NAVAIR **Systems Engineering** Transformation

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THE NAVAL AIR SYSTEMS COMMAND (NAVAIR) is implementing changes to speed delivery of acquisition through the Systems Engineering Transformation (SET). NAVAIR, headquartered at the Patuxent River Naval Air Station in Maryland, is charged with acquiring and sustaining the aviation capability for the Navy.

SET is a strategy developed by Dave Cohen (director of NAVAIR's Systems Engineering Department). It is intended to "blow up the current process" and transform how NAVAIR manages acquisition and reduce the development time of new weapon systems by streamlining the Systems Engineering Process. The term "transformation" is intentional, and means radical change in the process, not to simply gain efficiencies in the current system. Cohen established a small team, led by Jaime Guerrero, to begin the process. The team investigated a wide range of organizations, including industry, NASA, the Sandia National Laboratories and academic institutions, to determine how they reduce cycle time. Based on their research, the team confirmed two key knowledge points relevant to NAVAIR: (1) Transformative change is possible; (2) no critical show stoppers were identified.

The big remaining question was "What reduction in cycle time is achievable?" With strong support from the NAVAIR leadership, the team started researching reasonable goals and how to get there.

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Background

As stated in the 2018 National Defense Strategy, the United States has enjoyed uncontested or dominant superiority in every operating domain for many decades. Because of that superiority, we could deploy, assemble and operate our forces however we wanted. Today, every domain is contested—air, land, sea, space and cyberspace.

Throughout the Cold War, the U.S. military relied on superior technology and training to maintain its combat edge over our enemies, primarily the Soviet Union and the Warsaw Pact as well as China. Our ability to leverage this technological edge is disappearing. There is no shortage of articles and news releases about the rapidly closing technology gap between the U.S. military and its adversaries. This is especially true of certain nation-states such as Russia and China, but also applies to asymmetric threats and non-nation-states such as ISIS and other terrorist groups. These adversaries are introducing potent weapons—spanning the technological spectrum—into their arsenals at an alarming pace.

This dictates that the acquisition process develop and field new weapon systems much more quickly. The U.S. Air Force's F-15 Eagle fighter jet achieved Initial Operational Capability (IOC) after 9 years of development and initial production. The F-22 Raptor, designed to replace the F-15, was in development for nearly 20 years before IOC. More recently, programs such as the F-35 Lightning II (Joint Strike Fighter), the CVN-78 aircraft carrier, and the Joint Tactical Radio System have experienced development times of 15+ years. During these lengthy development cycles, new threats emerge and reduce the combat effectiveness of the yet-to-be-deployed systems. As technology and warfare domains evolve, this problem is exacerbated. What can be done to deal with this challenge?

Congress has enacted legislation in the National Defense Authorization Acts (NDAAs) to reform the acquisition process, emphasizing quicker delivery of systems to the warfighters. These initiatives include:

The Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics was reorganized to give more autonomy to the military Services and agencies.

Each of the Services has stood up rapid capability offices to be more agile and responsive.

Other initiatives from the Fiscal Year 2016 NDAA are under way to reduce the time required to meet the needs of the warfighters—such as Middle Tier of Acquisition, increased use of Other Transaction Authority, and Rapid Prototyping/Rapid Fielding.

The Services are taking other steps as well to speed the acquisition process. Within the U.S. Navy, ADM John Richardson, the Chief of Naval Operations, has rolled out Capability Based Acquisition (CBA), an overarching concept designed to trim the entire acquisition cycle. This covers the spectrum from identifying requirements to deploying new systems to the user community, or more commonly known as "the Fleet" within the Navy.

The traditional Department of Defense (DoD) acquisition system relies heavily on the Systems Engineering Technical Review (SETR) process to provide oversight to contractors developing and producing weapon systems as well as maintaining insight into how they are doing. It includes a sequence of technical reviews to assess the progress of the program, risks and other issues during development. A tried and true methodology, preparing for and conducting technical reviews, is resource intensive. It centers on documentation, depends on contractor-generated information and requires significant investments of time from program personnel—those of both the contractor and the government. It also constrains the pace of development since the contractor depends on successfully completing the technical reviews before being allowed to advance to the next step in the design process.

A new approach is needed to provide timely, informed decisions to accelerate delivery of capability to the warfighters. Central to NAVAIR's transformation is the use of Model Based Systems Engineering (MBSE). According to the International Council on Systems Engineering (INCOSE), MBSE is the formalized application of modeling to support system requirements, design, analysis, verification and validation, beginning in the conceptual design phase and continuing throughout development and later life-cycle phases. MBSE focuses on domain models as the primary means of information exchange between engineers and other system stakeholders, rather than on document-based information exchange. An explanation about MBSE provided by the Massachusetts Institute of Technology (MIT) states that, "The differentiating factor of MBSE is the movement and conversion from the static, text-based, document-driven development to a living model that provides a thorough multidisciplinary understanding (different engineering domains, operational considerations, etc.) of the system, data and interfaces between different sub-systems." This living model represents the information accumulated from the different disciplines and provides a single source of truth for continuous interaction to improve system design features, consistency and completeness.

MBSE has been embraced by industry in specific niches and is being used more widely. Some defense industries are adopting MBSE and using it in limited DoD acquisition applications. It is a dramatic culture change from how DoD now does business—and it requires significant resources. Despite the associated challenges, use of MBSE is a key tenet of SET efforts to reduce development time.

David Meiser, co-lead of the SET team, explained that the goals of MBSE are to reduce cycle time, increase collaboration with industry, achieve a more tightly coupled development cycle and produce a graphical representation of processes—with all these activities resulting in schedule savings. Guerrero adds that MBSE does two things:

- It accelerates the knowledge to the left to allow higher quality decisions faster, effectively reducing schedule.
- It captures data such as models, knowledge and experience for future use.

NAVAIR is deploying the SET through an incremental approach. The team's deployment strategy includes multiple increments, each with increasing levels of maturity.

They begin by laying out the initial capabilities for the overall framework. This includes the modeling tools and languages used, the standard design model views, the integrated modeling environment, the model repository and training/mentoring. Each subsequent increment further matures and formalizes these capabilities. The desired end state is the use of MBSE as the standard practice for acquisition at NAVAIR.

Within each increment, six functional areas are in play. This article provides a short overview of each area. They include the following:

- People—Workforce/Culture
- Process—Process and Methods
- Policy—Policies, Contracts and Legal
- Tools—Integrated Modeling Environment
- Research—Technical Research
- Deployment—SET Enterprise Deployment

People

Changing the workforce and culture is acknowledged to be the team's biggest challenge. Meiser said, "This includes generational differences. For example, recent engineering graduates know the tools (MBSE, Digital Design) and experienced employees know the domain. We need to have a working knowledge of both." Cohen added, "For newer members of the workforce (recently out of college, growing up digitally), this transformation is transparent. That's how they operate. For experienced workforce members that have been doing development using traditional processes, this is a much tougher transition." People who have reviewed paper documents (Contract Data Requirement List or CDRLs) and attended technical reviews in person throughout their careers may be reluctant or find it difficult to work in the model-centric world.

In response, NAVAIR identified, or developed when extant options were not available, a comprehensive suite of training options to familiarize employees with MBSE, modeling, and how the SET will impact their programs. These range from distance learning courses such as MIT's "Architecture of Complex Systems" to classroom based "hands on" training in the Systems Modeling Language (SysML). Also, NAVAIR is developing workshops targeting program offices and IPTs to help introduce and use SET/MBSE methodologies.

The SET involves changes in how people work together. There are plans for groups to meet in collaboration-center spaces designed for interaction—such as developing and/or reviewing system-related models and artifacts in an Integrated Modeling Environment.

Process and Methods

To facilitate deployment, the SET framework is broken into four elements that align with the DoD acquisition developmental life cycle. The elements are depicted in Figure 1.

From a timeline perspective, Elements 1 and 2 cover the pre-contract award phase. Element 3 aligns with contract award to the completion of the Critical Design Review (CDR). Element 4 covers the timeframe from post-CDR until the delivery of the test-ready article.

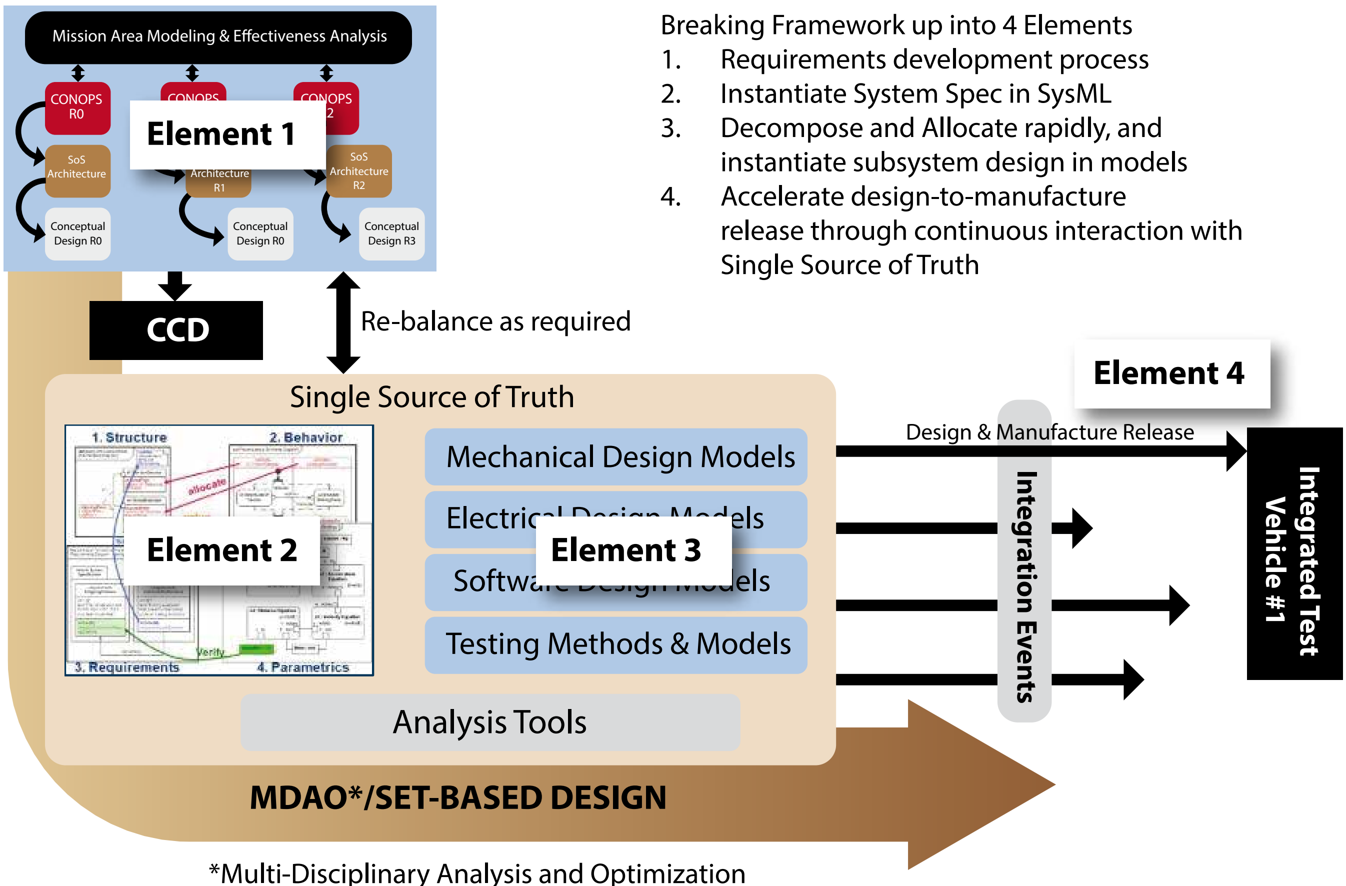
During these elements, the conventional Systems Engineering processes are accomplished, but with some unique differences due to use of the Model-Based approach.

The activities in Element 1 focus on the requirements development process and include mission effectiveness optimization and warfare analysis. These tasks help determine the right number of Key Performance Parameters (KPP) derived from the essential mission elements. The KPPs then will be captured in the Capabilities Development Document.

In Element 2 (System Requirements and Analysis), the key process is the "instantiation" of the system specification in a model using the SysML language. To instantiate means to represent, to create a particular realization of an abstraction. The resulting system model represents key system aspects including structure, behavior, requirements and parametrics. It will further connect to mission effectiveness models within Element 1 and then to other subsystem models and designs in subsequent elements.

Within Element 3 (System Design and Analysis), the system is further decomposed and modeled so that all lower-level functional and performance requirements are documented and allocated to subsystems. The goal is to ensure that a complete set of system requirements

Figure 1. SET Framework: Four Elements



Source: NAVAIR.

are developed and represented in digital models. Similar to what occurs in Element 2 at the system level, the subsystem designs then are instantiated in models. The design is validated using the appropriate engineering models (such as structural, electrical, aerodynamic) and other analysis tools.

In Element 4 (System Implementation, Verification and Validation) the goal is to transition rapidly from design and development to manufacture of integrated test articles. This accelerated timeline is enabled by NAVAIR's continuous and real-time involvement through the model environment, allowing for asynchronous design and manufacture release decisions.

As mentioned earlier, the overarching goals throughout this process are to reduce the cycle time required for development and enable continuous design insight through a collaborative digital environment.

Policy

In changing the old way of doing business, we must consider the impacts to areas such as contracting, data rights and intellectual property. SET requires changes to policies that govern the acquisition process, the language used in Requests for Proposals (RFPs), contracts and other associated documents. There will be legal impacts that must be considered, such as intellectual property, data rights and the ownership of technical baselines. The functional team charged with this area has researched other programs for how they used MBSE language in their Statements of Work and other contract language to incorporate best practices and lessons learned. Industry also has been solicited for feedback on how best to implement these changes. A key aspect of this effort is to obtain industry buy-in. Unless the appropriate contract language is included and benefits are evident, there is little incentive for industry to participate.

Tools

Again, MBSE uses models to represent the system under development. For the complex and diverse weapon systems developed by NAVAIR, a robust modeling language is required. A modeling language provides the syntax, notations and semantics that help define the use of the language to develop a representation of a system. The SET

Team surveyed many modeling languages and tools during their research of other organizations using MBSE. The NAVAIR team elected to use SysML, a well-known general-purpose architecture modeling language for Systems Engineering applications. SysML supports a broad range of systems including hardware, software, information, processes, personnel and facilities.

With a decision made for the modeling language, the team then studied myriad system modeling tools. This is an area of heavy competition with many options to explore. NAVAIR currently is leveraging No Magic products as the primary tool suite for MBSE. Cameo Systems Modeler provides the foundation for model development and interaction, with Teamwork Cloud serving as a model repository to enable multi-user access and concurrent development of system models.

Research

In conjunction with the SET implementation, Dr. Mark Blackburn of the Stevens Institute of Technology, is leading a surrogate pilot program. The pilot program is being used to exercise the use of MBSE and allows for a full emulation of the SET process. Using a fictional unmanned aerial system called "Skyzer," a Search and Rescue at sea platform, acquisition tasks were completed to help assess the SET framework. The tasks included:

- System Modeling—representing the requirements (or specifications) in models
- Requirements Analysis and early Verification and Validation
- Defining contractual language such as the Statement of Work, Sections L and M of the RFP (formatting instructions and criteria intended for use in awarding the contract), draft RFP
- Using models for design data in place of CDRLs
- Using models in Source Selection

The surrogate pilot program has been a valuable test bed in proving out ways to overcome issues such as configuration management of models. It also has helped in defining further steps in the process. One example is to link engineering models (structural analysis, computational fluid dynamics, propulsion, etc.) maintained by the contractor to the government system model providing a rapid and comprehensive ability to evaluate the effect of design changes to the overall system performance.

Enterprise Deployment

Successful transformation requires a comprehensive approach addressing people, technology and support. The Enterprise Deployment team focuses on enabling program adoption of SET principles and practices. In the early stages of transformation, it is necessary to provide a constant feedback loop between the programs implementing SET and the enterprise team developing the core training, tools and starter products. This feedback is critical to ensuring that SET investments and resources are best aligned to program office needs. The Enterprise Deployment team is responsible for developing and capturing metrics, providing a barometer to measure the progress of implementing SET across NAVAIR.

What's Next?

Meiser used the analogy of the evolution of the cell phone. Initially cell phones were "bag" phones or simply portable devices with the functionality of a telephone. Now 20 years later, we have advanced "smart" phones that have significant power and features well beyond that of early cell phones. Smartphones now have capabilities no one could have predicted a few short decades ago. Similarly, the implementation of SET across NAVAIR programs will unlock enormous potential for advanced system design, analysis and development.

Although the SET is well under way, significant work remains to be done. Deploying this NAVAIR-wide will require a sustained effort. Leadership has established a goal for the year 2020 to have SET institutionalized across NAVAIR programs. Training and enabling the workforce as the SET advances in NAVAIR will remain major emphases. Transforming how Systems Engineering is accomplished is a monumental task. A significant focus area is multi-discipline integration into system models, including Cyber Security, Reliability and Maintainability, and Safety. This integration is key to realizing the tremendous value of model-centric engineering.

NAVAIR is coordinating with the other System Commands within the Navy, as well as the other Services, to share lessons learned, align investments and chart a common approach to DoD-wide MBSE implementation. While there is progress, developing uniform processes and structures will take time and sustained effort by leadership.

Conclusion

The 2018 National Defense Strategy calls on the Armed Forces to "shed outdated management practices and structures" in pursuit of a rapidly innovating Joint Force. This imperative provides the U.S. military forces with a clear technological edge in protecting the nation and its allies. To achieve and maintain this advantage will require a multifaceted effort across the DoD, the Services and industry partners. The SET at NAVAIR is an example of actions that help achieve that end, reducing by half the time required to develop and deliver weapon systems to the fleet. It will be exciting to follow the journey.

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