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Vega: Shining a Light on the Battles of Data Collection and Management

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International Cost Estimating and Analysis Association

5/16/2023

Abstract

Every cost organization battles both the collection and management of cost, schedule, technical, and programmatic data. This paper describes how the Office of Cost Estimating and Program Evaluation (CEPE) at the National Nuclear Security Administration has built and matured this capability since the office's inception in 2015. This paper will present seven years of lessons learned that will pay dividends for any cost organization looking to optimize how it collects and manages mission-critical data.

Keywords: database, data storage, policy, data structure, data

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Introduction

The need for more stringent data governance and a coherent federal data strategy has become a topic of critical importance in recent years. In 2019, the Office of Management and Budget (OMB) published *Federal Data Strategy—A Framework for Consistency*, a memorandum that defined data as a strategic asset and aimed to define consistent data infrastructure and practices. The Government Accountability Office (GAO) highlighted in 2020 that "Federal decision makers need data of sufficient quality to assess whether federal programs achieve intended results and to set priorities for national objectives" [GAO 21-152]. Congress also has taken steps in the past few years to establish data governance as a top priority across all agencies. Data is playing an increasingly important role in both mission operations and investment planning, especially in the face of scarce federal resources.

This need for data is especially prevalent in the field of cost estimating. Cost estimators require authoritative, reliable data in order to produce forecasts that accurately represent federal programs that can span into the billions of dollars. Further, federal decision-makers require credible cost estimates to inform budgetary and investment decisions and track contractor partners' performance as programs progress through the acquisition life cycle. The credibility of the estimates that these decision makers receive is often judged by the data and analytical methodologies that underpin them.

The Office of Cost Estimating and Program Evaluation (CEPE) within the National Nuclear Security Administration (NNSA) was established to provide the analytical capability to assess and track major acquisition programs within the Nuclear Security Enterprise (NSE). CEPE acts as the principal advisor to the NNSA Administrator on program performance and resource allocations across the portfolio, which includes but is not limited to modernizing the nation's nuclear stockpile. The office's ability to meet its mandate is heavily dependent on its ability to analyze NNSA programs and quantify major risks and opportunities associated with these programs.

Since 2016, CEPE has undertaken an enterprise-wide data collection campaign that changed NNSA policy and established a data repository, known as Vega, to serve the

needs of cost and program analysts throughout the NNSA. This system, which is housed on both classified and unclassified networks, provides analysts with the ability to access authoritative, historical data on the nuclear security enterprise that can be used to perform a wide range of operational analyses. Vega is used to inform major acquisition and investment decisions and represents the central repository of authoritative NSE program data.

CEPE's Beginnings

The NNSA is tasked within the Department of Energy (DOE) with maintaining the United States' nuclear deterrent, advancing nuclear nonproliferation, promoting international nuclear safety, and providing support to the Nuclear Navy. The NNSA has an extensive portfolio of infrastructure projects, weapons modernization programs, science missions, and research and development activities across its sites and production agencies (see Figure 1).

Figure 1: NNSA Sites and Production Plants

In the National Defense Authorization Act (NDAA) of 2014, Congress charged the NNSA with establishing a new office, CEPE, reporting directly to the NNSA Administrator. The office's missions — as laid out in the NDAA — include advising the

Administrator on policies and procedures related to cost analysis; conducting independent cost estimates (ICEs) for major NNSA programs and projects (including assessments of risk and confidence levels); and advising the NNSA Administrator on planning, programming, and budgeting activities among other responsibilities. Congress recognized that data would be at the heart of each of CEPE's mission sets and included the following charter:

> *DATA COLLECTION AND ACCESSIBILITY. —The Administrator, acting through the Director, shall, as appropriate, seek to use procedures, processes, and policies for collecting cost data and making that data accessible...*

CEPE's initial data collection effort focused on support to ICEs for the NNSA's campaign to upgrade and modernize the United States' nuclear weapons stockpile, known as Life Extension Programs (LEPs). Subsequent NDAAs have established CEPE's responsibility for ICEs on major capital acquisition and construction projects as well. Those statutes established the following requirements: 1) data drives decisions; 2) CEPE has responsibility to collect and apply data in performing its missions; and 3) CEPE makes data available to a wide swath of stakeholders.

Data Governance and Best Practices

To improve the quality and usability of data available for analysis, an organization must establish data governance policies and procedures. Any organization that acts as a data steward should implement effective data governance in both strategic and day-to-day, tactical data decision making. The first step in effective data governance is to establish policy for how data is gathered, stored, processed, and disposed. Data governance can be difficult to fully define and attain; however, poor data management can not only adversely impact an analysts' ability to deliver credible analysis, which in turn can undermine the decision support that it provides, but can also undermine an agency's ability to deliver on its core mission.

Proper data governance is a force multiplier. First, it enables individuals and decision-makers to make data-driven decisions with improved efficiency. Because data is

collected consistently, is centrally located, and is readily accessible to a wider swath of the organization, analysts aren't required to consistently undertake a comprehensive data collection and cleansing process.[1] This serves to improve resource management by eliminating duplicative data collection efforts. Second, governance improves trust both inside and outside an organization because data can be traced back to a standard set of quality assurance checks and standards.

Lack of data governance can easily make a data collection effort fruitless. For example, in January 2020, the GAO released a report on the Drug Enforcement Agency's (DEA) data policy and the "usefulness" of the data being collected. The report listed two core findings:

- Limited proactive and robust analysis of industry-reported data [GAO 20-118]
- No data governance structure to manage all drug transaction data [GAO 20-118]

The report noted that those two findings contributed to the DEA's reduced ability to "proactively identify suspicious activities or registrants that may warrant investigation." Had the DEA invested in data governance policies and procedures prior to implementation, the agency likely would have been able to take advantage of both its internal data as well as industry-reported data to bolster its internal analyses.

Data governance should ultimately be driven by the needs of the agency and focused on enabling an organization's core mission. This policy may also be determined by organizational size and complexity. Smaller organizations may have less redundancy and more informal data practices, whereas large organizations may have departments with cross-departmental powers.

Federal Data Strategy

Data governance requires difficult cultural reform across the implementing organization in order to succeed. Congress, in recognizing the importance of making policy decisions using "[evidence] building activities, open government data, and confidential information protection and statistical efficiency," [OMB] passed the Evidence Act in 2019. One result

[1] Data collection often encompasses the vast majority of the analytical process, with analysis encompasses roughly 20% of the effort. This is known as the 80/20 rule for data analytics.

of the act was establishing the Federal Data Strategy (FDS). The FDS is the current vision of how the Federal Government will "accelerate the use of data to deliver on mission, serve the public, and steward resources while protecting security, privacy, and confidentiality" [FDS Website].

That led the OMB to publish the FDS memorandum to the heads of executive departments and agencies [OMB]. In that memo, OMB defined 10 core pillars of good data governance (see Figure 2), which are grouped by ethical governance, learning culture, and conscious design.

Figure 2: OMB-Defined Good Data Governance Pillars

Along with the 10 pillars of good data governance, OMB provided 40 best practices, grouped into three broad goals:

- Building a culture that values data and promotes public use
- Governing, managing, and protecting data
- Appropriate data use

Although OMB implemented the FDS after CEPE was established, CEPE's data collection improvement efforts have followed the FDS' three broad goals.

A Campaign for Improvement

CEPE's data collection campaign — and establishment of Vega — is an effort to correct poor data management within the NSE cost community. Because the NNSA Management and Operating (M&O) contractors operate as independent entities[2], data reporting standards across the NSE are unique to each site. The differences in reporting standards extend to every level of the data, from metadata that describes programs and work being performed to the details of the data itself.

When the CEPE office began to staff-up in 2015, it added contractor staff from Technomics, Inc. to supplement its organic staff. Together, the federal and contractor staff worked to establish a new data collection apparatus.

The team's charter was to:

- Establish a Gold Standard for cost estimating data that would meet CEPE's mission goals and identify potential sources and gaps.
- Implement policies and procedures to collect and manage data.
- Create a system to house and share data and analytical products.

This charter directly reflected the challenge of the FDS to establish data culture, data governance and management, and data use, respectively.

Creating a Gold Standard

Building a culture that values data and promotes public use

To achieve the gold standard for cost estimating data— the foundation of Vega — CEPE aimed high. The team wanted to apply the best practices of other successful cost estimating organizations, including the Department of Defense (DoD), Department of Homeland Security, the Intelligence Community, and others. This goal resulted in a vision for a comprehensive, accessible, and credible set of data from which cost estimators could use to perform robust analysis and draw actionable insights. CEPE

[2] The NNSA encompasses a network of government owned, contractor operated sites, known as the M&Os. These include Sandia, Lawrence, and Los Alamos National Laboratories; as well as the Pantex plant, Kansas City National Security Campus, Y-12 plant, and the Savannah River Site. These are colloquially known as the NNSA Labs, Plants, and Sites.

divided targets for data collection into cost, technical, and programmatic data. Table 1 outlines the characteristics and example sources CEPE sought.

Data Type	Target Characteristics	Example Sources
Cost	• Native Work Breakdown Structure • Over time by month • Breakout of Non-recurring and Recurring costs • Hours and Dollars actuals • Elements of Cost, with native Labor functional categories and Overhead	• Site charge code accounting actuals • Actual Cost of Work Performed • Budget execution actuals
Technical	• Unit Quantities • System Quantities • Component descriptions and pedigree • Test Plan and pedigree • Technology Maturity Levels • Manufacturing Maturity Levels	• Quantity trackers • Production planning documents • Engineering drawings
Programmatic	• Detailed schedules • Major milestones and dependencies • Program and site risks	• Site schedules • Integrated Master Schedules • Quarterly Program Reviews • Risk Registers

Table 1: CEPE's Gold Standard of Data

By tailoring data collection targets beyond traditional sources, CEPE ensured that the cost data would be supported by the proper context needed to provide a full set of appropriate cost estimating techniques. The most important requirement was to define which data represented historical work performed, and thus a realistic representation of

the programs in question, and systematically collect that data at a sufficient level of detail to support current and future efforts.

The goal of the Gold Standard was to provide a framework for maturing CEPE's data collection over time. CEPE started by collecting data at a "basic" level that would not require a drastic change in M&O or Federal Program Office (FPO) operations, and slowly move to collect higher quality and comprehensive data. This allowed CEPE to concurrently mature its analytical capabilities as the data collection process progressed (Figure 3). This process is consistent with FDS practices to "leverage data standards" and "align quality with intended use." By first establishing the long-term goal for the data collection strategy, CEPE was able to have focused discussions with data providers and ensure that it could iteratively mature data and capabilities as relationships and underlying data improved.

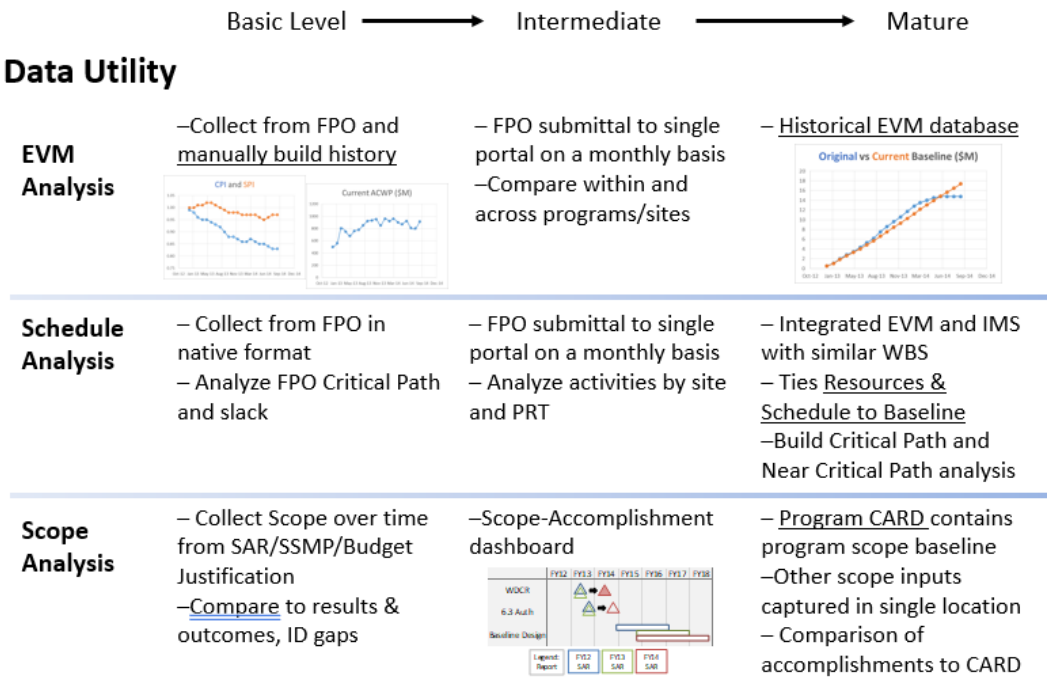

Figure 3: Example of CEPE's Plan for Maturing Data Collection and Capability

Organizations are successful in deploying data governance when they identify individuals who already have some responsibility for individual pieces of data and seek to formalize processes and management practices [Seiner]. After developing an initial data strategy for the office, the CEPE team met with individuals and organizations

throughout the NSE and the broader DOE to understand current data systems, target users, access mechanisms, and data elements. CEPE benefited from starting with discussions with data providers, conversations that enabled the office to understand what data existed within the NNSA.

While CEPE was building its organic collection capabilities, it also gained access to the existing data systems that had already been established throughout the DOE/NNSA and evaluated these systems against the Gold Standard. While none of these data systems had express purposes related to cost estimating, they were oriented to program management, real-time monitoring, accounting, finances, and other missions. Some were considered systems of record to fulfill other federal statutes or requirements, which often restricted the scope of the data collected or de-emphasized the preservation of historical data. However, nearly all these systems provided some value to the cost estimating process, which offered new data to fulfill the Gold Standard.

After performing a review of each system, CEPE established a stoplight chart for all elements of the Gold Standard and showed where that system provided all, some, or none of the characteristics that were required. While there were elements that could support cost estimating, no single system or combination thereof would provide the data that CEPE needed to fulfill its statutory requirements, as seen in the example output from 2015 (Figure 4).

	Data Reporting Dimension/Field	DOD	STARS Monthly	PARS II	PARS II DMS	FIMS	G2
Data Dimensions	Programs/Projects	YES	YES	YES (Capital Asset Projects Only)	YES (Capital Asset Projects Only)	YES (Capital Asset Projects Only)	Yes (Recap Projects and Facilities O&M Only)
	Phase	YES	NO	YES	YES	NO	PARTIAL
	WBS	YES	NO	YES	YES	NO	PARTIAL
	Recurring / Non-Recurring	YES	NO	NO	NO	NO	NO
	Actuals-To-Date / At-Completion	YES	PARTIAL	YES	YES	PARTIAL	PARTIAL
	Baseline / Performed-To-Date	YES	PARTIAL	YES	YES	NO	PARTIAL
	Labor Functions: Professional, Engineering, Scientific; Craft/Trade; General; Management and Administrative	YES*	NO	NO	PARTIAL	NO	NO
Data Fields	Quantity	YES	NO	NO	PARTIAL	PARTIAL	PARTIAL
	Technical Characteristics (Physical/Performance)	NO	NO	PARTIAL	PARTIAL	PARTIAL	PARTIAL
	Schedule (Start/End)	YES (IMS)	NO	YES	PARTIAL	PARTIAL	YES
	Labor Hours	YES	NO	PARTIAL	NO	NO	NO
	Labor Dollars	YES	NO	NO	NO	NO	YES
	Labor Overhead	YES	NO	NO	PARTIAL	NO	PARTIAL
	Raw Material (Concrete, Steel, Specialty Piping, Other)	PARTIAL	NO	NO	PARTIAL	NO	NO
	Purchased Parts	YES	NO	NO	NO	NO	NO
	Purchased/Leased Equipment	YES	NO	NO	NO	NO	NO
	Material Handling Overhead	YES	NO	NO	NO	NO	PARTIAL
	Other Direct Costs: Direct Reporting Subcontractors	YES	NO	NO	NO	NO	NO
	Other Direct Costs Not Shown Elsewhere	YES	NO	NO	NO	NO	NO
	Cost of Money	YES	NO	PARTIAL	NO	NO	NO
	G&A	YES	NO	NO	NO	NO	PARTIAL
	Fee	YES	NO	NO	NO	NO	NO

Figure 4: Example Comparison of Existing Systems to CEPE's Gold Standard

In considering the Gold Standard and how CEPE would collect data, the CEPE team assessed the needs of end-user stakeholders: CEPE analysts, the NNSA Administrator, and Congress. While other offices also balance the needs of some or all the same stakeholders, each is answering different key questions for the NNSA. For instance, accounting/financial data serves a different purpose from raw operating data (such as charge code level accounting data) and, while the two numbers will work out to be close, they are not the same.

It is important to note that another best practice from FDS is to connect data functions across the agency. Each arm of NNSA was (and still is) collecting data specifically for their own needs without aligning the data to potentially serve multiple use cases and reduce redundancy. CEPE has synergized the different data sources to connect the different data owners where able.

Best Practices: Data Culture

CEPE has focused on building a data-centric culture internally and externally since the office's early days. Figure 5 outlines OMB's characteristics of a Data-centric Culture. At the kickoff of every estimate, analysts outline the data sources that make up the

methodology and assumptions and use that outline to identify strategies to enrich the data with new data sources. This necessarily requires analysts to build trusting relationships with program offices to facilitate data collection.

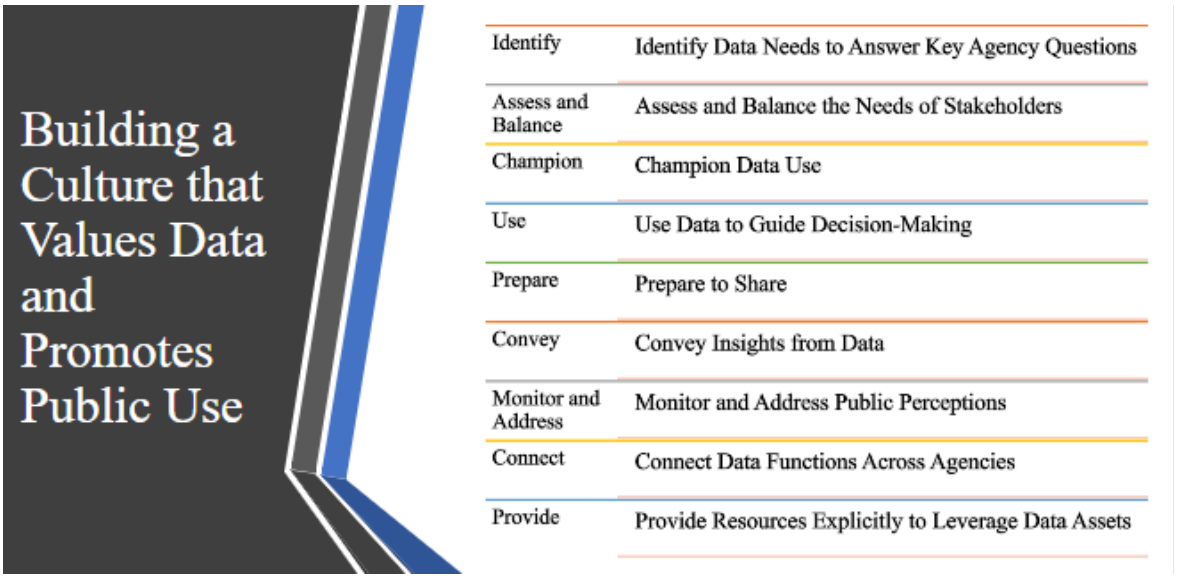

Figure 5: OMB-Defined Best Practices to Building a Data Culture

This culture enables analysts to regularly find new sources of data or categories for cost drivers that previous efforts had not captured. CEPE analysts also scrub documents to capture data fields such as Technology Readiness Levels and part counts that enable the integration of technical drivers into cost estimating relationship development and further enrich the data they are analyzing. As CEPE has matured, the office has worked with program offices to understand what data fields CEPE could improve upon by understanding the development and manufacturing processes associated with the programs of interest. For example, CEPE and the Federal Program Offices (FPOs) undertook an iterative effort to develop policies and templates for a Cost Analysis Requirements Description (CARD). This effort enabled CEPE to find a collection format that also helped the program office understand its own internal data.

Collecting those additional data elements was a cultural shift for many stakeholders throughout the NNSA. Cultural change is a difficult process; however, consistent communication and feedback have fostered change and improvement.

Developing Data Policies

Governing, managing, and protecting data

At the core of any data organization is a robust data policy and strategy that senior leadership champions. For example, to address the GAO's recommendations, the DEA established a data strategy and additional data policies.

In the FDS, OMB places a special emphasis on governing, managing, and protecting data. CEPE leaned heavily on its statutory requirements to prevent challenges to its missions, and to enable the continual collection of data in an unencumbered fashion. Those policies also enabled CEPE to communicate its needs more clearly, further breaking down barriers to collection efforts. It became obvious that having a strong set of policies outlining specific requirements would be the surest mechanism to build the data that CEPE needed.

Driving Forces for Policy Development

In establishing the Gold Standard, CEPE determined that many data owners within NNSA and DOE had concerns about an overarching data collection campaign. Many believed that their own system was the most appropriate way to house or distribute data and that any other method would result in undue burdens or threaten the authoritative nature of the data.

Additionally, in 2016, CEPE conducted its first ICE on the B61-LEP. The ICE took approximately six months and involved traveling to the M&O sites to collect data on past and current programs. The significant challenge during that process was to explain to the FPO and contractors the need for collecting cost, programmatic, and technical data to develop accurate, reliable, and credible estimates. Unlike DoD Major Defense Acquisition Programs, NNSA modernization programs are not tied to specific contracts nor associated with contractual reporting requirements. As such, CEPE could not contractually require M&O contractors to provide program data without establishing official NNSA policy. As a temporary measure, the NNSA Principal Deputy Administrator via an official memorandum granted CEPE authority to collect data in support of cost estimating.

CEPE's early experience interacting with the FPOs and M&Os with respect to data collection was critical to informing and developing primary policy documents. The multiple, one-on-one engagements also helped CEPE establish expectations for the data requests and enabled efficient concurrence of the NNSA policies regarding cost estimating data collection. Today, the combination of congressional statutes and agency-specific policies enables CEPE to develop and maintain Vega to fulfill its strategic mission.

Policies and Federal Support

CEPE's mission to provide independent, data-driven insights to the NNSA Administrator, and its ability to collect data in order to fulfill that mission, has been bolstered by two legislative articles. In 2014, Congress enacted Title 50 United States Code (USC) 2411 to establish authority for CEPE to use procedures, processes, and policies for collecting data in support of cost estimating. In 2018, 10 USC 499a clarified CEPE's responsibilities for collecting and storing cost, programmatic, and technical data relating to NSE's and nuclear forces' programs and projects. CEPE looked to these established federal laws to develop its primary policy documents, which are addressed below.

NNSA Policy (NAP) 413.3, *Responsibilities for Independent Cost Estimates* establishes responsibilities for the CEPE office, FPOs, M&O contractors, and other stakeholders in support of CEPE's mission to develop ICEs at major program milestones. The NAP also defines the requirement for cost estimating data to support defensible and credible ICEs.

NAP 413.1, *Data Collection for Cost Estimating* outlines the specific types of data collected (e.g., raw cost accounting data, earned value reports, integrated master schedules, etc.), identifies frequency of collection, and delegates data requirements to FPOs and all M&O contractors performing work under the NNSA. Because of this NAP, M&Os and FPOs submit data directly to CEPE at regular frequencies and are accountable when data is missing.

NNSA Business Operation Procedure (BOP) 413.9 defines the requirements, responsibilities, and expectations relating to the CARD for NNSA programs and projects. The CARD is a description of the salient features of a program/project at a level of detail appropriate for estimating costs. It describes the key technical, programmatic, and operational characteristics of an acquisition program, and provides supporting data sources and material. The GAO Cost Estimating and Assessment Guide (GAO 6) affirms that, the

> *"key to developing a credible estimate is having an adequate understanding of the acquisition program, acquisition strategy, technical definition, characteristics, system design features, and technologies to be included in its design. "*

To achieve that end, BOP 413.9 addresses the technical and programmatic scope of the cost data contained in Vega. This information is not compiled anywhere else.

Data Documentation

CEPE documents every step of the data management process with detailed notes. Those notes have paid dividends months (and sometimes years) later and have enabled the office to track errors in the data cleaning and mapping process, and manual transcription. Every line of data in the manual transcription traces back to the original document, enabling CEPE analysts to check when analysis reveals odd results. CEPE analysts can also isolate the data that a particular document reports to check incoming information against prior submissions or cross-program documents.

When new users and data managers are brought on, documentation can help them understand how historical information was mapped and bucketed. As the database has grown, the need for documenting decisions across multiple data managers has reduced duplicative efforts and streamlined the onboarding process.

Best Practices: Data Governance and Management

CEPE has focused on consistently updating the data that various NSE organizations and offices maintain and collect by working directly with the data stewards. Each NNSA program has a slightly different process for collecting data, which often vary based on

lessons learned from previous programs or gaps in reporting requirements and work-package traceability. As such, FPOs have oftentimes opted to change the way they submit data. These changes are sometimes instigated by the programs to better understand internal risk; other times FPOs have elected to work with CEPE to understand data gaps or identify potential mechanisms to streamline data collection requests

Figure 6: OMB-Defined Best Practices to Govern and Manage Data

The OMB best practices for governing, managing, and protecting data provide organizations guidance for implementing data policies and data management processes (Figure 6). CEPE's Vega implementation adheres to many principles. Some of these principles were addressed from day one, including "leverage data standards" and "inventory data assets" in the creation of the Gold Standard. Others like "maintain data documentation" are a continuously evolving practice and effort.

Launching the Vega System

Appropriate data use

To collect, manage, and distribute the data CEPE gathers, the office established the Vega system. The Vega system is an all-encompassing data management system that includes mechanisms for data cleansing and aggregation, data storage, and interaction

that enable analysts to access data that is ready for use. Vega is the primary NNSA repository for consolidated cost, programmatic, and technical data. The system includes:

- Program schedules
- Charge code data
- Execution actuals
- Component specifications
- Architectural parameters

All these data elements are necessary to create a holistic view of NNSA projects and programs. With decades of data across hundreds of programs and projects, Vega provides unique analytical flexibility and enables trend analysis across the NSE.

Data Philosophy and Framework

Vega's framework (both classified and unclassified) revolves around tidy data principles [James]. That is, every row represents an individual record; every column is an individual variable; and every cell is an individual value. That simple data structure facilitates more efficient analysis by enabling analysts to wrangle data using standard tools, techniques, and methodologies without the need for excess manipulation. Aside from charge code-level data collected from M&O sites, it is rare to received native tidy data.

Take EVM data for example. EVM reports display data according to a hierarchical structure, with parent and child elements depicted by indenture rather than variable fields (see Figure 7 for example EVM data, specifically a Cost Performance Report, or CPR).

WBS	DESCRIPTION	LEVEL	CURRENT PERIOD - April-2017									
			PLANNED VALUE	EARNED VALUE	ACTUAL COST	COST AND SCHEDULE VARIANCES - CURRENT PERIOD						
						SCHEDULE		SV Flag	COST		CV Flag	CUR VAR TYPE
			PV	EV	AC	$	%		$	%		
PRG	Program 1	1										
PRG.10.01.01	AF&F System Engineering & Integration	2										
PRG.10.01.01.01.LD	AF&F System Engineering & Integration	3	$ 745,225	$ 767,715	$ 123,484	$ 703,347	94.4%	*	$644,231	83.9%	*	C&S
PRG.10.01.10	FS Integration	2										
PRG.10.01.10.01.LD	FS Integration	3	$ 174,480	$ 31,508	$ 164,058	$ 958,441	549.3%	*	($132,550)	-420.7%	*	C&S
PRG.20.01	Joint Test Assembly	2										
PRG.20.01.01.LD	Joint Test Assembly	3	$ 648,005	$ 523,689	$ 409,764	$ 541,230	83.5%	*	$113,925	21.8%	*	C&S
PRG.20.02.01	System Qualification Integration	2										
PRG.20.02.01.01.LD	System Qualification Integration	3	$ 530,976	$ 53,880	$ 696,263	$ 816,312	153.7%	*	($642,383)	-1192.2%	*	C&S
PRG.20.02.02	Ground Qualification	2										
PRG.20.02.02.01.LD	Ground Qualification	3	$ 785,853	$ 881,844	$ 528,388	$ 332,901	42.4%	*	$353,457	40.1%	*	C&S
PRG.20.02.02.02.LD	Leveraged Ground Qualification Tests	3	$ 257,996	$ 107,628	$ 175,685	$ 166,015	64.3%	*	($68,057)	-63.2%	*	C&S
PRG.20.02.03	Submarine Test Qualification	2										
PRG.20.02.03.01.LD	Not-Sub Test Qualification	3	$ 617,854	$ 70,916	$ 265,655	$ 146,665	23.7%	*	($194,739)	-274.6%	*	C&S
PRG.20.02.04	Random Test	2										
PRG.20.02.04.01.LD	Random Capability	3	$ 472,778	$ 706,947	$ 826,483	$ 239,538	50.7%	*	($119,536)	-16.9%		S
PRG.20.02.04.02.LD	Random	3	$ 522,936	$ 302,998	$ 201,365	$ 574,609	109.9%	*	$101,633	33.5%	*	C&S
PRG.20.04	System Integration	2										
PRG.20.04.01.LD	System Integration	3	$ 627,029	$ 569,970	$ 693,910	$ 945,332	150.8%	*	($123,940)	-21.7%	*	C&S
PRG.20.05	PRG ALT WR Integration	2										
PRG.20.05.01.LD	PRG ALT WR Integration	3	$ 764,163	$ 724,171	$ 172,547	$ 60,838	8.0%		$551,624	76.2%	*	C
PRG.30.01	Program Integration	2										
PRG.30.01.01.LD	Program Management	3	$ 837,226	$ 888,700	$ 814,616	$ 360,682	43.1%	*	$74,084	8.3%		S
PRG.30.01.02.LD	Program Management HE Refesh	3	$ 77,772	$ 953,348	$ 809,053	$ 746,804	960.2%	*	$144,296	15.1%		S
PRG.30.01.03.LD	Capital Equipment Purchases	3	$ 357,454	$ 531,403	$ 591,613	$ 515,272	144.2%	*	($60,209)	-11.3%		S

WBS	Description	Parent_WBS	Parent_Description	PLANNED VALUE	EARNED VALUE	ACTUAL COST	Variance_Schedule	Variance_Cost
PRG.10.01.01.01.LD	AF&F System Engineering & Integration	PRG.10.01.01	AF&F System Engineering & Integration	533464.504	367180.1553	651331.2589	778520.2991	-50874.19427
PRG.10.01.10.01.LD	FS Integration	PRG.10.01.10	FS Integration	681705.0303	685512.7504	172246.9987	588356.4767	7490.378158
PRG.20.01.01.LD	Joint Test Assembly	PRG.20.01	Joint Test Assembly	655501.1652	621664.8356	821916.9966	14465.7639	66013.61256
PRG.20.02.01.01.LD	System Qualification Integration	PRG.20.02.01	System Qualification Integration	652321.0626	978691.6788	235136.6315	883309.3773	-67641.52176
PRG.20.02.02.01.LD	Ground Qualification	PRG.20.02.02	Ground Qualification	719897.3113	245345.3662	300168.8153	25025.105	-319824.7245
PRG.20.02.02.02.LD	Leveraged Ground Qualification Tests	PRG.20.02.02	Ground Qualification	479350.5566	60662.3919	398291.9872	344795.8685	-451403.9676
PRG.20.02.03.01.LD	Not-Sub Test Qualification	PRG.20.02.03	Submarine Test Qualification	92115.08876	496538.7652	5972.765699	513178.0177	-679188.9043
PRG.20.02.04.01.LD	Random Capability	PRG.20.02.04	Random Test	943203.8824	321932.2923	665589.1435	892675.9506	90241.37942
PRG.20.02.04.02.LD	Random	PRG.20.02.04	Random Test	974001.9213	603450.8986	538789.4371	334391.4448	633618.7974
PRG.20.04.01.LD	System Integration	PRG.20.04	System Integration	629713.2582	889953.249	604658.6925	36565.20694	359122.3441
PRG.20.05.01.LD	PRG ALT WR Integration	PRG.20.05	PRG ALT WR Integration	393411.4579	849642.3357	397972.5566	679484.003	-636949.8213
PRG.30.01.01.LD	Program Management	PRG.30.01	Program Integration	726702.9676	287903.5181	518966.4546	166961.4541	-833746.4144
PRG.30.01.02.LD	Program Management HE Refesh	PRG.30.01	Program Integration	20122.36253	681726.0022	146177.1877	488988.1886	-234297.0545
PRG.30.01.03.LD	Capital Equipment Purchases	PRG.30.01	Program Integration	332916.8704	345846.0162	901727.1972	975735.5544	464609.1456

Figure 7: Legacy CPR Report vs. CPR Flat File

While it may be valuable to view data by parent-level elements (such as PRG.30.01 in Figure 7), there is no efficient means for processing such data at scale without significant manual effort.

Vega assumes that the native data submissions that are extracted from the M&O financial and enterprise resource planning (ERP) systems is the “authoritative” format, and CEPE does not prescribe that the data submissions adhere to any additional form or policy. By collecting the raw data, CEPE analysts ensure that their data manipulation is consistent with the way that they will eventually use it for analysis.

Architecture

The Vega system was originally developed to house data on NNSA weapon systems, which necessitated mechanisms to store the data in a secure environment. Because data on nuclear weapons requires stringent access controls, and the classification of such data differs from weapon system data associated with both the DoD and the intelligence community, no form-ready system existed that would enable the efficient storage of the data in the appropriate environment.

This led to the development of the classified Vega system. The basic architecture includes a back-end database that houses the data, custom built processing algorithms that transform and aggregate data into the appropriate forms, and a front-end interface that enable users to interact with the back-end without the need to understand the table structures or the knowledge to write custom queries. The pre-defined query parameters were based on knowledge of the data itself, as well as the analytical needs of the analyst (for example: queries by program, component, site, etc.). This ability to query the data, and ensure analyst confidence in the queries, was a central tenant of Vega.

The original Vega iteration enabled CEPE to store weapon system data, at the appropriate classification level, and without the need to worry about data-aggregation issues. Individual users were partitioned to ensure that need-to-know (NTK) protocols were adhered to, and sensitive data associated with individual M&O business processes were not compromised. Once CEPE’s data collection mandate was expanded to include data on capital acquisitions, the office instituted an unclassified Vega system so as to not unnecessarily comingle classified and unclassified data

The Vega system’s architecture relies on a simple conceptual framework intended to support efficient access to authoritative data in a tabular format. CEPE collects raw data from each of the M&O sites, normalizes it through a set of scripts that are tailored to each site, and loads it into a back-end database (see Figure 8).

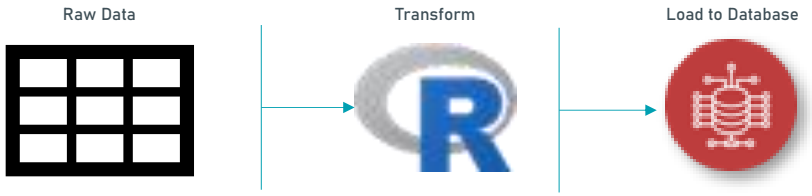

Figure 8: Data Ingestion Process

Tailored Extract-Transform-Load (ETL) scripts are the system's linchpin. They ingest the raw data, which vary by M&O site; validate the data against prior submissions; and transform the data into a structure that is consistent with the back-end table structure. That process ensures data integrity within the database itself, thereby providing confidence that database queries include the information that analysts expect to receive.

Vega required extensive evaluation of standards, policies, and procedures. CEPE navigated multiple challenges in data collection and communication with stakeholders to establish good data governance and ensure that the needs of the office and the individual analysts were met. Management of these challenges and thoughtful consideration of "need to haves" versus "nice to haves" enabled CEPE to build a data system that best meets organizational needs and maintains the flexibility to address future growth.

Business Processes

Each of the 7 NNSA sites report data based on a common set of fields that reflect the operating environment. Accordingly, the business processes underlying the common data fields directly contribute to Vega's design and are central to Vega's conceptual framework. The relationships between the NNSA sites, weapons, infrastructure, and materials are relatively consistent across programs, which lends these relationships to a data structure that can model the enterprise's operations. For example:

- Every site tracks and reports on its operations by weapon system (e.g., B61, W88, W76).

- Each of the NNSA design agencies are responsible for certain types of components (e.g., nuclear, nonnuclear), which feed into dedicated production agencies.
- Each of the NNSA production agencies are responsible for either producing specialized materials and components or assembling specific components and subsystems, which are consistent across weapons.

The design of the data tables in the back-end databases present a parsimonious representation of the way the NNSA operates, with dimension tables that create relationships between the production and design agencies and the weapon systems. Additionally, the data relates logically to technical documents that describe the components, processes, and programmatic aspects of the weapons and infrastructure programs that are housed in SharePoint repositories.

By relating this information in a logical structure, analysts can enrich their understanding of the program they're analyzing and produce more defensible estimates.

Dashboards and First Pass Analysis

In order to facilitate user interaction with the data without the need for scripting or coding experience, CEPE integrated front-end dashboards with database querying functionality. This was done to ensure that users of all experience and skill levels were able to access and leverage the power of the data.

For example, to access the unclassified Vega enterprise, users connect to a CEPE-managed Tableau server that hosts a suite of dashboards. These dashboards provide a mechanism for first-pass analysis of the annualized budget, programs, and individual project data. The classified system leverages an internal SharePoint site that houses a custom-built dashboard that enables users to preselect parameters that query the backend database.

Dashboards and user interfaces provide users flexibility in customizing the view of the data while also featuring a data download option that enable manipulation of the data off the server, or translate the data to reports or briefs. Through individual customization,

users can filter out the irrelevant data and combine only the useful data that is pulled from multiple data sources.

As CEPE collects and standardizes more data, the front-end user interfaces will expand to display the new data. Additionally, as Vega's users grow, more views and aggregations will cater to these new users.

Data Access Controls

Vega user access is strictly controlled by analyst NTK and verified in coordination with program office representatives. While all unclassified users access data through the Tableau server dashboards, not every Vega user can view each dashboard. Dashboard creators internally determine permissions that set each user's view of the server. For example, creators can restrict any proprietary data that is uploaded to the database to only users with a need-to-know. If a user does not have the proper permissions, then the restricted dashboard will not show in their view.

Furthermore, the NNSA Information Management (NA-IM) organization manages clearance requirements associated with the classified system. Analysts are bucketed into user groups that dictate which programs and sites they can access. Prior to consolidating all the information into a central repository, CEPE also verified that consolidation would not increase the data's classification. This data aggregation concern was critical to ensuring users could not access information above their approved clearance level and data would not exceed the classification limits of the system.

Best Practices: Data Usage

In the FDS, OMB stresses appropriate data usage (see Figure 9). With the Vega system and the overarching data collection campaign, CEPE has reduced the burden placed on the M&O sites by requesting data in raw formats as opposed to standardized formats that require raw data manipulation. This has produced several positive outcomes:

- Analysts can reduce duplicative requests to sites to reformat data.
- CEPE has the flexibility to bucket data to suit various use cases.
- CEPE understands cost structures with a greater level of detail.

- CEPEs knowledge of the data has enabled the office to collect data in any format, without the need for additional/burdensome data manipulation on behalf of the submitter, which has enabled greater collaboration across the NSE

Figure 9: OMB-Defined Best Practices for Appropriate Data Use

The Gold Standard helped CEPE to “align quality with intended use” and has assisted CEPE’s ability to “communicate planned and potential uses of data,” as outlined in the OMB best practices for data use. The formatting of Vega and the collection of information at the lowest level of data all support the “use and reuse” of data. CEPE has led many conversations with NNSA headquarters, sites, and outside stakeholders concerning how data is collected and used by different organizations. These conversations have served to foster understanding and trust that will further future collaboration.

The Value of Raw Data

In contrast to other Federal cost organizations that impose specific data format requirements on data providers, CEPE’s goal from early-on has been to collect raw, unaltered data. was an early CEPE goal. Raw data exports from M&O contractor financial systems provide analysts with flexibility during aggregation and modeling and significantly decrease potential misinterpretation and misapplication of the data. The raw data enables data parsing and aggregation at a level that is impossible at higher

levels and accordingly CEPE's resulting data systems and processes are designed to enable analysts to sort and analyze data as required to meet their independent cost estimating needs

EVM Data

For both weapons systems and capital construction projects, the NNSA requires M&O contractors to submit Earned Value Management (EVM) data. Historically this data is provided via the DoD Integrated Program Management Report Format 1 and delivered to either the program office (for weapons programs) or the DOE Program Assessment Reporting System (for construction projects).

Even though EVM data is intended for program management and monitoring purposes, CEPE derives value from a couple different EVM data fields that provide insight into actual costs and final projections, specifically Actual Cost of Work Performed (ACWP) and Estimate at Complete (EAC). EVM data also provides insight into an M&O contractor's Work Breakdown Structure (WBS), which serves to inform other data collection efforts and WBS development for future cost estimates. Because the NNSA does not adhere to a standard WBS (such as those outlined in the MIL-STD-881), an EVM WBS can provide significant insight into current and future design and production activities.

Charge Code Data

Early Gold Standard assessments determined that actual accounting data from the contractors' accounting systems in its raw form provides the best balance between CEPE's analytical flexibility and contractor ease of extract. For the weapons programs, CEPE established an understanding of each site's underlying accounting system and how it supports the reporting of EVM actuals. The office leveraged that information to inform the collection of sample outputs to the lowest level tracked by each site using its native labor categories, elements of cost, and WBS detail below the EVM level.

The outputs from the individual M&O contractor ERP and financial systems differ. However, because each site is responsible for specific mission activities, it is rarely necessary to combine data across sites.

While charge code data associated with weapon production activities has been the primary focus to date, CEPE has invested significantly in collecting data on construction projects. That data has been much harder to consistently collect due to institutional and political challenges. However, efforts to increase the accessibility and availability of construction data should continue to improve.

Technical and Programmatic Data

The primary source for weapons program technical and programmatic data has been the CARD. Contractors and program offices create a draft CARD at the beginning of an ICE and then provide a final CARD 90 days prior to the milestone. The CARD helps establish a common understanding of plans for staffing, quantities, scope, interdependencies, and other areas of interest.

Additionally, CEPE collects many other program artifacts, including Quarterly Program Review briefings, Program Management Plans, Project Controls Documents, and Selected Acquisition Reports, among others. Those data elements provide context to the cost data and enable defensible applications of cost estimating relationships, analogies, unit cost measures, learning curves, and other cost estimating methodologies.

Some technical requirements come from outside the program office and provide insights into the program's strategic direction. That information informs the program of record for future quantity requirements for weapons, which the DOD and NNSA ultimately agree upon and are outlined in the Requirements Planning Document and Program and Planning Document. CEPE has thus established historical databases that contain data extracted from these documents.

For construction projects, CPDSs delivered with the annual NNSA budget request provide a consistent technical and programmatic data source for high-level descriptions of scope and accomplishments of ongoing projects. At the start of an ICE, CEPE collects mission need statements and other programmatic documentation. Detailed technical data sometimes exists within project closeout reports but is inconsistent. Other data sources with information such as project sizing or hazard categories are inconsistent or unreliable. More work remains to mature the construction data collection.

Schedule Data

The schedule data available for NNSA programs often has more detail than any other data source. Many programs and contractors use resource-loaded schedules as the basis for their cost projections, budgets, risk analysis, and EVM data. Each contractor's site schedules typically consist of tens or hundreds of thousands of tasks in Primavera format. There is usually a mapping within the site schedule to an NNSA Integrated Master Schedule (NIMS), a higher-level schedule of a few thousand tasks that includes integration points across each contractor or site. Although site schedules are provided to the program offices on a monthly basis (and integrated into the monthly NIMS), CEPE typically collects them on an annual basis to avoid undue burden on the program offices.

Financial and Budget Data

Reliability, timeliness, accessibility, and their intersections are the principle raw financial and budget data challenges (Figure 10). CEPE strives for data that is authoritative and consistent across multiple data sources. Unfortunately, reliable data can take more time and be less accessible than desired.

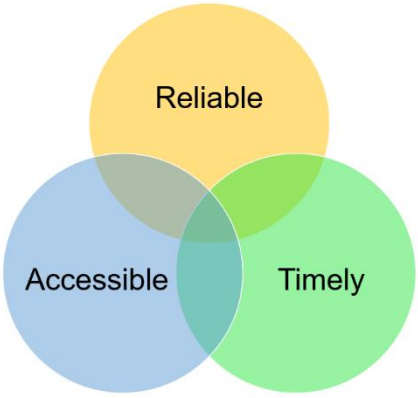

Figure 10: Data Requirements Venn Diagram

Both execution data and budget data are reliable, but not easily traced to each other. Because the authoritative budget data in Vega is published annually in the DOE's Congressional Budget Request, it is viewed as a more reliable representation of the programs from a budgetary perspective. While financial execution data should always reconcile with the authoritative budget data, inconsistent naming conventions and levels

of detail between the execution and budget data make comparisons challenging. Differences in publication timing can drive some of that. To overcome inconsistent naming conventions for better time-phased analysis, CEPE traces dollars of similarly named activities to standardized program, project, and activity titles. CEPE maintains a database that maps raw names to standardized names as a nonauthoritative source of budget data within Vega. Similarly, CEPE reformats the levels of details for project activities to maintain a consistent parent-child structure over time and across activities.

When properly cleansed and mapped, execution data provides additional details about sites and subprojects and does so more frequently (monthly vs. annually) than budget data. Because the budget data exists in an annual report, it is difficult for analysts to know the current financial status or program health. CEPE also manages nonauthoritative sources including standardized program lists, program office assignments, and program categories and groupings, which are all updated regularly with new information.

Case Studies

CEPE built Vega to not only act as a stand-alone repository but also fulfill CEPE's mission to achieve data-driven decision-making within the NNSA. This necessarily supports the ability to provide better situational awareness and defensible actionable recommendations. to the CEPE Director, NNSA Administrator, and Congress.

Vega enables CEPE to generate a chart of the NNSA enterprise funding over time, referred to as the NNSA enterprise mountain chart (Figure 11). The chart displays view of funds at different levels or across different layers within the NNSA as a stacked area chart, creating a mountain of funds. It is highly customizable, and users can adjust it to include multiple decades of annual funding. For example, users can include or exclude construction projects, different appropriations, individual activities, specific capabilities, and change the displayed time period. Further, users can see how different scenarios impact the entire enterprise if construction projects have different alternative spending plans or priorities shift over time.

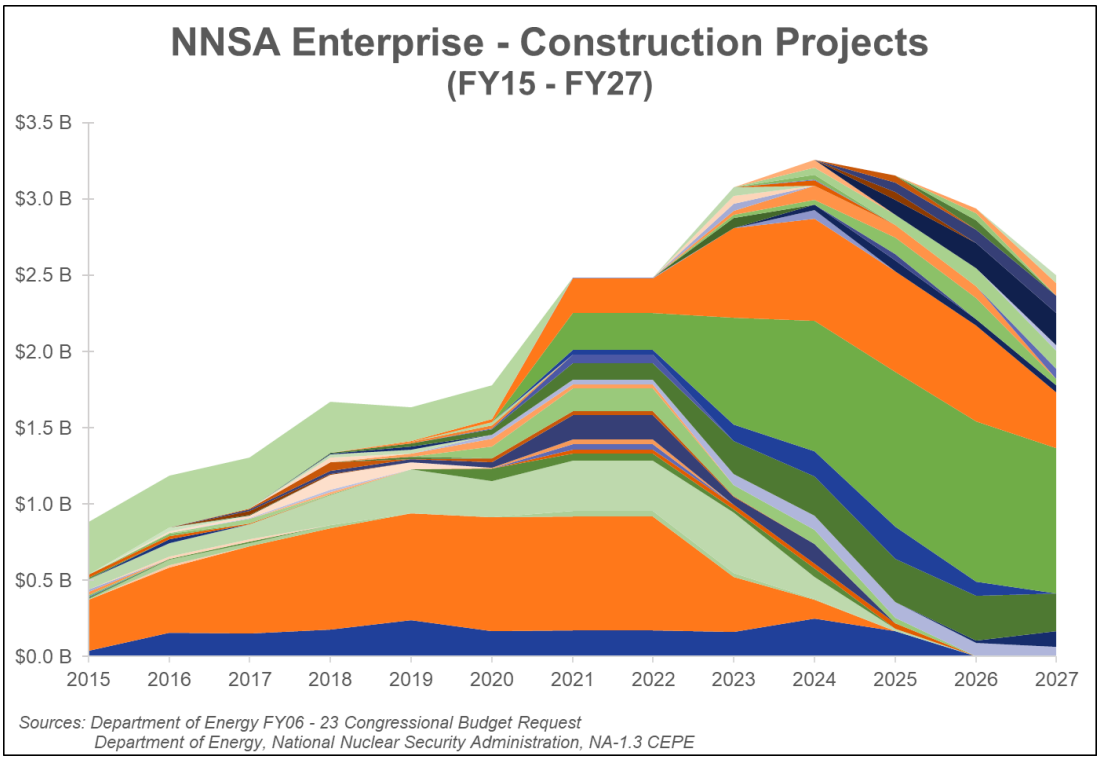

Figure 11: Example Enterprise Mountain Chart generated in Vega

CEPE provided one view of the enterprise mountain chart to Congress showing all of the NNSA's line-item construction projects, while CEPE provides a different view to NA-90 (NNSA's newly established infrastructure organization) that shows NA-90's detailed construction and operations. Vega also ensures both views use the most recent available data.

For capital acquisition projects, users have visibility into several project cost categories, including: engineering design and support, construction, major equipment procurement, project management, site preparation, and transition to operations. This detail enables development of cost estimating relationships and comparisons to data-driven benchmarks when estimating the cost for a complex nuclear facility. Users can also independently assess the schedule of critical decision milestones with the Vega data and calculate decision milestones with the Vega data and calculate schedule duration and contingency for construction projects.

Vega provides unique visibility into costs at lower levels of detail. This has been invaluable on the LEPs, where CEPE tracks costs at the component level. As of the

date of this paper, no other database in the NSE tracks data at this level of fidelity and breadth such that an analyst can analyze cost by labor category, element of cost, or phase of a component. This has enabled the office and NSE stakeholders to perform more detailed cost analysis for use in credibly evaluating engineering build-up estimates at a detailed level.

Organizations outside of CEPE have recognized the system's value. When the NNSA Management and Budget (NA-MB) office wanted to perform component-level analysis, it asked for access to the detailed data housed in Vega. CEPE was able to provide access to support NA-MB's efforts in a timely manner, thereby preventing NA-MB from having to undertake a large data collection effort to study a potential one-time use case. The Air Force and Navy have also requested data extracts to analyze NNSA-managed components and mission sets associated with their programs, thereby overcoming the fact that this level of detail is impossible to glean from DoD reporting systems.

What Would We Change

CEPE's data collection has been incredibly successful in large part due to the power of the original congressional requirements and thoughtful planning by CEPE's federal/contractor team. Regardless, CEPE's experience-to-date includes important lessons-learned for any office beginning a similar effort or maturing an existing capability.

Documentation

As previously mentioned, documentation is a key characteristic of data management. CEPE implemented a formalized documentation standard from day one on all the raw data and file management. All raw files are saved in the original format and consolidated folders and scripts that consolidate them to ensure that data is not corrupted. CEPE has original and secondary versions of all correspondence associated with the data. However, when it initially set up Vega, CEPE did not implement documentation of the system itself with the same level of rigor.

A key part of effective data governance is having a formalized set of processes, standards, and management. The start of Vega was largely ad-hoc. The CEPE team

had six months from solution approval to the demonstration of a deliverable. CEPE was able to achieve the initial goals of the database and had processes in place to manage the database and provide access. Since then, CEPE has started to formalize those processes that it created on an as-needed basis.

While the speed enabled CEPE to successfully demonstrate a commercial off-the-shelf solution, writing Standard Operating Procedures after the fact has been less than ideal. At points, the office has played catchup and tried to recreate items that would have been easier to generate in the beginning.

External Buy-In

CEPE prioritized engagement with working-level stakeholders at all major points in the office's evolution, from the Gold Standard definition to the survey of existing data to education of the ICE and data collection policy to site-by-site mission and purpose introductions. However, along the way several organizations have not understood or were obstructing CEPE's goals. CEPE was not successful in building consensus of mission need or data use cases across the organization.

The effort may have benefited had CEPE worked top-down, prioritizing buy-in from each organization's leadership to examine both the benefits of CEPE's proposed work (the proverbial "carrot") and the statutory and policy requirements (the "stick") for their organization. If working-level teams received direction from their leadership, they may have recognized CEPE's mission and goals earlier in the Vega development process and not hindered its progress. Eventually, CEPE delivered defensible, timely and accurate analytical products, which helped turn some skeptics to advocates.

Requirements Generation

As with any IT-focused federal project, the requirements-generation process is central to a system's success. Federal data management programs are often divided into two buckets that are considered discrete:

- IT Infrastructure
- Analysis

By ignoring analyst input during the initial stages of the project, developers and IT integrators often miss key requirements that enable analysts to use the system for its primary purpose: performing analysis.

Rather than going through a rigorous business framing and requirements-generation process early in the Vega development, CEPE assumed it had identified a viable solution to meet the NDAA requirements to stand up an authoritative data store — namely DoD's Cost Assessment Data Enterprise (CADE) system. While CEPE brought in a special team to perform a rigorous feasibility study that identified a number of potential solutions to stand up the CADE system within the NNSA firewall, the study was unfortunately focused on the IT infrastructure itself not the ability of the infrastructure to meet analytical requirements.

The analytical requirements that led CEPE to pivot away from the DoD solution simplified the process and enabled CEPE to stand up a data store in a short amount of the time and for a fraction of the cost. Had the CEPE team considered the NDAA requirement holistically and analyzed the potential solution set with more rigor, it would have streamlined the project and implemented a better solution implemented sooner.

Path Forward

Currently, Vega has a few remaining silos. Most items of cost data are well-integrated across sources and sites, but much of the technical and programmatic data remains in separate databases within both classified and unclassified Vega. CEPE is actively working to build additional common mapping structures and integration points to bring the vision of a one-stop data shop to life.

When complete, cost analysts will log in to Vega for quick access to multiple sets of data most relevant to their project and query the data seamlessly by predetermined filters and keyword searches. Program analysts will find dashboards that show programs and projects within their scope and how their program fits within the enterprise's portfolio. That may include how a change in one program might affect a change in another program. Even individuals outside CEPE who are currently reaching out for updates to CEPE products, like the enterprise mountain chart, will be able to log

in to their own Vega page and see the latest products. Users will always have the most recent data and analysis available to them.

Currently, CEPE is working on creating mapping scripts to consolidate information related to specific scope items (i.e., cost of providing security). As these scripts get tested and refined, CEPE will incorporate the capability into cost estimates and use the results to provide deeper understanding of detailed cost drivers on individual projects and across the portfolio.

Vega has already proven to be a central resource for classified nuclear weapon data and will only continue to expand the data types and sources that are available through the system. CEPE has maintained some classified data sets in silos, but will work to create more integration points with cost, schedule, and technical items. Front-end analytical capabilities also will evolve to mirror those on the unclassified side, such as the ability to query and automatically visualize historical time-phased data.

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Acronyms

BOP	Business Operation Procedure
CAPE	Cost Analysis and Program Evaluation
CARD	Cost Analysis Requirements Description
CEPE	Cost Estimating and Program Evaluation
CPDS	Construction Project Data Sheets
CPR	Cost Performance Report
DEA	Drug Enforcement Agency
DHS	Department of Homeland Security
DoD	Department of Defense
DOE	Department of Energy
ERP	Enterprise Resource Planning
ETL	Extract-Transform-Load
EVM	Earned Value Management
FDS	Federal Data Strategy
FPO	Federal Program Office
GAO	Government Accountability Office
ICE	Independent Cost Estimate
LEP	Life Extension Program
MIL-STD	Military Standard
M&O	Management & Operating
NA-IM	NNSA Information Management
NA-MB	NNSA Management and Budget
NAP	NNSA Policy
NDAA	National Defense Authorization Act
NIMS	NNSA Integrated Master Schedule
NNSA	National Nuclear Security Administration
NSE	National Security Enterprise
OMB	Office of Management and Budget

OSD	Office of Secretary of Defense
USC	United States Code
WBS	Work Breakdown Structure