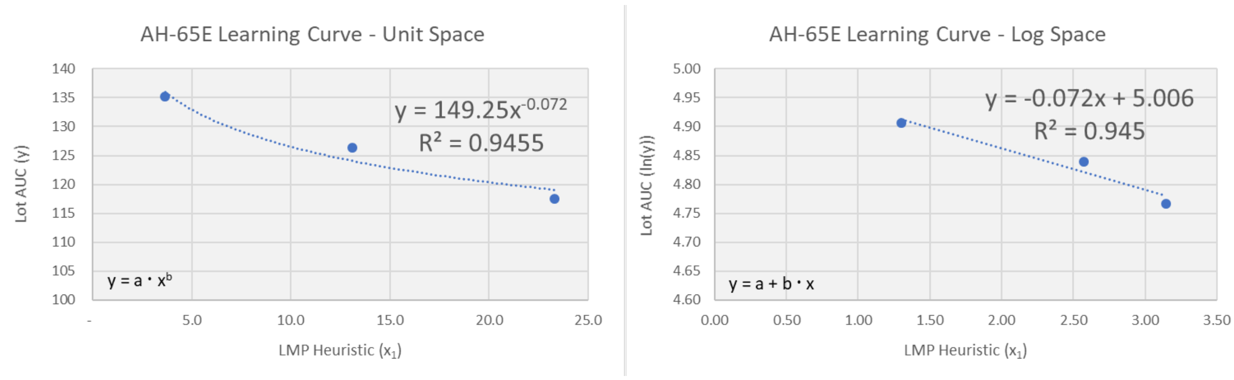


Figure 40: Learning Curve Plots for LMP Heuristic

The slope of the linear trend line reported a b-value that could be used as the learning curve exponent (LC slope = 2^b), while the y-intercept could be used to convert back to the T1 labor hour value (T1 = e^a). Ava was able to use simple Excel functions on the log-space data to calculate the slope and T1 value for her AH-65E data (**Figure 41**).

	A	B	C	D	E	F	G	H	I	J
1										
2			1921-1 Data					1 - LMP Heuristic		
3		Lot#	First Unit (F)	Last Unit (L)	Lot Qty (N)	Lot Subtotal Cost (Hrs)	AUC (Hrs)	LMP_1 Heuristic	$LN(LMP_1)$	LN(AUC)
4		1	1	8	8	1,082	135.2	3.7	1.30	4.91
5		2	9	18	10	1,264	126.4	13.1	2.57	4.84
6		3	19	28	10	1,176	117.6	23.3	3.15	4.77
7							y	x_1	$ln(x_1)$	ln(y)
8										
9								Heuristic		
10								LMP		
11							*b =*	(0.0718)	*= SLOPE(J4:J6, I4:I6)*	
12							*a =*	5.0056	*= INTERCEPT(J4:J6, I4:I6)*	
13							*LC slope*	0.9515	*= 2 ^ b*	
14							*T1*	149.3	*= EXP(a)*	

Figure 41: Calculations for Learning Curve Slope and T1 Values

Next, Ava used the b-value from this first regression to compute more accurate LMP values.

$$LMP = \left[\frac{1}{N} \cdot \sum_{i=F}^{L} i^{b}\right]^{(1/b)}$$

After rerunning the regression again (using her original AUC data and new LMP values), Ava obtained the final learning curve slope for her AH-64E new build data (**Figure 42**). Her T1 and slope values changed just slightly after increasing the accuracy of the LMP values. For the AH-65E LRIP lots, Ava calculated a final learning curve of 95.1%.

Repeating the same process for the six production lots of Vandalay's AH-51 program, Ava calculated a learning curve of 93.4%. Finally, she checked to ensure that her CSDR data for AH-65D, previously pulled from CADE, matched the labor data values used within the MS B calculations. As expected, her dataset accurately reflected the original AH-65D lot subtotals used at MS B, plus the final few lots produced after the MS B analysis. She proceeded to repeat her previous learning curve process a third time using the updated AH-65D lot subtotals (again corresponding to WBS elements 1.2.5 and 1.3) and added the

	1921-1 Data					1 - LMP Heuristic			2 - LMP Calculation		
Lot#	First Unit (F)	Last Unit (L)	Lot Qty (N)	Lot Subtotal Cost (Hrs)	AUC (Hrs)	LMP_1 Heuristic	$LN(LMP_1)$	LN(AUC)	LMP_2	$LN(LMP_2)$	LN(AUC)
1	1	8	8	1,082	135.2	3.66	1.30	4.91	3.71	1.31	4.91
2	9	18	10	1,264	126.4	13.11	2.57	4.84	13.16	2.58	4.84
3	19	28	10	1,176	117.6	23.28	3.15	4.77	23.31	3.15	4.77
					y	x_1	$\ln(x_1)$	$\ln(y)$	x_2	$\ln(x_2)$	$\ln(y)$

	Heuristic LMP_1	Actual LMP_2
b =	(0.0718)	(0.0722)
a =	5.0056	5.0070
LC slope	0.9515	0.9512
T1	149.3	149.5

Figure 42: Iteration for Final Learning Curve Slope and T1 Values

final few lots produced after their MS B analysis. This yielded a 90.6% learning curve. Next, Ava normalized these curves for comparison (**Figure 43**); she added bands for individual production lots to highlight the learning curves' differences across respective periods of the Production schedule. Due to its representation of a historical Vandalay product line, Ava selected the AH-51 learning curve for use within her Production labor estimate.

Within Ava's T1 calculation workbook, she saved a copy of her normalized AH-51 production learning curve factors. She applied each normalized factor to the corresponding procurement units, phased by fiscal year according to the Vandalay portion of the quantities table within the CARD (**Table 15**).

Finally, Ava returned to the EVM-based labor phasing crosscheck she had seen at the peer review of her colleague's estimate. She reviewed the AH-21 monthly CPR labor hours for both EDM 1 and EDM 2 in order to plot monthly progress of EVM metrics (i.e., Budgeted Cost of Work Scheduled (BCWS) and Performed (BCWP), Actual Cost of Work Performed (ACWP), Budget at Completion (BAC), and EAC). Afterwards, she confirmed that the MS B phasing assumptions for Production labor, a beta curve assuming 60% of expenditures by the halfway point of a fourteen month schedule, were still reasonable. Using the EVM "Gold Card" metrics for Percent Complete, or cumulative BCWP divided by BAC, her EVM metric plots actually showed that Vandalay completed approximately 56% of their planned labor hours by the halfway point of EDM 1 production and 61% of their plan by the halfway point of EDM 2 production. She annotated her crosscheck calculations of the beta curve with the same source documentation from MS B. Finally, Ava phased each fiscal year quantity according to the beta curve assumption and turned her attention to labor rates.

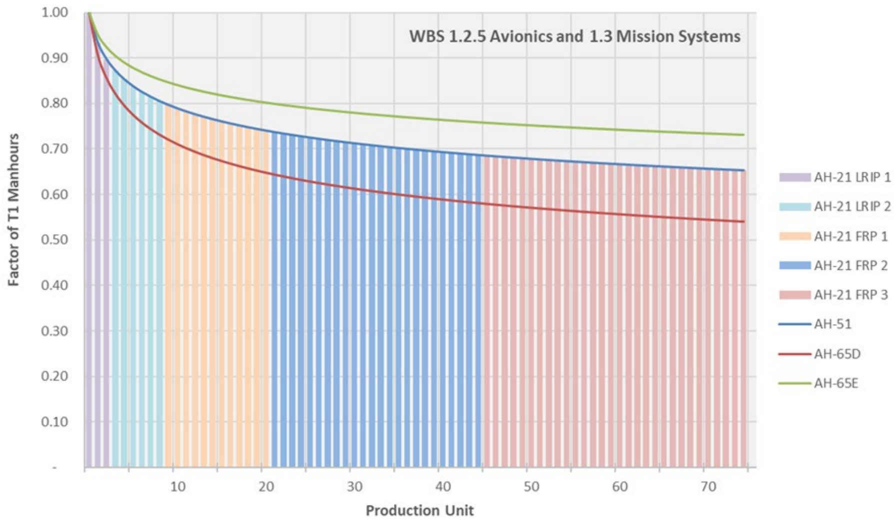
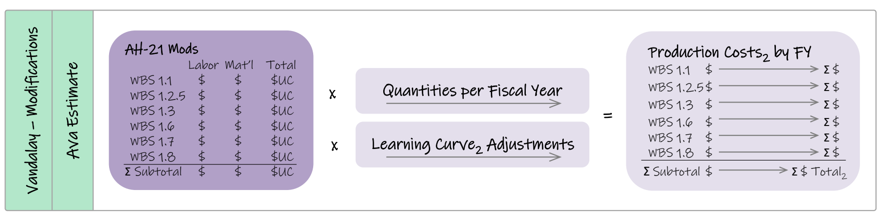


Figure 43: Production Labor Hours – Summary of Learning Curve Analysis

Applying Labor Rates



Ava had collected several recent 1921-3 CSDRs from Vandalay during her data collection on the CADE portal; she returned to them now. Reviewing the final labor dollars EAC for CACEG EDM 1 at delivery and the current metrics for EDM 2, she was careful to review rates according to the available Vandalay labor breakdown in order to ensure that various labor pools were not blended within the subtotals. Similar to her review of SPO contractor support labor rates, Ava noticed that these labor rates implied by the data were slightly higher than the FPRA. She suspected that the current skill mix utilized on the EDM units could be more experienced than the mix captured within the FPRA, so she asked Tim to look at the direct and overhead rates that she was calculating.

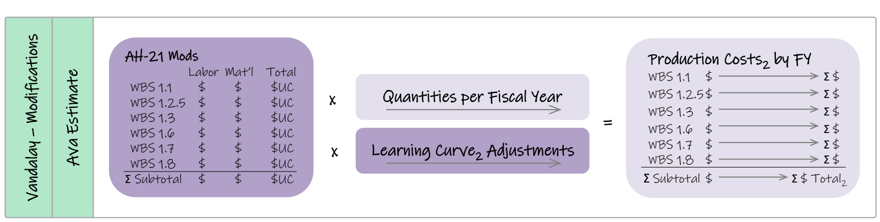
Tim confirmed her findings and suggested that they reach out to the Defense Contract Management Agency (DCMA) representative at Vandalay for additional insight. The DCMA representative was in the Subject Matter Expert (SME) on Vandalay's rate structure, accounting systems, and current product lines. In addition to the likelihood of the skewed skill mix that Ava suspected, the DMCA representative shared a few of the details from their latest audit and let Tim and Ava know that both Vandalay's manufacturing direct rates and overhead rates (across labor pools) had increased within their recent Forward Pricing Rate Proposal (FPRP), submitted earlier in FY2021. DCMA said new collective bargaining agreements recently finalized with the Vandalay worker's union resulted in the direct rate increases. Further, despite the introduction of the AH-21 production work (which would normally bring overhead rates lower because of the spread of fixed costs across additional direct hours), the overhead rates would also increase as a result of capital expenditures at the facility. Apparently, the AH-21 security protocols, already implemented during the EMD contract, were only a fraction of business changes planned at the AH-21 production facility. With this new information in hand, Ava decided to utilize the slightly higher direct rates that were inherent within the EDM CPR data. The DCMA analyst e-mailed her the draft FPRP, so Ava utilized this in place of the FPRA values. They were slightly higher than overhead rates implied within the CPR data, but the DCMA representative suspected that the FPRP had probably been included for reference within the actual LRIP proposal that the SPO was busy evaluating. Ava documented their conversation carefully and saved a record of her assumptions within her Production labor workbook. Tim recommended that she send a follow-up email to the DCMA representative, summarizing the highlights of their conversation, both to confirm that they had not misinterpreted any part of the discussion and to provide a record of the conversation and assumptions. Ava took Tim's advice and then saved a PDF copy of the email once the representative confirmed her key takeaways.

With updated labor rate assumptions in place, Ava could finally finish her point estimate for another major cost contributor. She carefully applied her selected direct labor rates, which she had normalized from the fiscal year of their source CPR to the estimate CY, to her phased labor hours estimate. She added a summary of direct labor costs and overhead labor costs to the top of her summary table and began comparing her results to the old MS B estimate.

ASCAA Midterm Review & Action Items

Ava was grateful to complete the first cut of her labor estimating methodology ahead of their midterm review with Jay. Because she had begun to generate some initial costs, Jasmine had her add a few summary slides capturing the preliminary results of her initial Production labor and SPO estimates. Ava was unable to align them with the same WBS elements from their MS B estimate, since the MS B analyst had developed the estimate at the total Aircraft (WBS 1.0) level, which included both Incom and Vandalay's scope of work. Instead, she prepared a few notes on the main cost drivers and her associated assumptions. Jasmine was sure that both Jay and Marta would be interested to hear about the alternate learning curve analyses and the new FPRP that DCMA had mentioned.

The midterm review went well. Jay was pleased to see the additional detail in their estimating plan and the progress that Ava and the team were making in their estimate development. He suggested a couple of crosschecks – reviewing recent estimates for other USAF programs of similar size – in order to crosscheck Ava's SPO manpower and travel estimates. Jasmine and Marta had approved of Ava's proposal to hold off on specific crosschecks for her Vandalay touch labor (in WBS 1.1, 1.2.5, and 1.3) in favor of crosschecks to the total unit cost. Jay stated that he was fully on-board with that plan, but he asked Jasmine and Ava to make one significant addition to her current labor methodology. Although he agreed with the plan not to adjust lower-level details of the EDM 2 labor hours EAC (to reduce known, minor non-recurring costs), he asked the team to review a recent Naval Cost Center Division (NCCD) study regarding step-down factors between development and T1 Production costs. Later that afternoon, Jasmine asked Ava to look for the study in the CADE libraries. Ava had not noticed the Cost Libraries portion of the CADE Data & Analytics portal during her data searches, but she found it very easily (**Figure 44**). There within the CADE Library, Ava found the NCCD study that Jay had mentioned during their meeting.



After reviewing the NCCD in-house study on EMD to Production step-down factors, Jasmine asked Ava to run a sensitivity analysis using the study's step-down factor and Ava's three learning curve assumptions. The study seemed applicable to their AH-21 program since it utilized data from only aircraft programs. However, both analysts were concerned about applying a factor calculated based on total airframe production contracts to Ava's lower-level build-up of Vandalay modification work. As a test case, Ava went ahead and applied the rate to her LRIP 1 production hours calculation and compared the previous baseline results against the new estimate

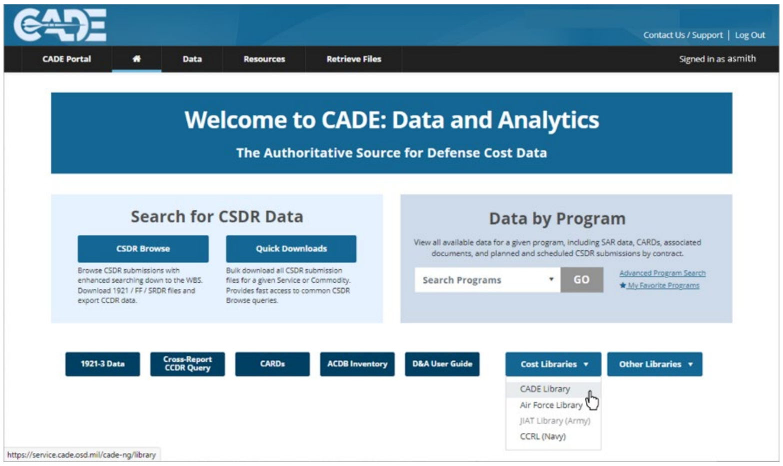


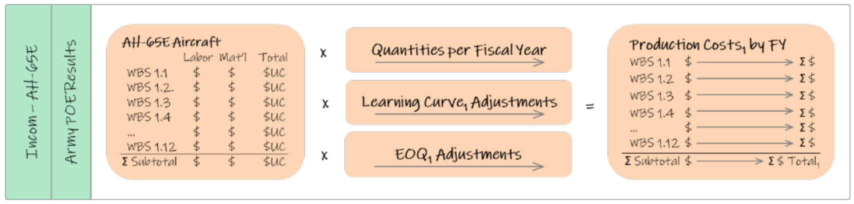
Figure 44: Accessing the CADE Library

including the step-down factor. After several rounds, trading between T1 and Ava's three learning curve assumptions, Ava developed two options. Option one was to apply the NCCD step-down factor and modify the learning curve assumption to reflect a higher learning curve percentage (in order to adjust for the significant savings between EDM units and Production caused by the step-down factor). In option 2, they could leave Ava's baseline estimate as-was, maintaining the most applicable learning curve sourced from one of Vandalay's own helo programs (the AH-51) and consider the step-down factor as a crosscheck to the steep improvements that the baseline 93.4% learning curve suggested. Since the results were similar, both Jasmine and Marta leaned toward the latter option to stick with the learning curve derived from Vandalay's data. Marta offered to handle follow up with Jay at their next management meeting.

The following day the team held a quick team meeting to discuss action items from Jay's review as well as priorities for the upcoming two weeks. Now that they had leadership concurrence over their current progress and direction, the team could proceed to focus on their midterm reconciliation with Tamara and the SPO. Of almost equal importance to Ava and Liam, they had a meeting the following week to review the AH-65E POE with the Army program office's lead cost estimator. Both analysts needed to be comfortable and well-versed in the Incom portion of the AH-21 estimate, and Liam had even more work ahead of him since he intended to incorporate the Incom O&S cost contributors in his estimate in detail.

Reviewing Army Estimate for AH-65E GFE

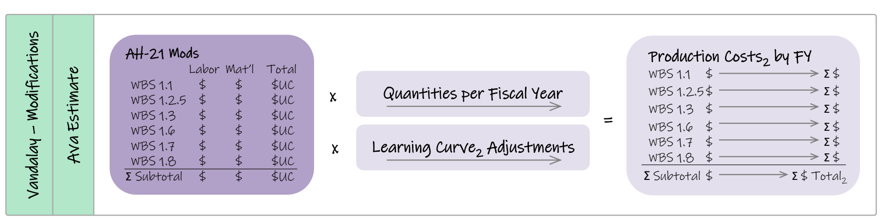
The following week, Joanna visited the office to discuss Incom's production line and the current Army estimate. Right away Ava could tell that Joanna knew her stuff. Although it seemed very different from their own Excel-based model, Joanna's model – built in the Army-mandated commercial tool – impressed the ASCAA team. It was a little difficult for Ava to follow initially because the Army-mandated cost estimating software was organized differently than the Excel-based models that Ava had seen thus far, but Joanna stopped pretty early on to explain the overarching navigation of the software and explain that the estimate generally built-up from input variables at the bottom, up through WBS estimating methodologies, and into summary results aggregated at the top. It made heavy use of named input variables and names for individual cost contributors. As she navigated, Joanna pointed out several unique features of the software that automated several aspects of the estimate architecture (like application of learning and inflation), documentation, and phasing allocations. The Army team would not have to worry about unintentional calculation errors, as long as they applied the underlying assumptions correctly.



Joanna walked the CACEG cost team through the new portion of the estimate where she had added the AH-21 Incom deliveries into the AH-65E Production estimate. She showed the team the highlights of specific backup documentation (received from Incom) regarding impacts to the Army production units; the Army was actually in the process of preparing a contractual change to account for the added workload on their AH-65E production line, so both Joanna and Jasmine were confident in the adjustments already incorporated in the estimate Joanna would prepare for their AH-21 estimate. As a mature program, both the Incom side and Army PO side appeared to operate with lean manufacturing principles. Both were tracking obsolescence and supply risks closely, and the AH-65E program was progressing as planned along a complex learning curve that accounted for both remanufacturing and new build product lines within the same facility.

Joanna walked the ASCAA team through her primary cost contributors, cost drivers, sensitivity charts, and uncertainty drivers. She showed them how she had not only accounted for duration uncertainty but also modeled her Production and O&S estimates dynamically to capture second- and third-tier impacts of any unexpected delay in delivery date. Liam really appreciated these dynamic schedule-related features and dove into a long list of specific questions about the O&S cost drivers, modeling architecture, and estimate results. Before wrapping up, Jasmine asked Joanna to show them a few automated reports. One full narrative report documented overarching estimate ground rules and assumptions alongside a summary for each row of the estimate WBS. The WBS row summaries included a methodology equation, preceding data sources, assumptions, and the calculated row results. Ava was pretty sure that Jasmine simply wanted to see how the Army's tool worked (as an alternative to Excel) just as much as she wanted the full documentation to review. The team walked away from the meeting confident in the estimate Joanna had prepared (and would update, as needed) for them. The fidelity of the estimate was clear. Joanna, her team, and the Army program office leadership had obviously invested significant effort in credibility and defensibility of their estimate. It was no wonder that ACEC, ASCAA's sister Army organization, had accepted their POE as the AH-65E SCP with only minimal adjustments.

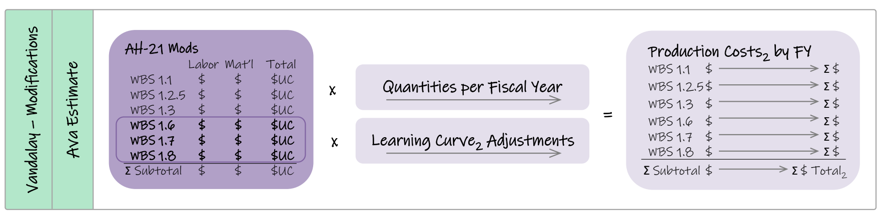
Developing Vandalay Material Estimating Methods



With new comfort in the Army estimate she would receive and drafts on the shelf for two significant portions of her Production estimate, Ava turned her attention to the material estimate and additional below-the-line costs on the Vandalay contract. Alongside the labor basis of estimate included in Vandalay's EMD proposal, Ava had received a detailed material basis of estimate to support the AH-21 modifications by Vandalay. She returned to this file now to dig deeper into the Bill of Materials (BOM), which was mapped to the EMD contract CWBS. The side-by-side comparison to the EDM 2 current material EAC showed very little deviation. Ava compared the expenditure data over the first half of EMD production and realized that Vandalay had experienced some cost growth relative to their baseline pricing for many of the hardware assemblies, but the EVM expenditures showed that they had bought a significant portion of the overall BOM ahead of the planned date documented within the proposal. Thus, Vandalay had benefited from buying material earlier (at a lower price than anticipated). The impacts were not jaw-dropping; however, Vandalay had purchased the bulk of their material almost as soon as the Air Force had placed the EDM 2 order six months before production began. Ava decided to account for this observation as best she could, by phasing 80% of her overall material estimate in the fiscal year of each planned LRIP order and 100% in the year of each FRP order. Neither the CARD, nor any discussion during her meeting with the AH-21 SPO team, nor any of her notes from the Vandalay site visit refuted this new phasing assumption, so she carefully made note of it within her working documentation.

Based on her review of the EMD proposal, she prepared a new workbook to summarize Production material costs. In line with her estimating plan, she captured total material costs for WBS elements 1.1, 1.2.5, and 1.3 and normalized the costs to the required base year. She phased these costs according to the procurement schedule in the quantities CARD table (**Table 15**). Like her draft labor estimate, she would need to hold off on crosschecking her material estimate against the MS B estimate, which did not break labor or material estimates down into Incom and Vandalay subtotals. Now that she had seen Joanna's estimate and documentation, Ava really looked forward to being able to combine her estimate for Vandalay modifications with the Army airframe results; it would allow her to compare unit costs for the total helicopter (and labor and material breakdowns) against the MS B estimate and other attack helicopter programs like the AH-65 variants and AH-51.

Developing Vandalay Below-the-Line Estimating Methods



Finally, Ava turned her attention to the below-the-line elements of Vandalay's portion of her WBS, which she had summarized a few weeks prior (**Table 23**). Jay had approved both Ava's primary and crosscheck methodologies for Systems Engineering (WBS 1.6), Program Management (WBS 1.7), and System Test & Evaluation (WBS 1.8). Furthermore, he approved use of the same factor methodology on Training Services (WBS 1.9.2), which had no equivalent scope included within the AH-21 EMD contract. Using the same 1921 reports she had leveraged during her learning curve analysis, Ava aggregated summaries of the labor subtotals for SE, PM, ST&E, and Training for the AH-51, AH-65D, and AH-65E programs by lot. For each program, she gathered subtotal labor hours for the "touch labor" WBS elements 1.1 through 1.5 (similarly to her learning curve subtotals of WBS 1.2.5 and 1.3 from **Table 30**). She calculated separate percentage relationships between each of the four below-the-line elements on each of the three programs before turning her attention to the EMD CPR data. **Figure 45** shows an example of Ava's calculations for Lot 3 of the AH-65E 1921-1 data.

Her initial plan was to utilize factors observed in the AH-51 program over any EDM unit EACs. She thought that the historical production data on another Vandalay product line would be closer aligned with ordering practices during LRIP and FRP. But she decided to look at the EDM 1 and EDM 2 factors in order to get a feel for how Vandalay was currently executing. To her surprise, the EDM EAC percentages were actually close to the full Production metrics that Ava had calculated for the other three Production programs. She decided to use this as the crosscheck methodology. Ava wasn't fully comfortable with using these factors for the SEPM estimates, since she knew these categories were unlikely to vary linearly with lot quantity, but she lacked sufficient insight into the engineering and program management FTEs to build her own level-of-effort analysis. For now, she kept these factors and planned to return to it later, if time allowed.

	A	B	C	D	E	F	G
1							
2		**AH-65E Lot 3 New Build Breakdown**					
3							
4		**WBS**	**AH-65E**	**Lot 3**	**% of Subtotal**	Col E equation	
5		**1.0**	**Air Vehicle**	7,123			
6		1.1	Airframe	1,536			
7		1.2	Propulsion	109			
8		1.3	Vehicle Subsystems	1,965			
9		1.4	Avionics	337			
10		1.5	Mission Systems	174			
11		1.6	Systems Engineering	1,149	27.9%	= D11 / D$16	
12		1.7	Program Management	782	19.0%	= D12 / D$16	
13		1.8	System Test & Evaluation	732	17.8%	= D13 / D$16	
14		1.9	Training	339	8.2%	= D14 / D$16	
15							
16			**Subtotal WBS 1.1 - 1.5**	4,120	100.0%		
17							

Figure 45: Example of Labor Factors Calculation for SEPM, ST&E, and Training Services

After documenting her calculation of labor percentages, Ava moved on to material percentages for the same WBS elements. Judging from her review of the EDM unit CPRs, she knew that the material portion of these elements would be significantly smaller than their corresponding labor percentages. Ava employed the same process using material cost values, and the crosschecks demonstrated use of the AH-21 EDM contract as a reasonable assumption for her baseline estimate. Ava considered what the most defensible methodology would be and prepared to bring up the issue during the team's upcoming peer review with other ASCAA analysts.

Midterm Reconciliation

With her estimating methodologies outlined in greater detail and much of the analytical legwork complete on her primary cost contributors, Ava began preparation for their midterm reconciliation with the AH-21 SPO. She had worked through several additional details of her estimate since the midterm review with Jay, but the heart of her presentation material was still applicable. It wasn't long before she had added new slides for her material estimate and below-the-line factors. Ava included a copy of the draft estimate for GFE aircraft that they had received from Joanna, and in a new comparison workbook she set about aggregating the labor and material build-ups of her Production estimate, applying her SEPM, ST&E, and Training factors, and adding a few summary rows to cover her SPO management and support cost elements. It was the first time that Ava had seen (almost) all aspects of her estimate aligned together and phased over the Production portion of the life-cycle. Ava took pride in seeing the full set of CY results, and for the first time, she was able to see how her estimate compared to the old MS B estimate. She knew that the new breakdown would help tremendously during their reconciliation with Tamara.

Ahead of their midterm reconciliation, Liam had aggregated the team's slide updates and prepped Ava briefly on what to expect during the estimate review. Ultimately, their goal throughout the milestone process was to arrive at a CCP for recommendation to the DAB. This had been abundantly clear to Ava as she reviewed the AFI 65-508 processes, which centered on development of the CCP. However, Liam explained that they did not need to finalize that estimate just yet; the CIPT estimating plan for this new type of helicopter had opted for development of a separate ASCAA estimate to balance the POE already developed and maintained by Tamara, which would ensure that the Component put forth a robust CCP estimate. Liam told Ava that it was not uncommon for program offices to become entrenched in their assumptions over time, and the ASCAA estimate would ensure a fresh set of eyes on possible requirements, risks, and opportunities to the program. He pointed out a section in chapter three of the AFI 65-508 (**Figure 46**) and explained that at this point they need not convince one another that one methodology was "right" while another was "wrong," as long as each was credible, accurately estimated with sound estimating judgment, and defensible. Later, they would either select one of the two estimates as the CCP or draw from both estimates to create a new, tailored CCP estimate. Their efforts during the present midterm reconciliation would allow for some collaboration and sharing of ideas and give them a jump start in identifying points of departure between their treatment of available data and choice of estimating methodologies. Even more importantly, the midterm review allowed both cost estimating teams to understand differences in assumptions and different understanding of established ground rules. Most importantly, the midterm review would bring to light areas where the cost teams may have misunderstood program requirements or CARD information.

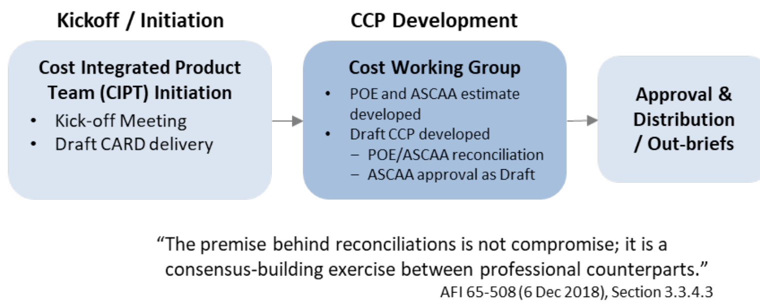


Figure 46: Subset of AFI 65-508 Guidance

At the midterm meeting, Jasmine and Tamara had agreed to step through each portion of their working estimate results according to the sub-divisions that the ASCAA team were working under (i.e., sunk cost, EMD To-Go, Production for Vandalay, Production for Incom, Production SPO support, and O&S). Tim was first up, listening to Tamara's high-level process for Enterprise Resource Planning (ERP) data analysis, and comparing his top-level results to hers. (The ERP accounting database was the primary source for their CACEG sunk cost data.) They began with the largest cost contributor and worked their way down one-by-one through 60-70% of his cost contributors. The discussion focused on cost contributors with the greatest delta between their two sets of working estimate results, comparing notes on the other's associated cost drivers and assumptions. Within the sunk cost & EMD To-Go portion of the working estimate they compared, Tim and Tamara were within 10 percent of one another, even with Tim only through about 80% of his analysis.

Ava was up next. In identical fashion to Tim's portion, she and Tamara stepped through the Production labor, material, the SPO management and support costs one-by-one. As expected, Ava and Tamara's T1 labor estimates for LRIP 1 were slightly different since Tamara had taken a different track in her learning curve analysis. Ava had calculated and selected her learning curve for the Vandalay modifications based on the company's prior history on the AH-51 program, and she had performed her learning curve regressions on the WBS subtotal corresponding to the new AH-21 scope of work. Tamara had considered the same approach initially, but explained that she eventually had concerns over a few changes to Vandalay's cost accounting methods that had occurred since conclusion of AH-51 production. Ultimately, she settled on a learning slope of 92.7% based on her analysis of AH-65D. Ava's analysis of the same 1921-1 data had produced a 90.6% learning curve, which Tamara heartily acknowledged. She had had more time over the last few years to develop her analysis; Joanna had helped her to normalize the AH-65D data further. They had removed first and second tier impacts of several early engineering change orders from Tamara's data, which ultimately increased the slope. The two teams took a few minutes to compare the merits and concerns associated with each approach and agreed to return to it later in the process. Jasmine requested a copy of Tamara's backup files on the learning curve and promised to review them before finalizing her estimate.

Before finishing the Production section of the review, Jasmine raised the topic of cost reporting for the future CACEG contracts. As a future user of these reports, Jasmine wanted to ensure that the SPO was incorporating the CSDR requirements into both the Incom and Vandalay planned contracts. She knew these reports would be critical to any future cost estimates for the CACEG or for follow-on platforms. Ava took this opportunity to bring up moving future reporting to the FlexFile format so that analysts could more easily use all of the detail in the reports. The SPO team assured Jasmine and Ava that they were working with the Defense Cost and Resource Center (DCARC) at CAPE and that CSDR plans for the LRIP contracts were almost complete. Jasmine asked that Ava be included in future cost reporting discussions so that ASCAA could ensure that the plan reflected the correct level of detail for the information to be collected. Ava was glad that Jasmine had started the discussion on cost reporting, but she had not known that she had a role to play in this type of data collection.

As was almost always the case, the focus of the meeting was on the early program phases and gave Liam less time than preferred to review his O&S estimate. Thankfully, he and Tamara were both well versed in their respective methodologies and inputs. With Liam further along in his estimate than either Tim or Ava, the team had two nearly-complete O&S estimates to compare. They quickly covered 50% of Liam's Level 2 CES elements and honed in on two areas with sizable deltas. To Ava's amazement, their actual estimating methodologies were very similar, but rate assumptions within the Unit Level Consumption and the Maintenance CES elements were driving the deltas between their estimates. They had utilized a different rate for the fully-burdened cost of fuel and generated slightly different assumptions for component failure rates. Owing to the rush and everyone's desire to beat the evening commute, Liam and Tamara agreed that they could easily continue comparison and collaboration on the rate selections via e-mail. Ava was grateful to head home just a bit later than normal, even though the collaborative discussion had energized her. It was encouraging to see consensus on major elements of her working estimate and know that she was on the right track.

ASCAA Peer Review

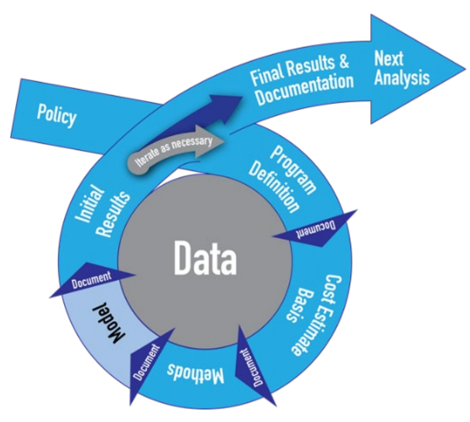
Riding their momentum from the midterm reconciliation meeting, the team held a peer review with other ASCAA analysts just a few days after returning to the office. The meeting offered Ava and the team an additional feedback loop from analysts not involved in the details of the CACEG program. Once again, Ava was ultimately encouraged by the comments and grateful to receive more feedback on her methodologies. A senior analyst had even asked her to share the NCCD study she reviewed in her analysis – hopeful that he could leverage it in an upcoming estimate. One significant question that Ava received helped her identify a gap in her estimate; the colleague had asked about whether she was capturing the program risk and opportunities registers within her estimate. She remembered seeing the term in her reviews of the DoD Cost Estimating Guide, but in all of her discussions with the AH-21 SPO, she could not recall mention of a formal register. They had, of course, discussed mitigation of the EMD non-recurring issues and talked about multiple plans that would improve production performance at Vandalay. Thankfully, Jasmine spoke up in response to the specific question and noted that the SPO updated the registers periodically and still owed the ASCAA team their latest version of each. Ava was a little embarrassed but grateful that someone a little further away from both her estimate and the specifics of the AH-21 program had caught her potential oversight.

Liam, Tim, and Jasmine could tell that Ava was worried after the review ended. In turn, the team reassured her that her risk register omission was exactly the type of oversight that made peer reviews a meaningful exercise. Apparently, it was far from the first time that someone had pointed out a way to improve another analyst's estimate. As an organization and a team, ASCAA wanted to leverage the collective experience of their analysts and produce analytical, credible estimates. Knowledge sharing and peer reviews were the best way to do that. As Ava reflected on their conversations, she began thinking about others' peer reviews in a new way. As a new analyst, she had felt that she should keep quiet and simply listen to the presentations. Although that approach had taught her a fair amount in the few peer reviews she had attended thus far, it was possible that, even as a new analyst, her questions about approaches and estimating methodologies might have been helpful to them and even more helpful to her understanding. Even if a question did not lead to some kind of change in the presenter's estimate, her questions might highlight areas where the team could improve its summary slides or explanations. Furthermore, while she had been gaining meaningful insight on the AH-21 program and how to best leverage her technical, programmatic, cost, and schedule data, she was also gaining specific insight that others might not have (due to their own estimating history and different areas of focus). Jasmine was interested to hear about Ava's new perspective on peer reviews when they spoke later that week. She agreed with Ava's new insights and, knowing Ava to be both insightful and considerate of her coworkers, Jasmine encouraged her to continue in the new line of thinking and speak up to help her colleagues when the next opportunity arose.

Critical Thinking Questions – Select Cost/Schedule Estimating Methods

- How are escalation rates forecasted? Which rates are most appropriate for which parts of the estimate?
- Are there any obsolescence issues with hardware during the production cycle? If so, how is this factored into the estimate? What is the impact to sustainment?
- How do estimating techniques and methodologies evolve as the program matures? Are methods used at MS B still the best technique at MS C?
- Are there defendable cross checks for all of the major cost contributors?
- How are SMEs determined? How is SME input best incorporated into the estimate? Does the SME speak in absolutes or in ranges?
- Is Learning Curve being calculated at the same level that you plan to apply it?

Model – Build Cost Estimate Model



With a good portion of her **Figure 38** to-do lists complete and draft estimates developed for her primary cost contributors, Ava was ready to start building her cost model, which would pull together all of the pieces of her estimate and, eventually, the different phases of the total LCCE. Through her earlier reviews, Ava had gained a good understanding of the MS B cost model and knew that she could save time by leveraging some of that framework to develop her MS C model. However, she had also found several issues within the MS B model that amounted to poor functionality overall. The Excel workbook itself seemed clunky. With a file size over 10MBs, Ava knew it would be too large to email during collaboration with Tim and Liam. More troublesome than that, the file took several minutes to load whenever she opened it, and after that wait, a dialog box always popped up with a circular reference warning, which made her feel uneasy. She wanted to address these issues and start with a fresh version of the workbook before incorporating too much of her MS C data and methodologies in the old file. Thankfully, Liam had observed the same issues and agreed that it was worth the time investment to both clean up the MS B framework and plan ahead for integration of their individual portions of the new MS C cost model.

Cleaning Up the MS B Model

Together, Liam and Ava worked to improve the old model. Beyond the simple navigational tricks that Jasmine had shown her during her review of the MS B model, Liam showed Ava a few hidden sources of extraneous data that had inflated the file size. They used the "Name Manager" functionality to review all of the named cell ranges within the model at once, and Ava was amazed at how many names were unused (and showing as a #REF! error) or duplicated within the model worksheets. Liam showed her how to quickly reduce the mess of named ranges, and they planned a naming convention for the new portions of the MS C model that they would develop independently and later need to integrate. They identified a few large working-level worksheets used to generate the EMD portion of the MS B estimate that could be eliminated from the workbook altogether. One of them even contained a macro, which Liam determined to be a working-level tool that a prior analyst had added to process data during Cost Estimating Relationship (CER) development. He explained that macros were hidden code within a workbook that could add to the file size unnecessarily if they no longer served a purpose within a model (as was the case with the EMD CERs). By the end of their working session, Liam had helped Ava to find and clear the circular reference error and reduced the workbook to a more manageable file size with tabs that were easier to follow and understand due to meaningful names and color-coding.

The extent of model functionality hidden beneath the surface of their Excel workbook amazed Ava. She was grateful for Liam's help in cleaning up the model framework to preserve summary and output worksheets. She knew that validating and preserving the MS B model architecture, which fed result outputs (e.g., Spruill charts and required APB tables) and the calculation of various cost metrics (e.g., Average Procurement Unit Cost (APUC), Program Acquisition Unit Cost (PAUC), and subtotal build-ups to Total Ownership Cost (TOC)), would be easier than trying to build the same outputs from a clean sheet. However, she had not anticipated the pitfalls that Liam's advice would help her to avoid. His tips and tricks on how to safely incorporate source data would save her time and trouble in the long run.

She realized that copying and pasting worksheet formulas and formatting into a clean sheet of her model (as opposed to inserting a copy of a worksheet from an external file) could avoid introduction of duplicate or irrelevant named ranges. Before Liam's recommendation, she had never considered that one could use Excel's Find/Replace feature to quickly replace cell ranges or criteria references across hundreds of instances of a formula or within an entire worksheet. If copying a worksheet from an identical file (with the same relevant named ranges and worksheet references), one could even save time by adding a letter or two ahead of the "equals" sign of all a worksheet's formulas, then copy/pasting the worksheet content and formats into the new workbook, and finally using the Find/Replace feature to remove that letter or two. This prevented the accidental creation of external links altogether, which Liam warned her was the safest way to go. He explained that external links would be broken and no longer update alongside their source file (causing calculation errors in the formula) if one purposely or accidentally changed the source file name or its file path location. An accidental external link that was unbroken might also prevent changes to the model from flowing through into estimate results; this error could happen very easily and go unnoticed if it still calculated properly and caused no formula errors.

As Ava began thinking about how many different data sources she would need to pull into her portion of the MS C model, she realized that she could end up introducing quite a bit of unnecessary background content into their MS C model – external links and background artifacts that might remain even if she ended up deleting the portion of the model that originally introduced them.

Considering Model Architecture and Data Flow

With this in mind, Ava decided to map out the flow of her own portion of the model architecture. During peer reviews of others' estimates, she had heard Jasmine and other leads warn that greater detail does not necessarily mean greater accuracy. This had not made a lot of sense to her in the past, but now armed with so many data sources and interconnected pieces of the AH-21 estimating puzzle, she realized that there were many details within her source data that did not need to be carried forward into her summary sheets for CY and TY results. In fact, if she simplified her estimate build-up, others – both those familiar with the program and those unfamiliar with the AH-21 program – might actually find it easier to understand the estimate. While it was important to preserve the primary source data for her estimate, no one needed her Production labor estimate broken down into the Vandalay internal breakdown subtotals shown in the proposal source data. She and Tamara had only focused on CWBS subtotal hours in their discussions about the EDM units, and her labor rates could be applied one-for-one to those subtotals, with a single FPRP pool rate applied to each subtotal. She had derived her learning curve using only WBS 1.2.5 Avionics and WBS 1.3 Mission System hours, but if she pulled the Level 2 subtotal hours from her relevant T1 labor build-up exhibits, she could apply the learning curve just as accurately. Her total Production material estimate would be just as sound if she limited the level of detail in her methodology build-up and only saved the component and assembly details within an appendix/exhibit worksheet.

Ava excitedly drew up a high-level flowchart of how her most important methodologies would be organized (**Figure 47**). She would save her proposal subtotal data in an exhibit worksheet, alongside additional exhibits to document the EDM unit EAC, her learning curve calculation, and FPRP rate adjustments. Then she would link only the relevant subtotals or rates from the exhibits to her Production methodology worksheet, where she would re-create many of the calculations from her development analysis of Production labor (everything from calculation of her T1 labor hours, learning curve application, phasing by fiscal year, and application of labor rates). Ava realized that simplifying the data flow from her input exhibits might allow her to build up the entire labor and material Production estimate on a single worksheet – despite multiple inputs with large amounts of source data. Before moving forward, Ava took her labor map to Jasmine to get feedback.

Jasmine loved Ava's modeling approach and encouraged her to continue mapping out the flow of her material estimate (and other below-the-line elements) and begin translating them into Excel. She also reminded Ava of their previous conversation – working to align data and high-level methods to each portion of the WBS – and asked her to give some thought to the model's delineation of Army GFE costs from the build-up of costs for Vandalay modifications. Together they decided to completely segregate Ava's initial build-up of Vandalay costs from the Army GFE costs within her Production worksheet before combining the two subtotal estimates in a single summary table. Jasmine explained to Ava that the approach would allow for review of the technical scope separately, but it would also allow for application of duration uncertainty variables within a single worksheet and potential lot cost comparisons.

Ava left Jasmine's office both excited about the progress she was making and worried. Uncertainty was a term that Jasmine and others had mentioned within the last few months, and one that she had seen here and there in the DoD Cost Estimating Guide, but for the last several months, her focus had primarily been on figuring out how to arrive at just one whole and reasonably accurate estimate. She began to worry that she might have forgotten a critical step along the way. She decided to talk to Liam

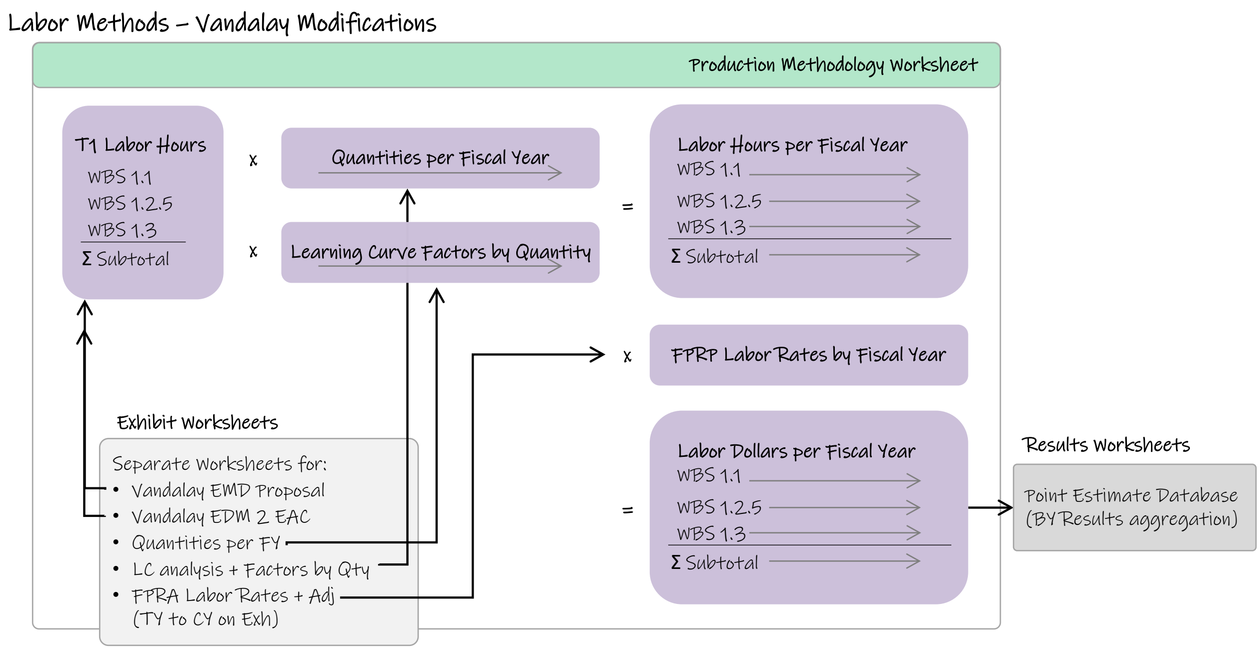


Figure 47: Labor Methodology Flowchart

about uncertainty– both the "variables" that Jasmine had brought up and how critical uncertainty was to finishing her Production estimate. He was out of the office on leave for another week and a half, taking his family on vacation to celebrate the end of the school year. Ava emailed him with a few questions to deal with when he returned and pushed her concerns aside for now. She was confident that he would have good advice when he returned at the end of June, and she had heard, loud and clear, from Jasmine that she was one the right track with respect to building her model.

Building the Production Portion of the Model

For the next week, Ava set about translating her Vandalay methodology mappings into her MS C model. Her organization of raw data files and working analysis workbooks made it easy to find each relevant source or intermediate rate analysis and incorporate them one by one within the cost model. As she integrated each source, she was careful to avoid links to her external working and raw data files. Wherever elements of her estimate related directly to one another, Ava established formula links to enable easier updating of the model if parameters changed, ensuring that updates to input variables would flow through her estimate appropriately. (Unbeknownst to Ava, this would also come in handy when the time came for what-if and sensitivity analyses of her results.) Applying cell or range names to the most critical cost drivers coming from each exhibit worksheet made it even easier to keep track of how data was flowing through the Production estimate.

Day by day, Ava filled in the Vandalay estimate WBS summary table at the top of her Production methodology sheet. With each new exhibit and methodology added, she carefully labeled the model worksheets according to the naming convention for structure that she and Liam had established. Output summary worksheets came first within the workbook, then methodology worksheets, followed by supporting data exhibits. At the top of each new exhibit, Ava carefully documented the filenames, date, and mode of receipt for each original data source, and in cases where she had normalized the data or derived a rate, she listed each step taken and all assumptions made along the way (**Figure 48**). Since the team had discussed the need for an electronic "appendix" folder to enable other ASCAA analysts to find relevant source data on their network drive, she copied each source file into a new folder and modified the name to reflect the exhibit number saved in the model.

Exhibit - SPO Government Personnel

Purpose: Estimate costs for the SPO Government and Contractor Support
Methodology: Labor + Travel // Build-up per Personnel Type (Labor) + Extrapolation from Actuals (Travel)

Detailed Methodology:
1 SPO Govt Civ (per grade) Labor = Govt Civ FTEs × (Avg Labor Rate) × (1 + Locality Rate) × (1 + Civ Fringe Benefit Rate)
2 SPO OGA Civ (per grade) Labor = OGA Civ FTEs × (Avg Labor Rate) × (1 + Locality Rate) × (1 + Civ Fringe Benefit Rate)
3 SPO Govt Mil (per grade) Labor = Govt Mil FTEs × (Annual DoD Composite Standard Rate)
4 SPO CTR (per contract, per functional area) Labor = CTR FTEs * (Avg Contract Labor Rate)
5 SPO Govt Civ (per grade) Travel = FY2021 requirement
6 SPO OGA Civ (per grade) Travel = FY2021 requirement
7 SPO OGA Civ (per grade) Travel = FY2021 requirement
8 SPO CTR (per contract, per functional area) Travel = FY2021 requirement

Ground Rule: SPO Govt Civilian and OGA located at Wright-Patterson AFB (Locality = Dayton-Springfield-Sidney, OH)
Assumptions:
1 Govt Civ and OGA labor rates reflect average of Step 1-10 (per GS pay grade)
2 Govt Civ and OGA labor rates based upon Calendar Year 2021 GS Payscale
3 SPO Contractor Labor reflect FY2021 execution labor rates (by functional area);
FY2021 execution reflects targeted skill mix for Production (FY2022-28)
4 Per discussions with SPO acquisition lead, FY2021 travel requirements and trip frequencies (quarterly meetings) reflect steady-state requirements throughout Production (FY2022-28)

Data Sources(s) / File Name(s):
1 "2021 General Schedule (GS) Locality Pay Tables," effective Jan 2021
https://www.opm.gov/policy-data-oversight/pay-leave/salaries-wages/2021/general-schedule/
2 "Fiscal Year (FY) 2021 Department of Defense (DoD) Civilian Personnel Fringe Benefits Rates"
https://comptroller.defense.gov/Portals/45/documents/rates/fy2021/
3 "FY 2022 Department of Defense (DoD) Military Personnel Composite Standard Pay and Reimbursement Rates"
https://comptroller.defense.gov/Portals/45/documents/rates/fy2021/
4 Manpower CARD table - FTEs by grade (Gov Civ, Gov Mil, OGA Civ, CTR total)
CARD AH-21 CARD Tables (2021.03.19 draft).xlsx - *update pending receipt of Final CARD*
5 SPO Contractor FTE counts (split among A&AS contracts and functional areas)
BFM email FY2021 execution plan data.xlsx
CARD *update pending receipt of Final CARD*
6 SPO Contractor Labor Rates
BFM email FY2021 execution plan data.xlsx
7 FY2021 SPO travel costs (Gov Civ, Gov Mil, OGA Civ, CTR total)
BFM email RE Request for AH-21 current year travel costs.msg *(received by Ava Smith on 4/29/2021 3:26PM)*
Convo Conversation with AH-21 acquisition lead and discussions during Vandalay site visit

Figure 48: Worksheet Documentation Example

Last on Ava's list was incorporation of Joanna's Army GFE estimate. It was such a significant portion of the overall Production cost, but Ava was struggling with what Jasmine had meant by "passing through" the estimate. She understood well enough that they were very comfortable with Joanna's estimate for the Army's portion of AH-21 and planning to use it as it was, but Jasmine's direction about somehow interconnecting the Vandalay and Army estimates with uncertainty, even though they were separate, still confused Ava. She had no idea what Jasmine had in mind. However, with Liam still out of town for another day, Ava went ahead and incorporated Joanna's result tables as an exhibit within the MS C model and began linking summary table to her total results. She decided to return to the DoD Cost Estimating Guide to look for insight there, but before she could do so, Jasmine popped up at her desk.

Ava had been so focused on creating her portion of the model that she had forgotten all about their weekly team meeting. Thankfully, Jasmine was not concerned about her absence as much as how she was doing. (It was not like Ava to miss a meeting.) Ava gave her a quick rundown of her progress since the week before, trailing off a bit nervously as she explained she was saving the Army GFE estimate incorporation for last. Jasmine exclaimed, "You got all of that done in the last week?" Ava nodded nervously. Jasmine's enthusiasm did not wane. She asked Ava to get together with Tim that afternoon in order to pull his sunk cost and EMD To-Go estimate into the model so that the team could do an initial review when Liam returned on Monday.

Integrating Sunk & EMD Portion of the Model

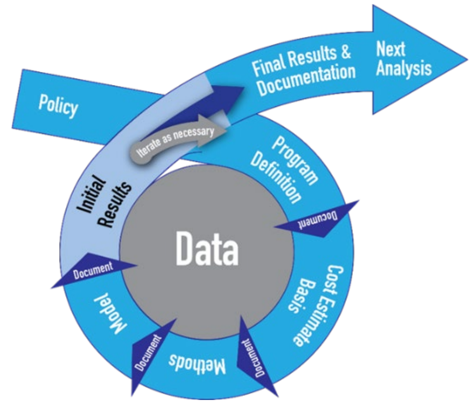
That afternoon, Ava sat down with Tim to integrate the sunk cost estimate within the MS C model. Tim had far more supporting exhibits than Ava guessed he would, and as they sat at his desk working on a new master copy of the model, he explained the process that he had used to capture both the Army and USAF sunk costs. He incorporated two large exhibits that he said were outputs from automated accounting systems; Ava had heard the term ERP before, but apparently both the Army and Air Force had their own separate systems, which Tim had painstakingly reviewed. He had worked with BFM analysts from both the AH-65 program office and AH-21 SPO, and he had somehow translated two tables mapping budget structure to ERP line items in order to arrive at only the relevant costs to their AH-21 program. At that point he began talking about the difference between tracking their expenditure data and obligations and how he was providing her with obligations to keep their model consistent and ensure the LCCE results present cohesive reflection of budget requirements. Expenditures, unlike obligations, reflect the spending profile and can lag behind the year of obligation. Ava appreciated that Tim was taking the time to explain his own work to her and trying to help her understand better how it married up with her analysis of Production costs. It provided her with a better understanding of the total estimate beyond her own work. Given his willingness to explain concepts to her and answer her questions, Ava decided to ask him about uncertainty.

Tim's response surprised Ava. He caveated his response by saying that he was not the office expert in uncertainty analysis, and he explained that uncertainty was a relatively new aspect of cost analysis, enabled by advances in computing power. Even though uncertainty was not a particular focus in his specialty area of sunk costs (since there should not be uncertainty around funds already spent), Tim explained that it was an important aspect of estimating future program costs and one that he regularly employed in all of his To-Go estimates for current contracts (like their EDM 2 estimate). Uncertainty experts around the ASCAA office liked to joke that, "The only thing we know precisely about an estimate is that it will be precisely wrong." This statement initially made Ava laugh, but as she considered it, she realized the wisdom in the thought.

Tim went on to explain how much program history he regularly needed in order to accurately parse sunk costs. Even when working with program data in hindsight, an analyst needed to know what problems had arisen and how the program had mitigated the issue; when looking ahead, a significantly greater number of factors *could arise* and affect the outcome for future program costs. The effort to capture known areas of uncertainty and translate them analytically within the estimate could provide decision makers with valuable insight into the range of possible cost outcomes. On the other hand, Tim said, any model operated under the rule of "Garbage in, garbage out", meaning that bad inputs to a model will produce bad outputs. Ava thanked Tim for his time and for explaining how his sunk cost and EMD To-Go model worked. She headed into her weekend more relaxed about the concept of uncertainty and more comfortable with how much she still had to learn on this topic.

Reviewing Initial Results – Point Estimate

On Monday, the team gathered to review Liam's working O&S model and the MS C model that Tim and Ava had consolidated, which now incorporated the TMMR, EMD, and P&D phase scopes. During the review, they found a handful of minor mistakes and areas for improvement in the MS C model. When integrating the historical data from the DoD aircraft study on OT&E testing, Ava had accidentally referenced her selected mean value in the original study's CY dollars and failed to normalize the units



from thousands of dollars to dollars millions. When they looked at the full WBS cost summary, the mistake was pretty obvious, but Ava had overlooked it multiple times after integrating that portion of the estimate. Jasmine was understanding of the mistake and pointed out that it was easy to overlook the forest when she focused on the trees. It was exactly the reason that the team held internal reviews. Similarly, Ava had overlooked incorporation of the latest inflation guidance, and she had accidentally pasted one of her SE and PM factors into the Production methodology worksheet instead of linking it to her backup exhibit. Lastly, Jasmine asked Ava to document her crosscheck analyses within the MS C model; she wanted them saved alongside the team's estimate but clearly labeled and separated from their baseline architecture (to prevent any accidental incorporation within the actual baseline estimate).

As the conversation pivoted to next steps, the team reviewed their individual action items, and Jasmine asked Ava how much she had thought about her uncertainty estimate. Ava took a deep breath and explained that she had been thinking about it a fair amount while trying to build out her Production model architecture; she continued by explaining that she did not really understand how the math would work, what her portion of the model would look like, or where to start collecting data again in order to build a probability distribution range. Jasmine's response set her mind at ease. She assured Ava that, based on their conversations during data collection and methodology development, Ava had already collected enough data and information to inform uncertainty in her estimate. She had measurable uncertainty available in the CER fit statistics associated with her learning curve; she had EMD pricing on Production material; and she had collected information for crosschecks on all of her below-the-line WBS elements. Alongside the robust schedule analyses they had received from the AH-65 program office and AH-21 SPO, they had a good idea of how primary cost drivers might differ from their point estimate values and a robust uncertainty estimate for the GFE portion of the helo. Jasmine further explained that Ava did not have to worry about performing the thousands of calculations involved in performing uncertainty analysis since she would use a simulation tool alongside her existing model architecture. Based on many of the modeling best practices that Ava had already employed, she could assign ranges to uncertain variables within the estimate. As long as changes to an input variable flowed through the model's build-up of cost equations into the aggregated results of interest, the simulation tool would properly capture the results. The tool handled random sampling of the defined ranges, kept track of results for any summary result of interest, and tabulated statistical results that Ava and the team could use to assess ranges on their summary results.

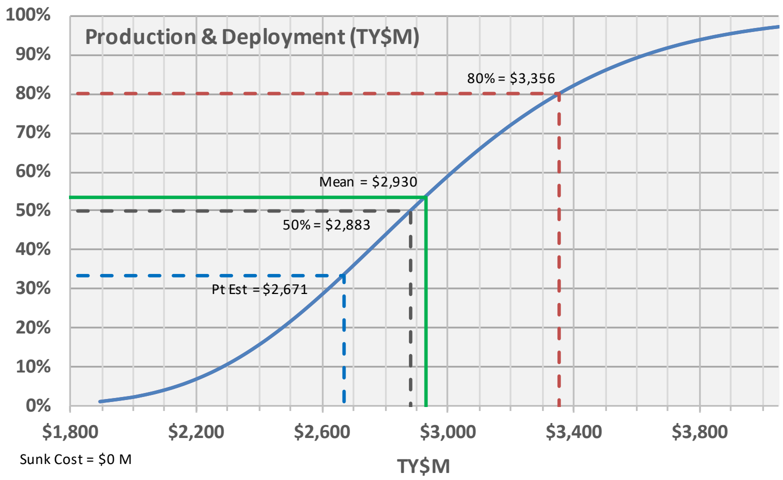
Jasmine asked Ava to take care of the point estimate action items relevant to her Production portion of the model and coordinate with Tim to knock out his short list within Sunk and EMD To-Go portions of the model. After Liam fixed his action items within the separate O&S model, he and Ava should get together to integrate his model structure into the MS C cost model. Integration of Tim and Ava's working model with Liam's O&S model meant that one Excel workbook would finally house the team's full PLCCE. Jasmine hoped that this would be complete before the end of the week so that the entire team could relax and enjoy their holiday weekend. Before ending their meeting, Jasmine asked Ava to review her notes from the last few months and highlight and flag any information relevant to specific range information, overall uncertainty of a cost driver or cost contributor, or general qualifications like "high/low," "optimistic," etc. that SMEs might have mentioned during meetings. These notes, alongside the WBS-level crosschecks that Ava was adding to the model, would help Jasmine and Ava to craft the uncertainty estimate.

Developing Production Uncertainty & Integrating the Incom Estimate

During the week following Independence Day, Jasmine set aside time for a series of working meetings with Ava. Together they reviewed Ava's notes and used a commercial uncertainty analysis software package (via Excel add-in) to modify an inputs worksheet in Ava's model that she had previously used as a simple hub to organize her major cost drivers. Jasmine explained that their overall approach was inputs-based, which would align with both the Army GFE estimate they were integrating within the LCCE and Tamara's approach within the POE. Together, Jasmine and Ava worked their way through the existing uncertainty inputs and variables that Ava had added for use in her point estimate. Jasmine patiently explained probability distributions, helped Ava to select distribution shapes in line with the type of information that she had collected about each variable (e.g., whether the range of possible outputs was continuous or discrete or whether a finite minimum or maximum bounded the variable's possible outcomes), and helped Ava to define each variable within the simulation tool. They talked about where the point estimate value fell within each distribution and how to interpret each crosscheck's high and low values within the distribution range. They connected the variables via a correlation matrix after considering how individual variables, and the cost contributors they impacted, should move relative to one another in different real-world scenarios. Along the way, Jasmine continually referenced different principles and rules of thumb from the JA CSRUH, which Ava had read a little bit about within the DoD Cost Estimating Guide. Between meetings, Jasmine gave Ava specific tables and sections to review and consider before their next working session. Occasionally, this came with a bit of homework for Ava – reorganizing some smaller elements of her estimate in order to streamline their uncertainty modeling. Thankfully, Ava's thoughtful modeling minimized this rework, and the only significant restructuring required related to the risk and opportunities registers (which she had received from the SPO after their ASCAA peer review).

Finally, the day arrived; Jasmine said that they had finished defining variables and checking links within Ava's model architecture. Jasmine pointed to a few point estimate results, clicked a button to assign output targets to them, and clicked the button to begin the simulation. They had spoken about run preferences in the past, so Ava had an idea of how the tool was "randomly" sampling her data (according to the tool's statistical guts of Microsoft VBA logic). A dialog box popped up to show them progress relative to the number of test trials Jasmine had entered, and after a short wait for the simulation to finish, Jasmine started opening other dialog boxes showing statistical results and the "s-curve" chart showing cumulative probability for Ava's estimated costs associated with the procurement appropriation (**Figure 49**). She proceeded to set up new results worksheets in the MS C model to keep track of summary metrics for a host of different program subtotal results, which she said would be helpful when they met with Tamara to compare and reconcile their final estimates.

Ava was amazed to see the results of her cost estimate in a new way; it was like seeing into a new dimension. Tim's words about providing a range of possible outcomes to decision makers resonated with Ava as Jasmine flipped through the different chart views and statistical summaries. Within her Production costs, Ava noticed that the point estimate, or calculated result of all her "most likely" cost inputs and methods, fell at only 34% probability within the uncertainty results. Without considering the range of possible outcomes associated with her inputs and certain methods (like her learning curve regression), Ava might have recommended an estimate far lower than the mean, or average value, than their uncertainty results suggested. Clearly, it was important to quantify all of the best information available, even its associated uncertainty, when building an estimate.



Percentile	TY$M
Mean	$ 2,930
Pt Est	$ 2,671
90%	$ 3,633
80%	$ 3,356
70%	$ 3,169
60%	$ 3,018
50%	$ 2,883
40%	$ 2,754
30%	$ 2,622
20%	$ 2,476
10%	$ 2,287
CV	0.182

Figure 49: S-Curve for Production Cost

Finally, Jasmine declared that it was time for “the tough stuff” and she set up a last meeting about uncertainty to integrate Joanna’s GFE inputs within their uncertainty estimate. Jasmine had helped Ava to automate her production quantities phasing while applying schedule-based uncertainty to durations within her estimate; she now explained that the exercise had been only the first step in tackling schedule uncertainty. The duration distributions that they had defined were in lockstep with those used within Joanna’s GFE estimate. Since their LCCE model included both the GFE and Vandalay portions of the AH-21 program, the uncertainty results for each should, to the greatest extent possible, reflect the same assumptions at the same time during the simulation. With the Army estimate housed in a completely different tool, it was a significant challenge to combine the estimates. Duplicating the detailed Army model architecture within the MS C model was not an option within the estimating timeline. Thankfully, Jasmine was able to combine a short, but specific, breakdown of Joanna’s estimate and mimic the overall range of each subtotal using curve fits that Joanna had provided. Jasmine then correlated the GFE variables in line with Joanna’s results and correlated the duration-driven portions of her estimate to their own Vandalay assumptions in order to ensure that those portions of their overall LCCE estimate moved up or down their respective ranges together during the simulation. Jasmine said that it wasn’t perfect, but it was a decent approach and the best that they could do within the time available. Ava was quickly learning that there was never enough time to approach every problem or scenario perfectly.

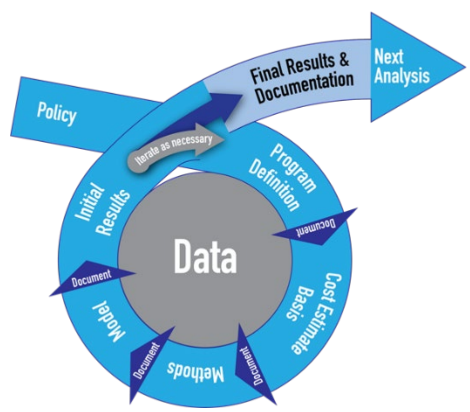
With that in mind, Ava turned her attention back to her estimating plan and the time they did have available. Jasmine was right; deadlines were approaching fast. There were only about a week before their final review with Jay, planned for July 19th. After that, they had another week to incorporate his comments and prepare to reconcile final results with Tamara and her management chain. Their CCP had to ready for review with the CAPE, then there were a handful of complicated-looking Cost Review Board (CRB) slides that Liam had shown her. They still had a lot of work ahead, but their estimate was finally complete. Liam warned her to hold off on the urge to use the term “finished;” they had completed development of their cost model and their initial estimate, but they had not received the final CARD from the SPO and numerous reviews awaited them. Ava knew that he was right, but they had also reached a milestone. She felt that she had crossed a milestone of her own; she had completed a full draft of her portion of the estimate and even acted as the lead integrator for their ASCAA cost model. She had learned so much about the cost estimating process; reading the guides had been helpful, but going through the process had already taught her more than she could have hoped for back in February when Jasmine first pulled the AH-21 estimating team together. As she looked forward, she wondered how much more she would learn as they worked to finalize, present, and document their MS C estimate.

It was now about 45 days prior to the CRB meeting. Ava knew from the estimating schedule that the ASCAA team owed the draft estimate to the Eduardo, as well as the final CARD. After learning from the SPO that the CARD would not be finalized for another few weeks, and discussing with Eduardo that they could provide a more complete estimate if he waited until after their review with the ASCAA director (July 19th), all parties agreed to delay these two deliverables. Ava worried that delivering these items late would reflect badly on the team. However, Jasmine, Tim, and Liam all assured her that this was very typical.

Critical Thinking Questions – Build Cost Estimate Model

- If your estimate is developed across a variety of tools, can you integrate all of the results in a detailed, defendable manner?
- Is reference to a single variable for different WBS elements introducing functional correlation?
- Are portions of the estimate functionally correlated by a shared input variable or uncertainty variable? Should they be correlated, or should they move independently of one another during an uncertainty simulation?
- What modeling tools exist outside of Excel that may be used for a cost model? What are the advantages and disadvantages of using them?
- How easy is it for someone else on the cost team to use the model? How about for someone outside of the estimating team?
- How will configuration management of the model be maintained? Why is this important?
- What documentation can be included within the model to explain how it works?
- What is the proper classification marking for the input data and the resulting model?
- What is the proper classification marking for input data and the resulting model? What about the estimate documentation?

Final Results and Documentation



Ava and the team set about preparation for their final internal ASCAA review with Jay and submission of their draft estimate to CAPE. Although Ava had a fair amount of working documentation prepared within both her portion of the cost model and her midterm review slides, she knew that much of her current documentation would need to be translated into a more detailed, cohesive final package that could stand alone, without a presenter's additional audio explanations, to communicate all aspects of their estimate and associated analyses. This way, a reader could understand ground rules, framing assumptions, input data, estimating structure, cost estimate assumptions, and methodology calculations, even if they were unfamiliar the program. The template that Liam had shown her actually did not contain too many slides, but it was comprised of slides that needed to be present within the team's brief for reconciliation and their final estimates. Following reconciliation with Tamara's POE, the team would need to update the CRB template slides would need to reflect their final CCP estimate. At the end of the day, they would have full documentation packaged for their ASCAA estimate, the POE, and their eventual CCP estimate. All three would contain the CRB template summary information, and ultimately the CRB slides would reflect the summary slides for their CCP and contain the full detailed documentation within backup. This way, those briefing their results up the review chain would have a consolidated, standard set of results slides while maintaining all of the backup detail that leadership might need to answer specific questions during the formal review process. Liam explained that their job was to prepare a package that their management both understood clearly and was comfortable briefing, since it would not be any of the team, Jasmine, or even Marta who presented the CCP at the DAB. As the division chief, Marta would probably accompany Jay, but Jay himself needed to understand the details and be comfortable communicating key elements to the final decision-makers.

Preparing Production Estimate Documentation

Ava was interested to hear that slides would continue to be the medium for their documentation. However, she realized that use of PowerPoint slides would allow her to quickly organize and emphasize specific information according to the audience at each step of the review process. Liam confirmed that most analysts used Microsoft Word for their written documentation; a narrative document was another effective and accessible medium that could easily grow and change over time. However, during the estimate review process, the goal was to communicate their results in a format conducive to presentation at a chain of meetings. With each higher-level review, the highlighted summary content would become narrower and more focused on the final CCP results. During reconciliation there would also likely be changes to their estimate. For these reasons, PowerPoint was the perfect, flexible medium to meet the need and allow for changes or tailoring in short order.

After their conversation, Ava looked back at the latter part of their original estimating schedule and printed out a copy of the dates and meetings ahead (**Table 32**). She had just over a week until July 29th when the documentation of their final estimate was due to Marta for her review.

Ava began to update her working brief by reviewing her inclusion of all basic details from her cost estimate plan. She had covered the purpose of her estimate, but she needed to incorporate a few other important details in order to revamp her brief into a stand-alone document. She added the organization that performed the estimate and when it had done the work. Next, she reviewed the ground rules already aggregated in her working documentation. Ava knew that these were very important to include with any stand-alone documentation; they established the "guard rails" to bind the estimate in terms of scope inclusions and exclusions, which would also be important to communicate early in any level of estimate review. Within the ground rules, she included a brief description of technical scope, acquisition strategy, and a high-level program schedule. In addition to these, she cleaned up a working level slide highlighting the base year of the estimate, procurement quantities by LRIP and FRP lot, and further detail on the (Incom) GFE material that the Air Force would provide to Vandalay. Finally, Ava separated a few additional ground rules into separate Acquisition and O&S sections. Here, she noted a few additional specifics on technical scope included or excluded from that portion of the estimate. For instance, within the Acquisition portion, she noted that the O&S portion of the estimate would capture the ongoing maintenance and support of the tactical software, developed and tested during the EMD phase of the program, rather than the Acquisition section.

After expanding upon the program-level documentation, Ava moved on to consolidation of the core estimate. The midterm reconciliation and peer review briefs had given her a significant head-start in summarizing the overall approach and many of the team's estimate details. However, she had updated or finalized several items during the modeling phase. She and Liam would need to expand their slides to cover uncertainty variables and distribution choices as well. Fortunately, Ava had been diligent during the modeling process; she had practiced good file management and already consolidated many of her relevant backup files, and within the team's methodology worksheets, and she had aggregated notes on relevant data sources for each particular worksheet. This made it easy to quickly add a concise list of their data sources to the beginning of each major portion of their estimate. She was able to flag which sources contributed to primary methodologies and which sources supported crosschecks or uncertainty parameters. Ava also had a few unused data sources identified within her working files. Instead of simply ignoring the unused data sources, she created a backup slide to document their review and the reasons she had ultimately avoided their use within her Vandalay labor or material estimates.

Table 32: AH-21 CACEG Final Review Schedule

Event	ACAT ID Days from CRB	AH-21 CACEG Dates	Duration Days
Final CARD to CAPE & ASCAA Draft POE and Draft ASCAA Estimate to CAPE	-45	~~July 11, 2021~~ July 19, 2021	34
ASCAA Final with ASCAA Director	-37	July 19, 2021	8
Final Reconciliation - Program Office and ASCAA	-30	July 26, 2021	7
Draft Reconciled CCP to ASCAA Director	-9	August 16, 2021	21
ICE/CCP Comparison Meeting	-7	August 18, 2021	2
Pre-CRB Meeting	-3	August 22, 2021	4
CRB Meeting	0	August 25, 2021	3
Formal ICE/CCP Meeting	2	August 27, 2021	2
Draft CCP Memo to Service Director, coordinate Full Funding language in ADM	4	August 29, 2021	2
CCP Memo meeting	10	September 4, 2021	6
Final CCP & Signed Full Funding to CAPE	11	September 5, 2021	1
OSD CAPE ICE Report/Brief (5 days after receipt of CCP & Full Funding)	16	September 10, 2021	5
OIPT	**21**	September 15, 2021	5
DAB	35	September 29, 2021	14

Within the Production portion of their core slides, Ava continued to subdivide the estimate into Incom's production (provided as GFE to Vandalay), Vandalay's modifications, and SPO management and support costs. The Incom portion centered on her final results from Joanna, the key cost drivers, and major methodologies inherent to those results. She further subdivided the Vandalay section into: Aircraft summary, Aircraft labor and material details, Aircraft below-the-line elements. Finally, she organized the SPO management and support portion according to the primary three personnel categories (i.e., SPO government, OGA, and SPO contractors), which corresponded to both the organization of their build-ups within her portion of the MS C model and the **Figure 32** drawing she had continually referenced over the last several months.

Each section included a short description of scope, and Ava included a small graphic in the top-right corner of each slide in order to orient the audience or reader to where the slide material fit within the overall system. As an example, **Figure 50** shows the orientation graphic Ava used on her Vandalay material estimate slides.

In each of her Production sub-sections, Ava gave clear explanations of the methodology, the relevant logic equation for the methodology, and a note on the phasing applied; she showed the sub-section estimated costs at the top of the first slide, in both CY and TY dollars. Ava again added a short series of backup slides to note WBS elements that she had seriously considered an alternate methodology for and the pitfalls that led her to ultimately discount the method from use as a primary methodology. This further increased the transparency of her estimate and overarching analysis. Beneath her methodology descriptions, Ava was careful to detail her efforts to normalize and validate her data. In hindsight, she noticed that several of her midterm documentation slides had omitted important steps that had seemed obvious at the time. At methodology levels where Ava had performed crosschecks, she included the description, again referenced the data source, and outlined similar methodology details to those included for primary methodologies. She knew that their inclusion would help to demonstrate that the overall Production estimate was reasonable, credible, and defensible through multiple means.

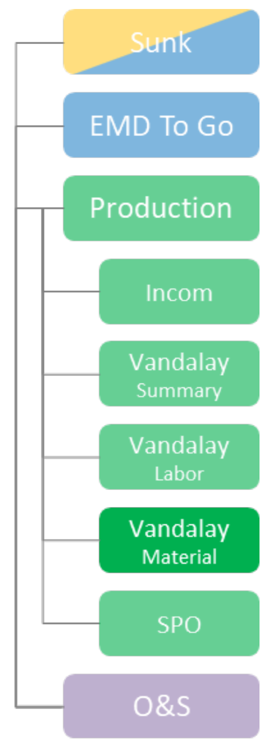


Figure 50: Slide Orientation Key

Following an overall summary of her point estimate and mean results, Ava incorporated a comparison to the same results from the ASCAA MS B Production estimate. At the total program level, her estimate fell within 10% of the MS B results. Portions of the estimate had decreased slightly while others had increased, but her average unit costs aligned well with the MS B results. This made sense to Ava since the overall program definition had not changed significantly since MS B, and she had built her estimate from a more granular level of detail (e.g., Vandalay EMD contract return data, the detailed Incom estimate in lockstep with Army AH-65E program assumptions, separate learning curve assumptions for the two production lines, and separate labor rate assumptions). The overall estimate demonstrated an increase over the AH-65E parent program's unit cost metrics (according to their most recent SAR); however, this was expected given the significant modifications (and technology upgrades) incorporated within the CACEG technical specifications.

Finally, Ava completed her Production documentation by including her descriptions of each uncertainty distribution applied within her cost estimate. Each uncertainty distribution included a graphic from the Excel add-in, which showed the distribution type and its defining parameters. Ava was able to add a line to each distribution showing the position of the point estimate within the distribution range. These key elements quickly oriented any reviewer familiar with probability to understand the range of input variables considered within the overall Cumulative Density Function, or s-curve, of uncertainty outputs.

Developing Charts

With her Production content nearly complete in the slide package, Jasmine asked Ava to turn her attention to creating several charts required either in the CRB slides or as standard ASCAA backup slides. She knew that the charts themselves could be a bit intimidating, so she pointed Ava towards the DoD Cost Estimating Guide, which discussed several common chart types, as well as the Air Force CRB templates and an example set of slides from another USAF estimate. Ava had also seen several of these while reviewing the AH-21 MS B documentation, and the DoD Cost Estimating Guide offered helpful descriptions of each alongside some best practices for displaying them clearly and effectively.

Ava decided that the first chart she would create was the Program Funding and Quantity chart, commonly known as the Spruill chart. This program-level chart showed current and prior year budget controls by appropriation and fiscal year and compared each to relevant portions of the cost estimate (labeled as "requirement"). This would be of key importance to decision-makers as they reviewed full-funding requirements of the program and would provide cost information in a standard format used across various types of weapon systems. Having preserved the Spruill chart architecture from the MS B model, it was relatively easy for Ava to populate the Spruill with updated budget controls and the cost estimate subtotals by year by appropriation. (It did require a few hours wait since Ava needed to request the latest CACEG program budget controls from the BFM in the SPO. Thankfully, the BFM understood the importance of this chart and provided the requested information quickly.) After updating all of the Spruill inputs, Ava was suspicious that she must have made a mistake – the total value in the Spruill table was meaningfully less than the total cost captured in the total cost summary worksheet of the model. After double-checking all the formulas and linked cells, she noticed that the Spruill table did not include costs for military personnel or other O&S phase costs not funded with the O&M appropriation. Worried that she had missed something, Ava sent Liam an email to confirm that this was correct. Liam explained that these elements were costs to the USAF that were directly attributable to operation of the AH-21 program and operations, but the CACEG SPO did not manage the associated budget lines. The Spruill focused on appropriations and budget line items directly attributable to Acquisition and O&S (and Disposal), but these additional elements contributed to the TOC to the Air Force.

Ava placed the updated Spruill chart prominently in her documentation and slides since she knew that deltas between the current budget and the cost estimate would be key points of discussion when reviewing the cost estimate with both SPO and ASCAA leadership. The Spruill chart would also document the estimated APUC and PAUC in CY dollars. Alongside the total LCCE, these two cost metrics represented important outputs of the overarching cost estimating process to support the OIPT and milestone. During their meeting to clean up the MS B cost model in preparation for MS C changes, Liam had explained that the APUC represented the total program procurement costs divided by the Production quantity; the PAUC represented the acquisition cost divided by the sum of both Development and Production quantities. He gave her a printout from the DoD Cost Estimating guide that outlined the build-up to the TOC (**Figure 51**) and added a few notes specific to their AH-21 estimate and the APUC and PAUC calculations.

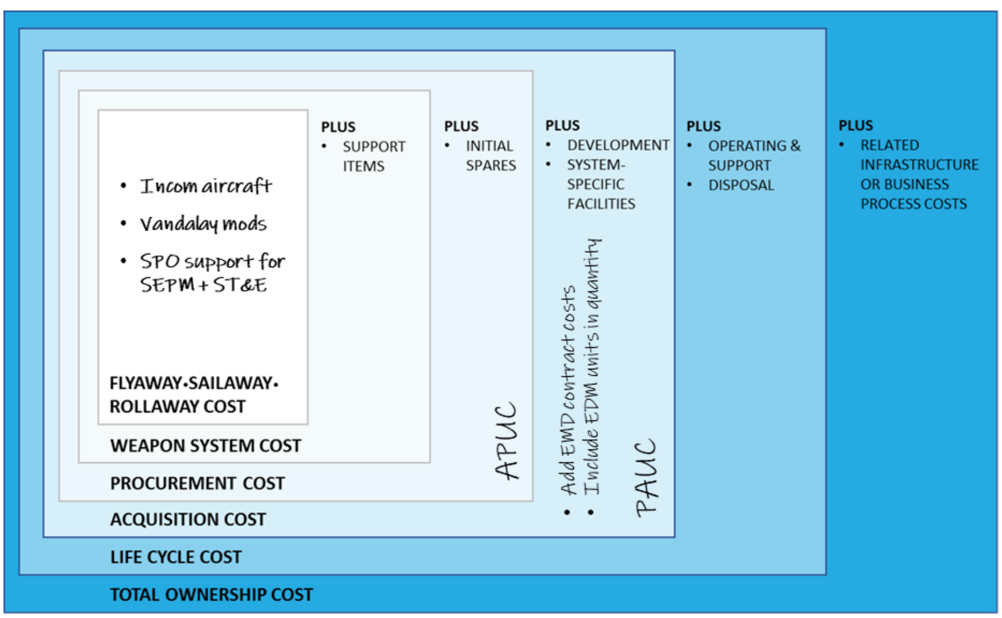


Figure 51: Total Ownership Cost Composition

Next, Ava decided to create a Pareto chart to show the largest contributors to the total cost of the Production portion of the program. While building this chart (**Figure 52**), she was careful to show cost contributors at a reasonable level of detail – too little detail could result in a nearly meaningless Pareto chart that would only show high-level scope items like "Aircraft" as cost contributors, while too much detail could result in a chart that was more confusing than informative. Ava settled on a level of detail within the WBS that allowed her to show Incom and Vandalay cost contributors for labor, material, and fee alongside SPO management and support costs for T&E activities and A&AS contract labor.

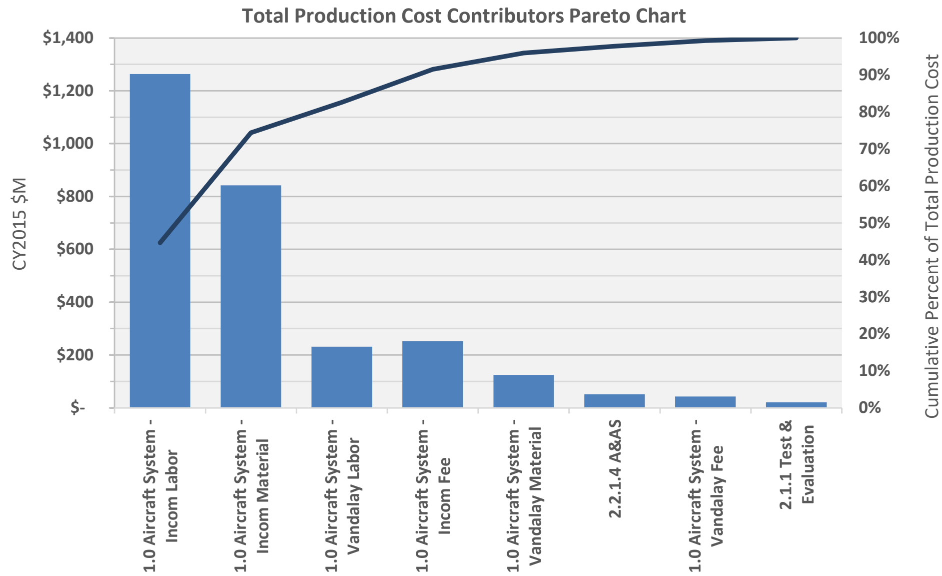


Figure 52: Total Production Costs (CY2015$M)

While generating the rest of the charts for her documentation, Ava kept in mind some advice from her team: "Be clear and concise in your presentation." To this end, she was careful to label her units consistently and to only include charts that explained issues anticipated by the team or helped to explain the output of the cost estimate. Ava avoided flashy graphics and other elements that could distract from the primary questions she was seeking to address through the charts she produced: How much does the program, and the elements comprising it, cost at the mean and/or across the range of predicted outcomes? What types of funding are required? When is the funding needed?

Finalizing Documentation & Pre-Brief with ASCAA Division Chief

Jasmine reviewed Ava, Tim, and Liam's individual slides and continued to align their formatting and language as the team added their chart documentation into the slide deck. She ensured that the flow of the presentation, as a whole, was well-organized. All overview slides essential to providing context for the program or an overview of the overarching cost estimate came first in the deck. Then the content proceeded to the detailed supporting information that each analyst had provided; these were organized in the general order shown in their slide orientation graphic (**Figure 50**). Ava placed highly-detailed backup slides at the end, with a section breaker slide to section them off from the "front matter" slides; these would not be printed or presented by default, but the team would carry hardcopies in case any were needed during questions or a "deep-dive" into details.

The team finally finished aggregating the deck and sat together to review the finished product. Jasmine felt that it was a strong representation of both their estimate and the analyses they had completed over the prior five months, and the team agreed that they were ready to brief Marta. It would be Marta and Jasmine who did most of the talking in their final review with Jay, and Marta would likely represent the team at higher level reviews leading up to the DAB. They needed her approval on both their results and briefing material before they could proceed to brief Jay again.

Marta had kept close attention on much of the work in progress, but their pre-brief of results in her office was the first time she had seen the entire estimate together, with all relevant details covered in the same level of detail. She pointed out a few spots where the team's internal jargon made it difficult for her to understand their full meaning and made just a few other suggestions. She complimented Ava on her slide summaries and the excellent job she had done explaining her Production methodologies and underlying data sources. Within her portion of the estimate, Marta suggested that Ava add a note on how she had reached her determination of the AH-51 subtotals for Avionics and Mission Systems as the most appropriate analogy for the AH-21 Vandalay labor effort. She also noted several places throughout the brief where she thought the addition of a "bumper sticker" (a prominent text box capturing the key takeaway from a slide) could be helpful for the audience. The team thanked Marta and began incorporation of her comments right away. They only had one working day to make the changes and prepare for the final estimate review with Jay.

Final CARD Delivery & ASCAA Estimate Final Review

On the morning of their final ASCAA review with Jay, the SPO delivered the final CARD to Jasmine. Tim, Liam, and Ava each independently confirmed that the final CARD addressed all outstanding issues described within the CRM. Additionally, they checked to ensure that all details and data inputs reflected the same SPO responses to earlier requests by the ASCAA team and Eduardo. These had been critical to completion of the ASCAA estimate and ICE, and the CARD needed to accurately reflect those inputs.

At the final review with Jay that afternoon, Jasmine confirmed that the SPO had incorporated all expected updates within the final CARD submission. She took a moment to review each analyst's area of responsibility within the cost estimate. She and Marta conducted the majority of the briefing session while the analysts stepped in to answer any of the specific questions Jay had. At the conclusion of their brief, he complimented their preparation and commented that he was impressed with their work. As Jasmine presented Ava's material estimate, Jay asked for more detail on the USAF military standard composite rate mentioned in Ava's slides, specifically asking if the rate she used included the retirement accrual. As Ava struggled to remember the exact definition of the rates, she realized that it would likely be better to "take an action" to provide him with this information after the meeting. She offered him the high-level information that she was absolutely sure of before acknowledging what she could not remember and making a note of the "look-up" action. Jay thanked her and was unfazed that she had forgotten the detail. Following the meeting, Ava went back to her desk and immediately began pulling together the information that Jay had requested. She included a new slide for the "backup" portion of their brief and sent a copy to Jasmine, Marta, and Jay. Ava was relieved to have resolved her first action quickly and thankful that their results had been well received.

Final Reconciliation

After working to incorporate Jay's comments on their slides, the team was ready for the final reconciliation meeting with Tamara and the SPO cost team. The reconciliation would be similar to their midterm review; the process remained identification of significant deltas between their two estimates and review of the underlying causes. However, this time their goal shifted to agreement on one final USAF estimate for submission as the Draft CCP, which would require a determination on which estimate to use as its basis. A third viable option existed as well. In accordance with their guidance from AFI 65-508 (**Figure 45**) and discussion during the CIPT kickoff, they could alternatively utilize portions of the data and methods associated with both the ASCAA and POE estimates in order to create a new hybrid estimate (**Figure 53**).

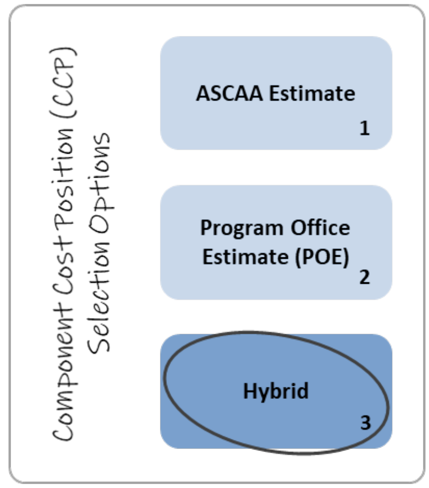


Figure 53: CCP Selection Options

During the final reconciliation meeting, it became apparent from comparing their cost contributor charts that Ava's and Tamara's costs for FRP units were quite different.

As they started to look into the elements driving the FRP unit delta, they realized that the difference stemmed almost entirely from their learning curve assumptions for the Vandalay modifications, which they had discussed but not resolved during their midterm review. Since their midterm reconciliation, Ava had maintained the same point estimate selection (with learning improvements assumptions based upon AH-51 program data specific to the Avionics (WBS 1.2.5) and Mission Systems (WBS 1.3) subtotals). After their midterm reconciliation discussion, she had proceeded to apply uncertainty bounds for her learning percentage based upon the comparable AH-65D and AH-65E data that Tamara used as her primary source. The ASCAA and SPO teams agreed that both learning curves were credible. However, Marta, Jasmine, and Tamara decided to use Ava's more conservative assumption within the CCP estimate. With its source data coming from a recent Vandalay assault helicopter program, the AH-51 was clearly applicable to the Vandalay modification work and would be easier to defend among those unfamiliar with Tamara's detailed analysis. (Tamara and Jasmine had both agreed that during high-level reviews the simplest answer was usually the best answer, or at least preferred over intricate details on data normalization.) Furthermore, the more conservative learning curve percentage would reduce the risk of production cost overruns during later production lots (i.e., FRP 2 and FRP 3) since the CACEG program would be fully-funded to either the CCP estimate or ICE depending upon selection by the Milestone Decision Authority (MDA).

While comparing the FRP unit delta, Tim pointed out that SEPM also showed a minor cost difference between the estimates. As soon as she saw the SEPM difference, Ava remembered that she had never revisited her SEPM estimate, which she had based on a ratio of AH-65E lot 3 SEPM to the total "touch labor". Tamara explained that her team had requested additional information from Vandalay about the FTE counts by year for engineering and program management on both the EMD units and for the AH-51 modification program. The team had then used that to build a level of effort estimate for the CACEG work, using FTEs and Vandalay labor rates. Tamara apologized for not sharing that data with either ASCAA or the CAPE, but Vandalay had only provided the requested information a few days before the reconciliation meeting. Jasmine and Tamara agreed that this was the better estimate to use in the CCP. Ava asked Tamara to provide that Vandalay data for her own records, and Eduardo remarked that he would likely update his ICE for that element if the data could be sent later that day.

Within their estimates for SPO support requirements, Tamara and Ava found another delta well over the roughly 10% threshold they deemed significant. Although the overall contribution to the total Production estimate was very little, they found that Tamara's travel requirements were close to 40% greater than Ava's estimated requirements. While Ava had used an analogy based on average annual expenditure data for FY2019-20 and applied no adjustment factor (since she assumed that the planned trip frequency would not change), Tamara's estimate consisted of a detailed build-up of annual requirements based upon trip counts. Tamara had researched both airfare and per diem rates on the GSA website; alongside the SPO's typical duration for quarterly meetings, she had calculated a cost per trip per traveler across the fiscal year (effectively capturing the seasonality of hotel rates). In line with calculations specified on the Office of Personnel Management (OPM) website, she adjusted the M&IE rates for two days at 75% (the first and last, or travel, days) on each trip. Furthermore, she had tailored her estimate based on expected travel durations for different portions of the team. After digging deeper into each of the two estimating methods, they found that Tamara's build-up included an assumed increase in travelers during the Production phase. Apparently, the SPO team would require additional personnel to attend the quarterly meetings in support of both EVM oversight and logistics team preparations for deployment of the aircraft. Tamara focused the discussion on her FY2021 estimate, where her assumed number of travelers was consistent with FY2019-20 trips, and showed the ASCAA team that the equivalent cost per trip was actually very similar to Ava's estimate by analogy. This demonstrated that the two estimates were well-aligned in terms of cost per trip, and that the increase to number of travelers within her more granular build-up was truly the main driver of the 40% delta between their estimates. This time, Marta and Jasmine acknowledged that Tamara's detailed build-up was the more accurate and defensible estimating method, and they opted to use her POE build-up for the CCP estimate.

The discussion of cost elements and compromises continued until both teams had reviewed the entire estimate. By the conclusion of the meeting, it struck Ava how significant the role of judgment calls was in arriving at each of their final results, particularly when the team found two different estimating methods equally accurate and credible. As this dawned on her, she realized in retrospect the importance of the somewhat mundane process of clearly documenting the choices she and others had made along the way. Without this insight, it would have been very difficult for someone outside the process to understand the disparity in the two teams' results. Fortunately, Ava's and Tamara's respective attention to details had allowed them to clearly show where they had diverged along the way and why both results were reasonable as a best estimate of an unrealized future cost. Overall, the team selected Tamara's methodologies for nearly all areas of the CCP determination. Apart from the Production labor costs influenced by their differing learning curve assumptions, a comparison of their top cost contributors had revealed deltas of less than 10% between the two estimates. Given the consensus on magnitude of estimated requirements and the robustness of Tamara's data analyses (e.g., Vandalay T1 labor hours methodology and SPO travel build-up), Marta and Jasmine agreed that use of Tamara's estimating methodologies and model, with several key modifications, would serve as the most defensible estimate. In addition to use of Ava's learning curve percentage, there were two minor changes within Tamara's O&S estimate that Marta requested (in alignment with Liam's assumptions) in order to produce the results for a CCP.

Preparing for the CRB

With their reconciliation between the ASCAA estimate and POE complete, Tamara and the team set about modifying the POE model according to their agreed-upon changes in order to generate the new CCP estimate. They had just one week before the August 16th review scheduled with Jay. As the ASCAA director, Jay served as the CIPT lead; he would need to approve their reconciled estimate as the Draft CCP before presenting it for approval (as the Final CCP) during the CRB.

Within just two days, Liam and Ava were able to provide Tamara with their backup documentation to enable incorporation of the necessary CCP methodology changes within Tamara's POE model. Tamara saved their finished product with a new file name indicative of the draft CCP, which was gratifying to all of the analysts. With just a few days left to prepare, they turned their attention to updating Tamara's POE documentation slides. There were only three significant modifications between the POE and their proposed CCP estimate; however, the changes affected a multitude of results tables and charts within the CRB template, as well as many of the necessary backup slides. The team needed to carefully update and review the entire slide deck prior to meeting with Jay.

Thankfully, Eduardo had not exercised the option to meet with the team on August 18th for a comparison between the CCP and ICE prior to the CRB. (Eduardo had reviewed their draft estimate documentation, provided at the beginning of the month, and he was comfortable enough with both estimates to delay comparisons to his draft ICE until after the CRB meeting.) Subsequently, the team invited both the AH-21 SPO leadership and Eduardo to join them at their review with Jay in order to keep all of the key players in the loop on their CCP estimate methodology. This scratched the "ICE/CCP Comparison Meeting" off of the final review schedule printed at her desk (**Table 32**), allowing the team to focus efforts on slide updates. They finalized the brief and completed reviews with both Marta and Tamara's boss just in time.

Throughout development of the ASCAA estimate and reconciliation meetings, Jay had kept a pulse on the AH-21 teams' progress (both SPO and ASCAA) leading up to final review of their reconciled CCP. Via formal briefings with his ASCAA estimating team and informal updates from Marta and Jasmine, Jay was well-informed of the estimating methodologies, final ASCAA estimate and POE estimates, deltas between the two estimates and the program's budget controls, as well as the teams' selections during final reconciliation. Thus, his final review of the reconciled estimate was more a formality with respect to approval of their estimate as the Draft CCP and heavily focused on preparation for the CRB meeting. All of the results slides within the CRB template were common between the ASCAA estimate documentation and Tamara's POE documentation, but this was his first look at the structure of Tamara's POE documentation, which had been the basis for this new CCP documentation. Even though most of their CCP documentation would remain in backup, only to be discussed if a stakeholder had specific questions, Jay needed to be comfortable with the slides he would carry with him to the CRB meeting. The ASCAA and POE teams fielded several questions from Jay about risks and opportunities highlighted during their reconciliation process. The AH-21 acquisition lead jumped in to support the teams' responses from the SPO perspective. Additionally, both Jay and Eduardo asked several good questions about crosschecks and comparisons between their AH-21 unit cost and the AH-65E new build unit costs, and the delta between EDM 2 costs and the CCP estimate for LRIP 1.

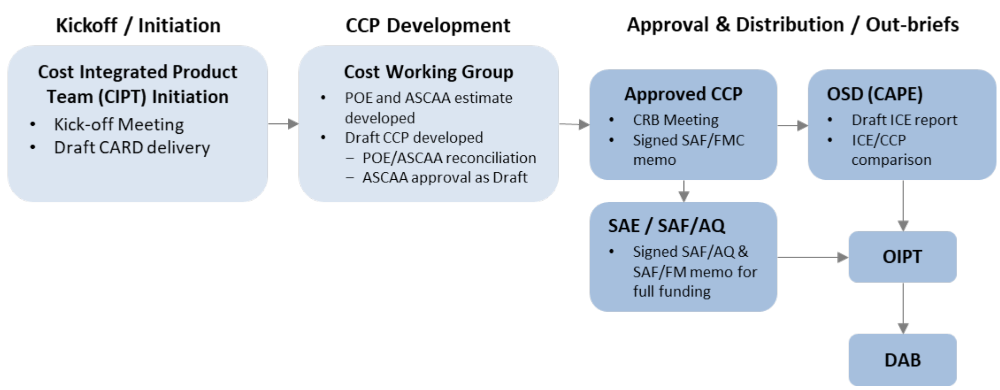


Figure 54: ASCAA-Tailored ACAT 1D CRB Process

With their reconciled estimate now approved as the Draft CCP, Ava refreshed her memory on the final review process for approval and distribution of the CCP (Figure 54). They had fully completed the CCP Development steps she had reviewed with Liam (Figure 46). Now her ASCAA leadership team would progress to the final steps outlined within the DoDI 5000.73 and AFI 65-508 processes. This began with Jay's submission of their Draft CCP to his boss for approval.

CRB Meeting and Beyond

Jay's presentation at the CRB meeting was well-received, according to Jasmine. She and Marta had been able to attend in order to answer any detailed questions about the CCP estimate, but space restrictions had limited Tim, Liam, and Ava to listening in via a conference line. (Verbal feedback during the meeting had sounded positive, but one never knew about expressions or side conversations during a phone call.) The CRB membership covered some of the same topics discussed in their last review with Jay, but the discussion had centered on technical risks of providing the airframe as GFE to Vandalay and the contractual clauses necessary to mitigate those risks. Eduardo had attended and fielded a few questions regarding his ICE analysis. Ultimately, Jay's boss, the Deputy Assistant Secretary for Cost & Economics (SAF/FMC), had approved their draft CCP as final. Barring the Production funding discrepancies, which the out-years of their Spruill chart highlighted, the ASCAA leadership felt confident that the CAPE's final assessment would be favorable to the AH-21 program proceeding to MS C.

A few days later, at their formal ICE and CCP meeting, Eduardo highlighted the procurement funding shortfalls late in the FYDP. However, his assessment went a step further than the CCP estimate, demonstrating even more risk in the out-year estimate (relative to FYDP budget controls) than the Air Force Component team had indicated. He too had based his unit cost estimate on the AH-65E new build product line, but he had given greater weight to Incom performance on early AH-65 variants, citing that successful EDM unit production by Vandalay was not a substitute for maturity of the Vandalay production line. (He did appreciate the team's selection of Vandalay's AH-51 learning curve for the modification estimate, and he acknowledged that his approach weighted the risk of the Vandalay modifications more heavily with respect to the fine-tuned Incom production of the base airframe.) His assessment included a note that his Production estimate fell within the CCP uncertainty ranges, and he acknowledged the Component's position of budgeting to the mean estimate whenever possible.

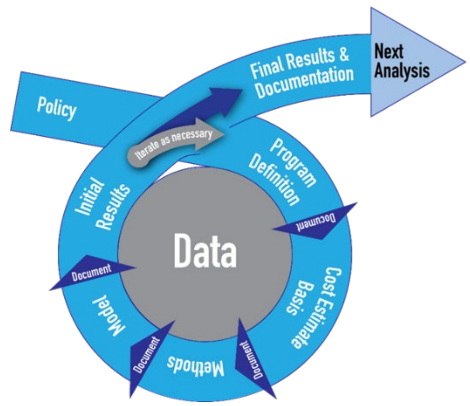
Marta was elated to be nearing the conclusion of another successful milestone. She put wheels in motion to draft the CCP memo for SAF/FMC signature, and once she had forwarded the memo to the SAF/AQ and SAF/FMB offices, she worked with the AH-21 acquisition lead to coordinate the additional full funding memo required. On September 3rd, Jay's boss met with her SAF/AQ and SAF/FMC counterparts to finish signature of both the Final CCP memo and its accompanying full funding memo. Marta sent both requirements to the CAPE, and five days later, the AH-21 team (both ASCAA and SPO) received a copy of the CAPE's ICE report.

Just a few weeks later, following a successful OIPT meeting, Jay returned from the DAB meeting with great news. The AH-21 program had successfully achieved its Milestone C decision! The DAB had approved the SPO to proceed with LRIP of the USAF's first heavy attack helicopter. During the meeting, Jay and Eduardo's boss had presented the CCP and ICE. After some discussion among stakeholders on the funding risks highlighted within CAPE's ICE, the MDA ultimately directed use of the Final CCP as the new APB via an Acquisition Decision Memorandum (ADM); he was comfortable with the Component's risk assessment. It was fantastic news; Marta, Jasmine, and the team congratulated one another all-around with handshakes and pats on the back before heading off just a bit early to toast their accomplishment.

Critical Thinking Questions – Final Results and Documentation

- What cost elements does a Spruill chart not include?
- How and where should final versions of the estimate model and documentation be maintained?
- Who should receive copies of the signed CCP memorandum? What about the signed ICE memorandum?
- Where can copies of prior estimate memoranda and documentation be found? Who can access them?

Next Analysis



The next day Ava returned to work on cloud nine. It had been a long six, almost seven months, since Jasmine had first called her in to assign her to the AH-21 estimating team. Now that their work was complete, she was not sure what to do with herself. In the few weeks between receiving the CAPE's final report and the subsequent OIPT and DAB meetings, she had completed the electronic cleanup and finalization of all their MS C supporting documentation on the ASCAA network drive. Jasmine and Marta had printouts of the final CRB slides on their shelves for reference, and Jasmine had told Ava that they would forgo any further documentation of the ASCAA estimate in Word format. Once the MDA signed out the ADM, Jasmine and Marta had coordinated with the AH-21 SPO and Tamara's leadership in order to update the APB cost tables. Tim, Ava, and Liam had each assisted by reviewing Tamara's draft tables before the MDA signed the APB.

With the milestone officially complete, Ava was at a loss, so she decided to see whether Tim and Liam were interested in a walk to her favorite coffee shop down the street. Along the way, they talked happily about how the last few months of reconciliation and CCP preparation had gone. Each analyst was excited to be less stressed about work and able to focus on more relaxed interests (like baseball playoff season and fantasy football, to name a few). During their walk back, Ava commented that she did not know what to do with herself for the rest of the day or the rest of the coming weeks for that matter. Both Liam and Tim raised an eyebrow. "You realize that the last six months aren't our normal, continuous work-pace," Liam said. "Sure, there will be other CCPs down the road; AH-21 won't be the only program you work on. But we've got the Full Rate Production decision just around the corner. That decision is less than two years away." They explained that their work responsibilities would slow down a bit and that they might have opportunities to help other ASCAA analysts either gearing up for, or in the throes of, other milestone estimates. However, in the same way that Tim had been tracking progress on the EMD contract, Ava would need to begin monitoring the Production contract that the SPO had just awarded. (This reminded Ava that she still needed to connect with the SPO and DCARC teams regarding the CSDR planning for the Production contracts.) There would be EVM submissions and CSDRs to review before she knew it, and both Jasmine and Marta's preference was that the team monitor progress and maintain their estimating methodologies as this new cost and performance data became available. By the time the FRP decision arrived, new data would be available for better crosschecks and perhaps even better estimating methodologies. Their time spent in the interim, keeping an ear to the ground on Vandalay's and Incom's respective performances, would only serve to improve the next estimate. "Interesting," Ava thought. The immediate goal of the MS C decision and an LRIP contract award had consumed her entire focus. Now she would get to follow the progress of the

Production estimate that she prepared; observing how closely she and Tamara had come to the truth, which risks and opportunities the SPO successfully avoided or actually achieved. It would be exciting to continue working on the CACEG program and to see it progress to an operational program firsthand.

Just then, one of the many Army helos crisscrossing the city buzzed overhead. Ava realized that soon she might be able to actually see AH-21s at work; it would be amazing to visit Vandalay again, but even one of those posters of a completed Production unit would be cool to see in her cube each day. She would go on to help on plenty of other programs in her career, she was sure of that, but it would always be gratifying to read about the AH-21s in action one day. She smiled and held the door open for Liam and Tim as they arrived back at the ASCAA building. For today, a nice coffee break and finally knocking out her overdue DoD training requirements would be gratifying enough.

Critical Thinking Questions – Next Analysis

- What is the value of maintaining communication between the SPO, Component, and CAPE cost teams between the major milestones?
- As analysts move on to new projects, how is the collective knowledge gained during the milestone process maintained?
- What lessons learned (data sources, new methodologies, cost research, etc.) should be shared with colleagues or the larger cost community? How should it be shared?
- How often are new EVM and/or CSDR data expected? When should this data be incorporated into the cost model? Can the cost estimator do anything if the expected data is not submitted?
- How can an estimator keep up to data on the current events in the program, without burdening the program office with questions or requirements for reports?
- How will current and future events impact the next estimate for this program?