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Advancing EVM with a Modernized Framework

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Abstract

DoD's FY24 proposed procurement budget is $842 billion. The cornerstone of this budget is the procurement of complex, technologically advanced systems. DoD programs require new technologies to meet end-user requirements; however, the challenges inherent in new technology often translate to significant cost growth. Program Managers utilize EVM analysis to make informed decisions and mitigate contract cost growth. The IPMDAR exemplifies DoD's recognition of the need for meaningful data by requiring a modernized data schema in the form of a machine-readable format providing near real-time cost performance. Likewise, Technomics implements a modern approach to EVM using data analytics software and Business Intelligence tools applied through a framework that incorporates a comprehensive view of EVM. This paper describes Technomics' EVM Framework (EVMS Surveillance, Contract Startup, Data Aggregation, EV Analysis, and Program Management), which implements modern tools to not only reduce recurring monthly reporting tasks but also perform powerful EV analysis that enables programmatic decisions.

Keywords: Data-Driven, Government, IPM, Performance Management, Program Management, EVM

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1 Introduction

1.1 Overview

The proposed budget for DoD in FY24 totals $842 billion. A key component of this growth is the need to develop and/or procure technologically advanced systems to stay ahead of adversaries around the world. Advanced technology often comes with increased complexity and risk. GAO's FY23 Weapon Systems Annual Assessment reports that the total planned investment to acquire the costliest weapon systems was at least $1.9 trillion dollars[1]. GAO completed assessments on 35 Major Defense Acquisition Programs (MDAP) programs. These programs saw total cost estimates rise by approximately $37 billon from the past year. Of the 35 programs, GAO analyzed cost changes for 32 that had been assessed in previous reports. Fourteen experienced cost growth of approximately $50 billion, with around $47 billion due to rising modernization costs, production inefficiencies, supply chain issues, and others. The remaining eighteen reported cost reductions totaling $13 billion due to cutting units, adjusting inflation calculations, and production efficiencies. Cost growth continues to be prevalent among acquisition programs, necessitating the need for effective project management and the ability to monitor program cost and schedule.

A longstanding, proven method for managing complex projects is Earned Value Management (EVM), a project management technique that has been integral to DoD program manager and contractor performance cost/schedule measurement since the 1960s. This technique integrates cost, schedule, and technical scope to assess program progress against a baseline for the purpose of identifying risk or opportunity and estimating cost at completion for defense contracts. EVM arms the government and industry with actionable information to identify or anticipate problems. EVM is a data-

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[1] "Weapon Systems Annual Assessment: Programs Are Not Consistently Implementing Practices That Can Help Accelerate Acquisitions." Government Accountability Office, GAO, 8 June 2023, www.gao.gov/products/gao-23-106059.

driven technique that relies on time serious data (i.e., monthly submissions) to analyze program trends over time (i.e., contract periods of performance).

The size and complexity of the EVM deliverables DoD requires industry to submit is growing and affords analysts access to an increased volume of information. The DoD's Integrated Program Management Data Analysis Report (IPMDAR) is an example of a deliverable contributing to this volume. Residing within the Office of the Assistant Secretary of Defense for Acquisition (ASD(A)), the Office of Acquisition Data and Analytics (ADA) Integrated Program Management (IPM) division reported that, as of June 2022, 23 programs had the IPMDAR on contract and 156 submissions were resident in the EVM Central Repository (EVM-CR). As of January 2023, this number had increased to 33 programs and 437 submissions.

Details on deliverables like the IPMDAR will be addressed later in the paper to highlight how a novel, data-centric approach is necessary to handle these complex data formats. EVM analysts need an organized and holistic Framework to properly handle EV data and provide efficient and effective program management. The robust Framework outlined herein clearly lays out and defines the steps of the EVM process, enabling the key points of each to be properly identified and addressed.

1.2 Problem

EVM suffers from several common pitfalls in the absence of a holistic Framework. In addition, EVM has been slow to incorporate modern tools and processes into its lifecycle. These issues are listed in Table 1 with details on how they typically manifest across programs that utilize EVM.

Table 1: Issues in Typical EVM

Issues	Description
Traditional EVM is Not Holistic	EVMS compliance and surveillance is seen as an oversight function (e.g., DCMA)
	EV Analysts focus effort on monthly analysis, leaving out other key steps
	Impact of early lifecycle steps is overlooked until too late
	CDRL development does not always include EV analyst

Lack of Analyst Involvement in EV Data Structure	Program office needs are not understood or accounted for in the CDRL
Inefficient or Ineffective Processes to Support Program Management	Failure to collect and use historical data to justify EAC methods
	Lack of streamlined processes throughout the lifecycle
	Ineffective and/or outdated communication methods to present findings

These issues can lead to time and money required to correct missteps, reduced value of the EVM data, use of flawed data, or analysis that is not supported by prior experiences. The Framework proposed and detailed throughout this paper lays out a holistic view of EVM that accounts for the areas where these issues occur.

1.3 Solution

In order to affect improved acquisition outcomes, EVM practitioners need to think holistically with a cradle-to-grave mindset to understand how each step is connected and impacts downstream steps. The EVM Framework does exactly that by breaking the process into key components, defining each component, identifying downstream impacts, and implementing modern tools to facilitate efficient and effective program management. This Framework comprises: EVMS Implementation/Compliance/Surveillance, Contract Startup, Data Collection and Aggregation, EV Analysis, and Program Management. Each step of the Framework contains key areas of focus to support EVM activities.
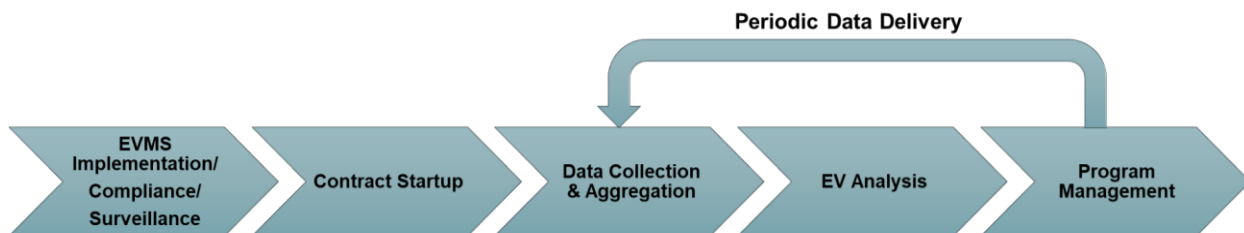

Figure 1: EVM Framework

- EVMS Implementation/Compliance/Surveillance
    - Assessment of a contractor EVMS utilizing data quality indicators and system description reviews.
- Contract Startup
    - Establishment of contract requirements in the SOW and CDRLs to support program analysis.
- Data Collection & Aggregation
    - Initial receipt and continued aggregation of data over time
    - Validation of incoming deliverables
- EV Analysis
    - Monthly analysis of program data to perform trend analysis and develop EACs.
- Program Management
    - Management of the program utilizing insights gained from EV analysis.
    - Development of client-specified tools that provide oversight into program contracting, budgeting, and management.

This Framework constitutes a repeatable process that ensures later analysis and program management avoids early missteps. This paper elaborates on each step of the Framework by defining the step, identifying key aspects, and providing examples that emphasize the purpose of this decomposition. The Framework provides the most benefit when implemented at the program office level but is a useful tool for any involved in the EVM process, most notably, industry and oversight organizations.

1.4 Modern Tools Definition

Modern Tools are the backbone of the EVM Framework proposed above. These tools include programming languages such as R, dashboarding tools such as Power BI or Tableau, and Excel features such as Power Query. These tools differ from others in that they can process large amounts of data efficiently, automate loading data, and produce repeatable analyses.

In addition, they offer visualization methods not available through other tools such as dynamic filtering when interacting with visuals. Dashboarding has expanded how

analysts can communicate with their clients through interactive features, compared to static PowerPoint briefs and written reports. Dashboards provide the ability to explore areas of interest or answer questions in real time that previously required back and forth communication to resolve.

Finally, automation drastically reduces time spent in setup and validation, allowing analysts to focus on analysis. A common criticism of EVM is that information is too delayed and therefore less valuable by the time the program office receives the results of analysis. Automation translates to significant processing and analysis cycle time reduction and quicker program office access to actionable information. In short, modern tools change the way analysts handle, view, and communicate data that improves the EVM process.

2 EVM Framework

2.1 EVMS Implementation

EVMS implementation, compliance, and surveillance are the foundational pillars that can determine the success or failure of a program's EVM application. As EVM reporting standards have changed over the years, updates to the EVMS Implementation processes are required as well:

- o In March of 2005, the Contract Performance Report (CPR) outlined by Data Item Description (DID) DI-MGMT-81466A required the submission of Formats 1 through 5:
    - Format 1: Cost and schedule data summarized by Work Breakdown Structure (WBS)
    - Format 2: Cost and schedule data summarized by Integrated Product Teams (IPT)
    - Format 3: Baseline plan
    - Format 4: Staffing forecasts
    - Format 5: Narrative report that detailed variances

- o In June of 2012, the CPR transitioned to the Integrated Program Management Report (IPMR), as defined in DID DI-MGMT-81861 and would eventually include schedule data incorporated in the same submission.
- o In March of 2020, DID DI-MGMT-81861B established the IPMDAR format which eliminated the Formats 1-5 structure to which industry had become accustomed over the last several decades.

Establishing a repeatable data pipeline to effectively utilize the newly implemented IPMDAR format is now a pivotal step for managing a program using modern earned value techniques. The transition from the human-readable formats of IPMRs to the machine-readable JSON files of IPMDARs opens a new world of possibilities from a data analytics standpoint. The introduction of the IPMDAR also marks the beginning of new data collection efforts as the ADA now requires the successful submission of IPMDARs to the EVM-CR. The ultimate objective of the EVM-CR is to create a data repository for future programs to leverage when assembling and assessing cost and schedule estimates. Program Offices and EVM analysts are now responsible for assessing contractor performance using EVM metrics while simultaneously ensuring that data is properly integrated into the EVM-CR. These significant changes in the data reporting process also create new data processing challenges that need to be addressed by both reporting defense contractors and Government reviewers.

2.1.1 EVMS Implementation Incorporated into the Modern Framework

From the Government's perspective, effective implementation of an EVMS should encompass more than simple assurances that a contractor has a reporting system that can pass the standard DCMA EVMS Compliance Metrics (DECM) checks. The switch to the IPMDAR reporting standard emphasized the importance of establishing an automated, repeatable process for the creation and delivery of data from the contractor at the outset of the program. In turn, the Government should be able to process, validate, and highlight issues with IPMDAR submissions efficiently to provide feedback to the contractor. If this wider and more holistic approach to EVMS implementation is not taken, the IPMDAR submission can quickly morph from a valuable, digital,

government asset to a burdensome CDRL submission that costs the taxpayer money while eroding contractor relations.

2.1.2 Elimination of Manual Intervention

The process for creating and delivering monthly IPMDARs (inclusive of subcontractor data) should have as few manual interventions (copy/paste, manual typing, etc.) as possible. Contractors with compliant EVMS systems can often still run into issues when generating IPMDARs due to lack of experience with the new file format. Contractors should work directly with the providers of the EVM accounting systems if they find themselves manually manipulating data within the Cost Performance Dataset (CPD) or Schedule Performance Dataset (SPD) to align with the DID. The DCMA EVMS Center also has designated SMEs to contact for questions regarding Policy, Training, and Tools.[2]

Similarly, Government reviewers should use available data tools, such as R or Power Query, to create repeatable processes that quickly provide feedback to contractors on cyclical deliverables. IPMDARs make manual inspection of raw JSON files largely infeasible. This necessitates automated checks that should replace the traditional, manually developed Comment Review Matrix (CRM) that is often the vehicle for feedback for CDRLs.

2.1.3 Data Integrity Indicators from Publicly Available Tools

The contractor should also be made aware of publicly available tools for IPMDAR data validation and should understand how to assess data quality before monthly submissions are first delivered. The Office of the Secretary of Defense (OSD) EVM Central Repository website has step-by-step instructions on how to use the modern EVM data formats with downloadable desktop tools to view and validate IPMR/IPMDAR

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[2] "EVMS." *DCMA Data-Driven Earned Value Management System Compliance Pilot*, www.dcma.mil/HQ/EVMS/. Accessed 8 Feb. 2024.

files.[3] Those tools allow contractors to test their datasets for compliance with the IPMDAR Data Exchange Instructions (DEI) and File Format Specification (FFS) for the CPD and SPD. There are also sample datasets and additional training information located on the OSD Website.

It is also possible for an IPMDAR submission to successfully pass through the publicly available tools from OSD while containing errors in the underlying data. In addition to the DEI and FFS assessments, it is also best practice to check the internal logic of an IPMDAR submission. Table 2 shows a sample of high level internal checks that can be performed in data tools, such as R or Power Query, to ensure that the data reported in the IPMDAR is free of glaring issues such as having a negative Budget at Complete (BAC) value in a Work Package (WP), or an Estimate at Complete (EAC) for a WP that is less than the cumulative Actual Cost of Work Performed (ACWP) for that WP.

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[3] Webmaster, OUSD A&S. "Assistant Secretary of Defense for Acquisition." *EVM-CR Resources*, www.acq.osd.mil/asda/ae/ada/ipm/resources.html. Accessed 8 Feb. 2024.

Table 2: IPMDAR Logic Checks

Indicator	Definition
1	BCWS_C > BAC
2	BCWP_C > BAC
3	ACWP_C > 0 & BAC = 0
4	ACWP_P > 0 & BAC = 0
5	BAC < 0
6	BAC = 0
7	LOE EVT w/ SV != 0
8	BCWP_C > 0 & ACWP_C = 0
9	Completed Work (BCWP_C = BAC) w/ ETC > 0 (ACWP_C > EAC)
10	Incomplete Work (BCWP_C < BAC) w/ ETC = 0 (ACWP_C = EAC)
11	Completed Work (BCWP_C = BAC) w/ ACWP_P > 0 & BCWP_P = 0
12	CPI - TCPI > 0.1, implying overly pessimistic EAC
13	CPI - TCPI < -0.1, implying overly optimistic EAC
14	ACWP_C > EAC
15	BCWS_C < 0 or BCWS_P < 0
16	BCWP_C < 0 or BCWP_P < 0
17	Reported PC > 0 w/ BCWP_C = 0 or PC = 0 w/ BCWP_C > 0

These checks are a reference to the DCMA Data Integrity Indicators listed within the EVMS Program Analysis Pamphlet. Data quality indicators inform the contractor whether the IPMDAR submission complies with contract language and will be usable by the Program Office. Indicator results can also inform analysis of possible issues within the contractor's EVMS. Both parties have a role to play and should become familiar with the resources available to them to fully utilize the IPMDAR to its fullest potential.

2.1.4 CDRL Rejections

Program offices should understand the importance of receiving compliant and usable EVM data early in the program and should reject IPMDAR submissions that do not meet data quality standards. Data cleansing can be a tedious process on a single program, but if the Government's repository of IPMDARs is riddled with non-conforming datasets, the value of this data for use on future programs is essentially nullified. Rejecting CDRL submissions is never a Program Office's preferred choice as it costs time and money while putting a strain on the client-contractor relationship. Going into a contract

negotiation with a clear idea regarding expectations for IPMDAR submissions can be mutually beneficial for both parties if acceptance criteria is clearly enumerated from the start.

2.1.5 Oversight Organizations

If data submissions repeatedly fail to comply with the contract, it is important for the Program Office to understand where to turn to help enforce IPMDAR CDRL requirements. Analysts should be aware of compliant data standards through oversight organizations (e.g., DCMA DECMs) to ensure the data in their deliverables is compliant and provide information to the contractor where it is not. The Earned Value Management System Interpretation Guide (EVMSIG) is the cornerstone to EVMS compliance, and the 32 Guidelines outlined by that document are the basis for the DoD's EVMS compliance assessments. Both contractors and the Government team should be well versed in all aspects of EVMS compliance, and should have a robust understanding of the DID, FFS, and the 32 Guidelines as they relate to their specific program. To support the proper compliance, the Government team should strive to automate the validation of contractor's IPMDAR submissions. Though this may not be the Program Office's top priority, helping the contractor better understand their data issues by illuminating specific deviations from the DID, FFS, or 32 Guidelines will ensure that the dataset is useable and in turn support the crucial analytical methodologies listed in Section 2.4 below.

2.2 Contract Startup

The second step in the Framework, Contract Startup, is the initial step of the EVM process for a program office. (Note: The first step in the Framework, EVMS Implementation/Compliance/Surveillance, is focused on ensuring the contractor's system aligns with the EIA-748 standard, which requires less involvement from the program office.) Contract startup stands out and requires its own place in the Framework due to how it shapes the EV Analysis and Program Management steps. This step encompasses development of the SOW and CDRL for the EVM deliverable. These two artifacts dictate what format the EV data will be delivered in, the granularity of the data received, and, ultimately, the usefulness of that data in addressing program

needs. Contract administrators often overlook the importance of this step by copying sample CDRLs or leveraging the work from similar contracts. During contract startup, programs are juggling a variety of responsibilities and a program office may see an EVM CDRL as business as usual. If that is the case, the data received may fail to meet the needs of the program office. The SOW and CDRL are important pieces as the avenue for the program to shape data that will be received.

2.2.1 Contract Startup Incorporated into the Modern Framework

Identifying Contract Startup as its own step in the EVM Framework ensures that it is given the attention it requires. This step determines what the Data Collection and Aggregation step will receive, the types of EV Analysis that can be performed, and how effective the information will be for Program Management. An EVM analyst should understand the customers' needs and help shape the CDRL to meet those. Depending on the standardization of a deliverable within an organization, this step can provide a head start to the Data Collection and Aggregation step as an analyst will know the data type and structure that will be received. This is especially true of the IPMDAR with multiple sample data sets available and less variability in the format/structure. Performance can still be measured if the CDRL is not tailored to the needs of the program office, but it will be less valuable.

Unlike other steps in the Framework, there is less that can be done to modernize the approach to contract startup. Rather, focus must be placed on understanding the deliverable and how to implement program needs in the CDRL. Contract start up should receive proper attention by compiling lessons learned, developing template CDRLs, and applying those to future contracts. The following examples will dive into two relevant areas to examine how the choices made here can shape future analysis.

2.2.2 IPMDAR

The IPMDAR exemplifies the importance of the Contract Startup step. It contains a variety of tailoring options that lead to different levels of granularity in the data. If these are not specified in the CDRL, analysts may be left with data that will limit their analysis. It is also important to forecast where data could be used beyond the current program. Specifying certain configurations and other tailoring options supports the use of this

data into the future for studies, method development, or for comparison to analogous programs.

The first area to understand is the IPMDAR's dataset configuration. The dataset configuration defines the granularity of the data within the deliverable. Configuration options are defined in Table 3.

Table 3: IPMDAR Dataset Configuration

Configuration Option	Description
Time Phased To Date	Data can be provided as time phased to date. All data prior to time now would be provided by period for all control accounts or work packages. If not requested, historical data will be provided as a cumulative value.
Direct Values in Detail Data	If requested, the direct cost by control account or work package will be provided. It will also be provided for each element of cost if that level of detail is requested. If not requested, it will only be provided at a total level.
Indirect Values in Detail Data	If requested, the indirect cost by control account or work package will be provided. If not requested, it will only be provided at a total level.
Work Package or Control Account Reporting	Data can be provided at the work package or control account level.
Element of Cost Data	If requested, element of cost data (labor, material, ODC) will be provided by control account or work package
OH, COM, and G&A Burdening	Each indirect element can be added, or not, to the total value in the detail data.

Each configuration option detailed in Table 3 leads to a variation in the data delivered by a contractor. At the maximum level of detail, a monthly deliverable will have:

Table 4: Maximum Level Configuration

Configuration Option
Time Phased To Date
Direct Values
Indirect Values
Work Package Reporting
Element of Cost
OH, COM, and G&A Burdening

In contrast, at the minimum level of detail a monthly deliverable would contain:

Table 5: Minimum Level Configuration

Configuration Option
Cumulative To Date
Control Account Reporting
OH, COM, and G&A Burdening

Dataset configuration choices significantly change the depth of data received and the types of analysis possible. These selections should be made with an understanding of program needs, value for future analyses, and pros/cons of the selection. From an analyst's standpoint, the maximum level of detail allows the flexibility to tailor monthly analysis to the intended audience while containing the underlying information required to answer certain questions. These decisions should also be made with the next steps of the Framework in mind. For instance, maximum level of detail leads to large datasets, increasing the importance of streamlining the Data Collection and Aggregation step via an efficient process utilizing the appropriate tools.

The data set configuration for the IPMDAR is one of the main ways to tailor the deliverable, but only effects the contract performance data (CPD). An additional tailoring option is custom fields. Both the CPD and SPD allow for custom fields that provide custom tagging to control accounts, work packages, and schedule activities. It is important to assess the need for custom tagging by, again, understanding the needs of the program office. Tagging CLIN/SLINs, Non-Recurring vs. Recurring, variants or ship sets, or risk register items in the schedule could be beneficial for a program office. The WBS may not be conducive to answering all questions, but custom tagging can help bridge that gap. Failing to identify and implement these during CDRL development limits the use of data during analysis as well as leads to unforeseen costs to amend the contract.

2.2.3 CDRL Content

The CDRL that dictates the format and structure of the EV data is the major component of the contract startup step. The previous section presented this for the IPMDAR, but other requirements can be defined in this document. The IPMDAR is not standard for all

Departments or Agencies, as many others have their own or rely on legacy formats. Regardless of the format in which EV data will be delivered, development of the CDRL provides the opportunity to include additional information for later analysis or to ensure the structure of the information meets the needs of the program office.

For example, a program office could dictate through the CDRL to track progress or EV metrics based on deliverables. Conveying this through the CDRL ensures the contractor can appropriately organize their reporting structures. If multiple systems or variants will be under development simultaneously, there could be a need to track the progress individually. Failing to specify EVM reporting by system or variant lessens the value of EV data to the program office as they will not have insight into key areas.

Not all EV deliverables contain the granularity of control accounts and work packages needed to perform analyses desired by the program office. In this instance, a supplemental accounting file may be the correct request to meet those needs. This supplemental file contains a more granular level of data than the EV deliverable, is easier for a contractor to export from their system and does not require the same rules as the EV data. It can be an excellent source of supplemental data to enhance analysis as well as fill data gaps the contractor does not meet in the EV format. Ultimately, the CDRL is an important contractual document that can set the program up for successful data analysis and program management insights if used to collect the right information.

2.3 Data Collection & Aggregation

Data Collection and Aggregation can be one of the most time intensive steps within the EVM Framework. With standard, machine readable data formats and modernized tools, this step can be entirely automated. EVM analysis can inform program level decision making when the EVM data is new, but its relevance fades as the data ages. Old data can still be valuable for other programs to leverage for planning purposes, but if a Program Office would like to use their program's EVM data they should move quickly. Time invested up front, on Validation and Verification (V&V) by both the Government and the contractor, can lead to quicker IPMDAR submissions, quicker responses to contractor deliverables, and the establishment of repeatable processes to accelerate analysis of program data.

This also provides a good example of the incorporation of modern tools into the Framework. The Framework operates seamlessly with the use of software that integrates into one another by incorporating automated processes. As mentioned in Section 1.4, the EVM analyst can use modern tools (Python, R, Power Query, Power BI, etc.) to connect to a user-defined database creating a linkage from the most up-to-date data (cleaned and normalized) to EV Analysis tools. Scripts or functions update these tools to complete the automated process, allowing more time for the user to focus on using the analysis to derive conclusions on program status instead of "manually" updating spreadsheet visuals and tables. Any time saved with the automation of visuals and reports can be reinvested performing deep dive analysis or special analysis requested by the program office.

2.3.1 Data Collection & Aggregation Incorporated into the Modern Framework

As an example, the IPMDAR data format can turn from an incredible asset to a serious hindrance for a program. If a contractor fails to establish a data pipeline before the first IPMDAR submission is due or if early submissions contain non-compliant data, the program office will lose valuable insight. At that point, the analyst must halt their current analysis to rectify any data issues. Including V&V steps in the Framework reduces issues that may arise during the EV Analysis step, due to the hands-on nature of working with the actual data discussed in later in Section 2.4. The Government's span of control decreases with each day of a program; lacking EV data early hampers the ability to affect change. Enablers for successful data collection and aggregation are divided between nonrecurring startup efforts and recurring monthly tasks. Once data has been validated, the contractor submits IPMDARs to the EVM-CR maintained by the ADA's IPM division.

Figure 2: EVM Central Repository Workflow[4]

Figure 2 outlines the overarching data pipeline responsible for collecting, reviewing, aggregating, and publishing valid IPMDAR data for future programs to use.

2.3.2 IPMDAR Specific Government Efforts

Early meetings following contract actions that level-set team expectations and maintain open communication channels are essential. Since EVM can be dismissed as a "check the box" type of CDRL, it is important to ensure that the contractor understands how imperative it is to produce sound data submissions. Additionally, changes such as additional WBS elements can cause issues in the inputs and/or outputs of the EVM tools and visuals. These EVM tools may not be set up to capture new WBS elements which will omit important program risks from monthly analysis. V&V processes easily capture the added WBS element, update the database, import the associated EVM data with the WBS element, and recreate the EV Analysis with the entire WBS into the monthly deliverable.

Identifying such nuances may be a difficult task for contractors who are new to the IPMDAR format, and they may struggle with the delivery of timely, compliant submissions. Addressing those issues quickly can set the tone for the working relationship between a Program Office and an OEM for the execution of the contract.

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[4] United States, Congress, ADA IPM. *Earned Value Management Central Repository (EVM-CR) Review User Guide.* https://www.acq.osd.mil/asda/ae/ada/ipm/docs/user-resources/EVM-CR%20Reviewer%20Guide.pdf.

Automation of data validation utilizing flexible data wrangling tools (such as R) is crucial for providing early feedback to the contractor to address non-compliance with the FFS or the DID. Providing the contractor with specific errors and the locations of those flags can significantly cut down on the time it takes to correct flaws in the data. Though the Government team is informing the contractor of deficiencies, it is important to establish a collaborative process at the outset of data reporting that improves contractor relations and ensures faster Government receipt of compliant submissions. Any time-savings due to automation of V&V checks and error reporting can be reinvested to perform deep dive analysis for the Program Office, thereby ensuring the appropriate data is leveraged to make proactive program decisions early-on in the program lifecycle.

2.3.3 IPMDAR Specific Contractor Efforts

Custom IPMDAR fields specified during contract negotiations are crucial for tracking specific program objectives such as performance data per system. These custom fields should be tailored within the contractor's EVMS using a configuration that is easily updated and repeatable month to month. Similarly, establishing defensible and repeatable processes for tracking agile software development progress or incorporating subcontractor data into the IPMDAR data submissions are crucial yet often overlooked steps in the EVMS process. The contractor should refer to the OSD and DCMA websites for best practices and actively engage with the proper IPTs to incorporate crucial data points seamlessly and in an automated fashion. Updates to "percent complete" fields for work packages should be relatively simple for a Control Account Manager (CAM) to make, and data exports should publish without the need of additional external manipulation to the dataset.

2.4 EV Analysis

The EV Analysis step of the Framework delivers the necessary analysis that's made possible by the Data Collection and Normalization step to the client or customer. EV analysis includes typical cost and schedule performance metrics broken down by WBS level or further depending on the type of program. Those familiar with EVM metrics will recognize the reporting of Cost Performance Index (CPI), Schedule Performance Index (SPI), To-Complete Performance Index (TCPI), Estimate At Complete (EAC), and

Variance At Complete (VAC) across different breakouts of the data to indicate performance trends and identify risks within the program. EV Analysis is the one step in the Framework that receives the most attention from program managers because it provides insight into past, current, and future performance. However, the previous steps in the Framework ensure the analyst creates processes and performs analysis that maximizes the effectiveness of the EV Analysis.

While use of metrics and performance analysis are nothing new to EVM, the strategy of incorporating the analysis in a broader Framework of complementary steps represents an improved approach to performing EVM. The preplanning and use of modernized tools allow the analyst to process EVM data in a more effective manner, such as combining multiple program datasets into a single repository. This creates an environment to use EVM data that utilizes data across multiple programs and leverages the data to influence higher level programmatic decisions.

2.4.1 EV Analysis Incorporated into the Modern Framework

EVM analysts often view EV Analysis as the final step. The client or customer receives the analysis and conclusions from the EVM technical team, and the PMO gains an in-depth knowledge of the program's cost and schedule performance. However, the modernized Framework does not stop here. The EV Analysis step naturally flows from the Data Collection and Aggregation step by utilizing scripts to retrieve periodic data and perform analysis. Continuing analysis in a traditional spreadsheet limits the computing power, recurring functions, and automation of analysis tools which cannot provide timely analysis or at least to the full potential as with modernized tools. This is further exemplified by the requirement of the IPMDAR as the preferred EVM data delivery. Since the IPMDAR is in a machine-readable format, modern tools represent the preferred method to read and export the data into a database.

2.4.2 EV Analysis Methodology

Analysts perform EV analysis in numerous different ways based on the tools they have available, their skillset, and their client needs. However, the methodology behind the analysis remains the same regardless of the delivered work to the customer. EV analysis utilizes past and current EVM data to determine cost and schedule

performance of a program and use that analysis to predict the influence of the performance on the final cost. Although deliverables may contain different types of visuals, tables, reports, dashboards, and tools to showcase EVM performance, choosing and integrating a platform within a modernized Framework allows the analyst to take advantage of the entirety of the EVM dataset.

The R Estimate at Complete (EAC) Tool (REACT) is a prime example of how an analyst can use a modernized tool to connect the Framework from Data Collection and Aggregation into EV Analysis for the client. It also showcases how a modern tool suite connects the steps of the EVM Framework together to take advantage of the many upsides of performing EVM holistically.

REACT is an evolution from a previously utilized EVM tool created in Microsoft Excel, The Performance Metrics Model and Study (PMMS).[5] The purpose of the PMMS was to take advantage of a large database of EVM data for a multiple system, ACAT I program. The tool uses historical data to predict future performance of current systems to create an additional EAC method. This tool analyzes percent complete ranges of a system currently under construction and compares to previous analogous systems at a similar percent complete range to determine the cost and schedule performance through delivery of the vessel. REACT applies the past performance of previous systems to the current program's EVM data to recommend an EAC methodology for each system's WBS element based on lowest average percent error. The calculations for the PMMS tool relied on the processing power of Microsoft Excel, which posed the following challenges:

- o Data surpassing Excel processing capabilities.
- o The length of the update process reduced the amount of time available for analysis.

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[5] "The Performance Metrics Model and Study (PMMS)," Derreck Ross, Haitham Ghannam, Richard Lee, Robert Jones, International Cost Estimating and Analysis Association (ICEAA), 2016, https://www.iceaaonline.com/wp-content/uploads/2016/06/MS09-ppt-Performance-Metrics-Model.pdf.

- The PMMS tool did not link directly to a database to create a fully automated process.
- The analyst could only calculate EACs at a single point in time.

REACT is a modernized version of the PMMS tool that is incorporated into the EVM Framework. The modernized version of the tool utilizes R scripts connected to a relational database which houses years of EVM data. Instead of Microsoft Excel needing an integrated data table to perform the calculations and provide a user-friendly deliverable, R can connect the data from the database and perform the statistical calculations in a fraction of the time. REACT exports the results into a readable Microsoft Excel deliverable without the need to rely on Microsoft Excel to perform the calculations.

2.4.3 Detailed REACT Example

Although REACT is still a tool visible in Microsoft Excel, R generates and exports the calculations, spreadsheet design, and EAC recommendations into a spreadsheet. Figure 3 shows the REACT process for a routine periodic EAC analysis.
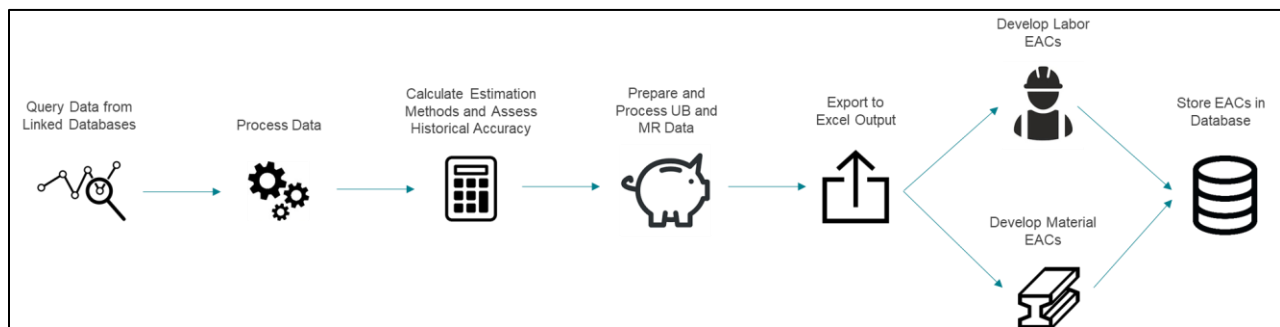
Figure 3: REACT Workflow in EV Analysis Step

The workflow begins in the Data Collection and Aggregation step with the original database design and the retrieval of new monthly/periodic data. Following Data Collection and Aggregation is the EV Analysis step where the newly loaded data in the database updates data queries. R scripts (the heart of REACT) process the new data by updating all WBS elements and system data with the necessary EVM metrics. These same scripts derive EAC calculations and percent error calculations to determine the recommended EAC method for all WBS elements and systems. REACT then adds the

Undistributed Budget and Management Reserve values to each of the EAC calculations to estimate Program Management Baseline and Total Allocated Budget. This is where the effort within R ends. R scripts produce a Microsoft Excel workbook that allows the user to perform EAC analysis by selecting EAC methods for the various WBS elements. REACT exports to two different spreadsheets for the analyst to focus their EAC analysis on both labor and material data. Finally, after the EAC analysis is complete, the analyst stores the newly created EACs (labor and material) and EAC method for each system.

The first four steps in the REACT Workflow are reflections of the modern update to the PMMS tool. These steps connect to a central database, utilize R scripts for calculations, and organize the Microsoft Excel spreadsheet. Once REACT exports the data to a Microsoft Excel spreadsheet, the analyst can begin the EAC analysis. Table 6 shows the tool output of the product parameters. The tool uses these parameters as inputs to identify the estimated product whether it is a system ID, certain part of the system or a specific contractor. This data also provides the parameters to perform the EAC standard error calculations. REACT labels this part of tool as the Model View. These ID columns are important for the model to select analogous systems that contain the same parameters as the system being estimated.

Table 6: Model View

Model				
As of Date	**Lead Effort**	**Sub Effort**	**Unit**	**WBS**
01/01/2001	Contractor A	Contractor B	22	01.01.01
01/01/2001	Contractor A	Contractor B	22	01.01.02
01/01/2001	Contractor A	Contractor B	22	01.01.03
01/01/2001	Contractor A	Contractor B	22	01.01.04
01/01/2001	Contractor A	Contractor B	22	01.01.05
01/01/2001	Contractor A	Contractor B	22	01.01.06
01/01/2001	Contractor A	Contractor B	22	01.01.07
01/01/2001	Contractor A	Contractor B	22	01.01.08
01/01/2001	Contractor A	Contractor B	22	01.02.01
01/01/2001	Contractor A	Contractor B	22	01.02.02
01/01/2001	Contractor A	Contractor B	22	01.02.03
01/01/2001	Contractor A	Contractor B	22	01.02.04
01/01/2001	Contractor A	Contractor B	22	01.02.05
01/01/2001	Contractor A	Contractor B	22	01.02.06
01/01/2001	Contractor A	Contractor B	22	01.02.07

EVM metrics are an important piece in calculating an EAC for a given WBS and System. The tool performs these calculations in R and exports the results to Microsoft Excel to allow the user to reference the performance of each WBS element. Table 7 shows the Metrics View from the tool output.

Table 7: Metrics View

Metrics								
WBS	BAC	BCWS	BCWP	BCWR	ACWP	SPI	CPI	% Complete
01.01.01	1,119.14	887.00	825.28	293.86	1,109.87	0.93	0.74	73.74%
01.01.02	0.37	0.37	0.00	0.37	0.00	0.00	0.00	0.00%
01.01.03	2,759.20	2,486.07	2,412.36	346.85	3,235.89	0.97	0.75	87.43%
01.01.04	305.32	304.12	297.77	7.56	390.72	0.98	0.76	97.52%
01.01.05	575.34	575.12	574.24	1.10	751.27	1.00	0.76	99.81%
01.01.06	455.21	455.21	455.17	0.05	577.17	1.00	0.79	99.99%
01.01.07	370.46	370.43	368.41	2.05	471.82	0.99	0.78	99.45%
01.01.08	379.97	379.97	314.53	65.44	302.69	0.83	1.04	82.78%
01.02.01	31.56	31.46	30.82	0.74	36.39	0.98	0.85	97.67%
01.02.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00%
01.02.03	1,243.62	1,238.99	1,239.15	4.47	1,607.22	1.00	0.77	99.64%
01.02.04	666.53	666.36	666.12	0.41	930.08	1.00	0.72	99.94%
01.02.05	261.82	261.77	261.77	0.04	330.29	1.00	0.79	99.98%
01.02.06	0.52	0.52	0.52	0.00	0.56	1.00	0.93	100.00%
01.02.07	298.22	298.20	298.22	0.01	356.05	1.00	0.84	100.00%

The Working Estimate shown in Table 8 provides the user with EAC options to select based on selections from the previous EAC analysis. REACT provides the recommended EAC method to alert the user of the method with the lowest average percent error compared to previous analogous systems. Note that while the tool provides the recommended method, it is not always the most sensible selection for the current system or WBS. This is due to various factors when performing EAC analysis, including: percent complete, amount of historical data, design changes, updated manufacturing processes, and past performance of the current system or WBS element.

Important factors to consider when selecting an appropriate EAC method is to understand the TCPI and CPI at Complete metrics. Selecting an EAC method without complete understanding of its use can cause these metrics to signal that the selected EAC methodology is not possible.

Table 8: Working Estimate View

WBS	Estimation Method	EAC	TCPI	VAC	CPI @ Complete	CPI @ Complete (Recommended)	Previous CPI @ Complete	Recommended Method
				Working Estimate				
01.01.01	BAC / (6 Month CPI)	1,774.29	0.44	-655.16	0.63	0.64	0.71	% Complete
01.01.02	BAC / 1.0 (Math Ext)	0.38	0.95	-0.02	0.95		1.00	
01.01.03	% Complete	4,495.07	0.28	-1735.86	0.61	0.69	0.65	Historical
01.01.04	BAC / (3 Month CPI)	419.77	0.26	-114.45	0.73	0.73	0.75	BAC / (CPI*SPI)
01.01.05	BAC / (CPI*SPI)	790.55	0.03	-215.21	0.73	0.73	0.76	BAC / (CPI*SPI)
01.01.06	BAC / (CPI*SPI)	606.24	0.00	-151.03	0.75	0.75	0.79	BAC / (9 Month CPI)
01.01.07	BAC / (CPI*SPI)	498.30	0.08	-127.84	0.74	0.74	0.78	BAC / (CPI*SPI)
01.01.08	Historical	429.41	0.52	-49.44	0.88	0.88	0.95	Historical
01.02.01	BAC / (6 Month CPI)	39.60	0.23	-8.04	0.80	0.81	0.84	BAC / (CPI*SPI)
01.02.02	BAC / 1.0 (Math Ext)	0.00		0.00				
01.02.03	100% Complete (ACWP)	1,687.99	Complete	-444.38	0.74	0.74	0.77	% Complete
01.02.04	100% Complete (ACWP)	976.83	Complete	-310.30	0.68	0.68	0.72	BAC / 1.0 (Math Ext)
01.02.05	100% Complete (ACWP)	346.89	Complete	-85.07	0.75	0.75	0.79	BAC / 1.0 (Math Ext)
01.02.06	100% Complete (ACWP)	0.59	Complete	-0.07	0.88	0.88	0.93	100% Complete (ACWP)
01.02.07	BAC / 1.0 (Math Ext)	373.95	0.00	-75.73	0.80	0.80	0.84	BAC / 1.0 (Math Ext)

Once the EAC analysis is complete, the analyst saves the designated EAC methodologies for each system and WBS elements and uploads them into R to update the tool and prepare the export for the next EAC cycle. Although R houses the formulas, tables, and calculations, the customer still receives the EAC analysis in a familiar format. The use of the modern tools creates efficiency between the data processing steps within the Data Collection and Aggregation step and within the EV Analysis. The tools provide a level of flexibility to accommodate those that are not an expert with specialized data science tools.

2.5 Program Management

The EVM Framework recognizes the fact that the EV Analysis step, while essential to measuring cost/schedule and providing actionable information to Program Managers for a given contract with industry, is not sufficient to meet broader program management

needs. The Framework includes the Program Management step to address the reality that there is another level of analysis that EVM analysts perform to help put program performance into perspective and enable informed budgetary decisions.

2.5.1 Program Management Incorporated into the Modern Framework

The EV Analysis informs the program office on current cost and schedule performance of a particular program and even produces an estimate at complete to inform program managers of future costs. However, there are officials making decisions at a higher level than the program office. Budgetary decisions presented to Congress need to have sound data and analysis techniques to inform a realistic Estimated Price at Complete (EPAC) that incorporates program risks. Having a process-oriented Framework allows for a single environment that stores the data in a relational database, flows into EV Analysis, and eventually provides the data to perform the budgetary analysis. Without this type of Framework, additional analyses could require their own independent environment. Specifically, analysts would need to find and compile the appropriate data within their possession, decide how to use the data for the analysis, and set up tools to perform the analysis and present to leadership.

2.5.2 Program Management Methodology

The Program Management step employs various program data artifacts to provide the program office with high level insight that support budgeting and financial analysis, contract management, risk management, or other system engineering areas that would benefit from EV analysis. The client can take advantage of the delivered EV analysis to make management decisions for the program at a portfolio level. The Program Management step showcases how a program's EVM insight and performance translates to actionable decisions at a higher level. The US Government needs this analysis more than ever in respect to the growing DoD budget to support their decisions and plan appropriately at a portfolio or even agency level.

An example of a tool that supports the Program Management step in the Framework is EPAC (Estimated Price at Completion). It is a statistical tool that combines the EAC analysis of a program with the risk and uncertainty element of making budgetary decisions. It incorporates a percent error methodology to determine appropriate

confidence intervals. EPAC answers the question, how much should the US Government budget to have a certain percentage of confidence in the EAC? The results that support this question allow officials to confidently report their necessary budget to Congress.

2.5.3 Detailed EPAC Example

An example of the type of analysis that can be performed with EPAC follows.

Step 1: Determine the percent error of the delivered EACs based on the price at complete.

The tool needs historical program data spanning several years or longer to generate valid and robust statistical analysis. It is important to understand the methodology and process behind the historical EACs as any change in this analysis may alter the percent error calculation and provide false results. For the dataset within the tool, the EVM analyst developed historical EACs using the same process for the length of the dataset. Dividing the EAC historical data into percent complete bins (5% complete per bin) and calculating the historical percent error for each percent complete bin produces the results in Figure 4. The results produce a few noticeable conclusions:

- o Generally, the distribution of earlier percent complete bins is wider than later bins, indicating that EACs produced early in a program will vary greater than those later in the program.
- o The average percent error (noted by the single marker for each bin) approaches zero later in the program, indicating that there is equal representation of over and under estimating.
- o Average percent error at the beginning of the program indicates that the EVM analyst tends to overestimate the final price at complete. This is most likely due to the EAC calculation accounting for early poor performance and assuming it will remain constant through the program.

So far, the tool has only considered historical data to determine the necessary percent increase based on the percent complete bin and the level of confidence an official wants to budget the program.
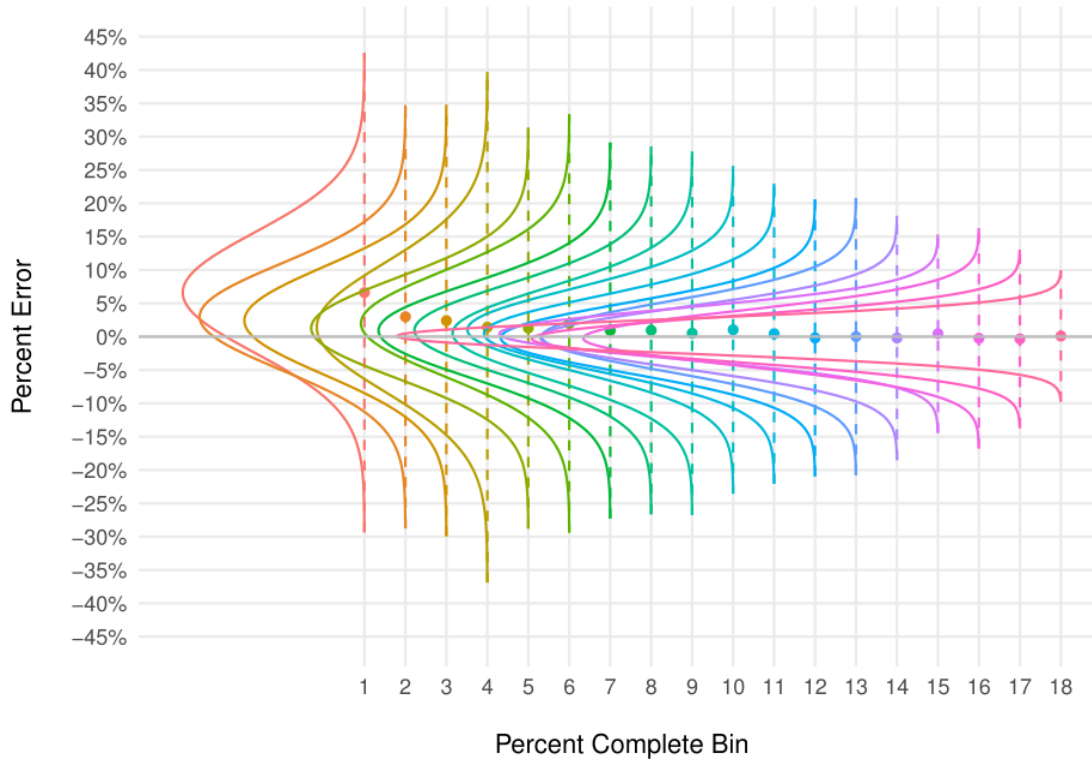
Figure 4: Percent Error Distribution by Percent Complete

Step 2: Determine and apply the percent error based on the percent complete bin and confidence bound.

This involves the use of two formulas shown below, one to calculate the EPAC adjusted EAC (EAC$_{EPAC}$) based on the confidence interval and percent complete and the other to calculate the EPAC Factor (Factor$_{EPAC}$) based on the percent difference from the EPAC EAC and the current EAC.

$$EAC_{EPAC} = \frac{EAC_{Base}}{1 + E_{0.75}}, \text{ where } E_{0.75} \text{ is the estimation error at the 75th percentile}$$

$$Factor_{EPAC} = \frac{EAC_{EPAC} - EAC_{Base}}{EAC_{Base}}$$

The tool applies the Factor$_{EPAC}$ to each of the current units with newly constructed EACs. The tool then multiplies the Factor$_{EPAC}$ by the current EAC to apply additional budget to the EAC at the selected confidence bound. The final number is the budgeted

price at complete based on the selected confidence bound that provides a comfortable tradeoff between risk and cost.

Step 3: Compare Actual Error to the EPAC Adjusted Error

Figure 5 demonstrates the comparison between the actual estimation error for a selected system compared to the error predicted using the Legacy and EPAC models for various selected percentile values and bins. When comparing against the Legacy EPAC model which added a flat percentage across the completion of the system the EPAC models more closely resemble the actual error observed.
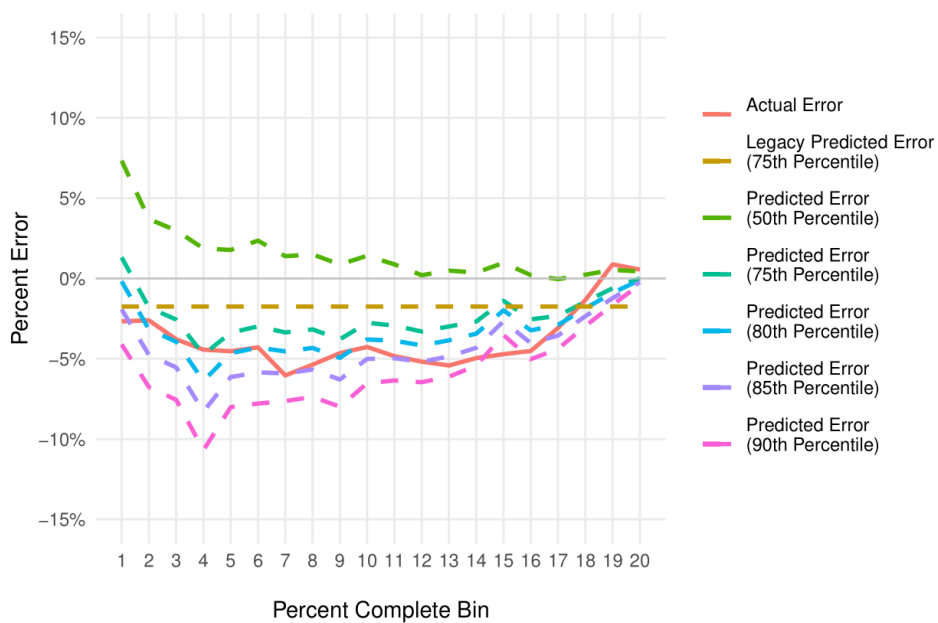

Figure 5: Applying Percent Error to Percent Complete Bins

The final output from EPAC is the risk adjusted percentages for each of the systems in construction. The output provides percentages for each of the selected confidence intervals shown in Table 9. When compared to the Legacy EPAC model, the EPAC establishes a risk adjustment percentage that effectively covers all uncertainty.

Table 9: EPAC Risk Adjustment Percentage

Unit	Effective EPAC Risk Adjustment Percentage					
	Legacy EPAC Model Error Percentile = 75%	EPAC Model Error Percentile = 50%	EPAC Model Error Percentile = 75%	EPAC Model Error Percentile = 80%	EPAC Model Error Percentile = 85%	EPAC Model Error Percentile = 90%
1	0.01%	0.00%	0.00%	0.08%	0.20%	0.35%
2	0.02%	0.00%	0.00%	0.08%	0.20%	0.35%
3	0.08%	0.00%	0.00%	0.08%	0.20%	0.35%
4	0.08%	0.00%	0.00%	0.08%	0.20%	0.35%
5	0.14%	0.00%	0.49%	0.76%	1.06%	1.44%
6	0.27%	0.00%	0.49%	0.76%	1.06%	1.44%
7	0.37%	0.33%	2.60%	3.18%	3.85%	4.68%
8	0.50%	0.24%	3.05%	3.76%	4.60%	5.65%
9	0.62%	0.19%	3.32%	4.11%	5.05%	6.22%
10	0.81%	0.00%	3.54%	4.44%	5.51%	6.86%

EPAC provides data driven results that enable leaders to make reasoned decisions based on confidence intervals that reflect leader risk tolerance. EPAC's utility is the result of past efforts in data collection, creating processes, and storing the data in a well-prepared database. Its creation utilized the same environment as the EV Analysis step which also connects back to the database within those same modern tools.

2.6 Periodic Data Delivery

The EVM Framework would be incomplete without consideration of a periodic data delivery schedule. Per IPMDAR guidelines, the contractor is to deliver EVM data in a periodic fashion (at least monthly) to fulfill CDRL requirements.[6] Understanding the repetitive nature of the incoming data allows the analyst to construct the necessary processes to efficiently retrieve and store the data. Although the Framework should explicitly draw out the data construct within the Contract Startup step, the analyst does not know what to expect from the contractor on a month-to-month basis until the data arrives. Work performed during the Contract Startup step can mitigate this risk, but ultimately the analyst needs the data in-hand to know the true quality of the deliverable.

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[6] DI-MGMT-81861C "Integrated Program Management Data and Analysis Report (IPMDAR)", August 2021

Despite the fact that DoD requires the contractor to deliver EVM data in a standardized format (IPMDAR), there are still nuances within the data or the deliverable that wreak havoc on automated scripts. This is especially true as the IPMDAR is still in the early phases of implementation and contractors are adapting to the new reporting format. It is key to consider and review each data submission to ensure the database tools can read and import the incoming EVM data into the database accurately without issues. Within the Framework, the monthly data delivery flows from the Program Management step to the Data Collection and Aggregation step where the modern tools process the monthly data through V&V processes and import it into the database. The Framework cycle then repeats itself to provide detailed EV Analysis to the program office through use of visuals and modernized tools explained earlier. This becomes engrained as the monthly EVM cycle within data reporting and analysis.

3 Conclusion

The EVM Framework described in this paper allows analysts, program offices, and industry to view EVM in a holistic way by breaking it down into its major steps. This decomposition allows an analyst to see the connection between each step of the process, how each can impact the next, and the important components.

The logic and value of the Framework can be summarized as follows. A compliant EVMS allows the analyst to trust in the data delivered. Properly identifying program office needs and addressing those in the CDRL ensures that analysis performed later can effectively support program management. The outcome of Contract Startup guides how the Data Collection and Aggregation step will be set up. Implementing an efficient, automated Data Collection and Aggregation process allows an analyst to focus time on analysis. Implementing modern tools allows an analyst to streamline repetitive analyses and more quickly identify the problems the program office will face or are currently facing. It all culminates in the ability to deliver analyses and insights that allow the program manager to make informed decisions for their program or address budget concerns in the future. Without a Framework the connections can be missed, an analyst

may just focus on their monthly deliverables, or a program office may not give proper attention to their CDRL.

The use of this Framework has proven a success for EVM programs. An ACAT I program was continually having issues within their Integrated Baseline Reviews for subsequent units within a program. The program office struggled to manage the entirety of the historical data and translate it to a comparison of the new unit's baseline. Technomics analysts supporting this program were able to produce performance management baseline analysis tools within R to directly connect to the EVM database, utilize existing data, and deliver comparisons at a low and analogous level. The time to manage the data and perform the analysis (Data Collection and EV Analysis steps) was drastically reduced and afforded the stakeholders more time to focus on producing questions for the IBR interviews.

Other programs have also benefitted significantly from the Framework. In many instances, upon receipt of the first EVM deliverables from contractors, the structure of the data is not adequate to answer program office questions. Altering this data structure would require significant contractor effort and in turn time and money. The Framework helped identify where the problem with this data originated and how to correct the problem and avoid it recurring in the future.

In a time when deliverables are growing in size and complexity (e.g., IPMDAR), it is critical to understanding the most effective and logical way to exploit the potential power of the information. Changing the approach to EVM supports a greater understanding of the lifecycle, allowing program managers and analysts to make better decisions in the management of their program. In addition, it allows analysts to identify areas to streamline their processes and focus on those that provide the most value. Utilizing modern tools, such as R, Power Query, or Power BI, in this Framework helps enhance the streamlining of processes and improve the way analysis is communicated. This Framework is a method to improve how the EVM lifecycle is viewed and addressed, enabling effective and efficient program management.

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