BAE Systems Model Based Systems Engineering Capability Summary

0120-861

Digital Engineering Challenge

Prime systems integrators (SI) in the U.S. Department of Defense (DoD) or Intelligence Community (IC) space face the challenges of working with increased system complexity, the continuous evolution of mission requirements, and the agility and speed of capability delivery demanded of our teams and stakeholders. Further, it is the responsibility of an SI to "own the technical baseline" of all systems and capabilities throughout the system life cycle on behalf of the customer, including:

- System and system-of-system (SoS) mission capabilities and stakeholder requirements
- System architecture, system, and subsystem requirements
- All engineering designs, at logical and physical levels, including all hardware and software configuration items, system test and evaluation
- As-built systems, including production and manufacturing, and supply chain
- As-supported systems, including operating training and support, maintenance, and availability

As a prime systems integrator, BAE Systems develops and sustains a large array of complex systems throughout their lifecycles and employs a wide array of engineering modeling and design tools across multiple engineering disciplines. This results in large amounts of cross-domain design and operational data from different system constituents. The entire industry faces challenges with the functional stovepipes of modeling and design tools and the limited interoperability between them due to the proprietary nature of the tools, multiple meta-models for each engineering discipline, and proprietary data formats. Most technical baselines contain segmented and disconnected data, typically within the stovepipe of their respective engineering disciplines (e.g., electronics, mechanical, and software). System owners (i.e., the Government program offices) often receive systems with inconsistent or incomplete data or no data at all. The available data they do obtain becomes obsolete over time, due to the lack of traceability between documents and the cost of maintaining the documents.

Our Vision

BAE Systems recognizes the challenges presented above and has embarked on a multi-year strategic investment in Digital Engineering (DE) to digitalize our engineering workforce and SE&I capability. To enable this vision, the company is investing in digital infrastructure and virtual, collaborative Digital Engineering Capabilities Labs (DECL) to drive rapid innovation, state-of-the-art digital technologies, and cloud migration. Our goal is to continuously increase our capability and support the Department of Defense's vision of "an integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."

Source: Department of Defense

Our vision is to apply a Model-Based Systems Engineering (MBSE) approach to transform legacy, document-based development stovepipes into a product-centric, integrated, digital engineering enterprise. This digital enterprise is built on a model-based, integrated development or data environment that supports multi-disciplinary, multi-organization stakeholders and leverages product-line reference architectures and a shared model library to develop, deliver, and sustain a system through its lifecycle.

BAE Systems, Inc.
Intelligence & Security
www.baesystems.com

This multi-year journey of digital transformation by the company has the following ultimate goals:

- Establishing a digital thread to connect the desktop to the factory floor and to fleet readiness, from development through the sustainment phase, to reduce lifecycle costs, break down disciplinary stovepipes, and enable a "paperless" product lifecycle
- Shifting the right side of the system engineering V to the left, to enable better system understanding, improved design decisions, early detection of defects, minimized rework, and overall risk reduction
- Enabling systematic design reuse to reduce lifecycle cost and improve the efficiency and agility for all engineering disciplines
- Significantly collapsing the cycle time from design to production, to improve the speed of product delivery
- Institutionalizing knowledge management and product know-how to empower engineering teams

This vision is consistent with the Office of the Deputy Assistant Secretary of Defense for Systems Engineering (ODASD (SE)) 2018 Digital Engineering Strategy (DES), and several DoD digital engineering (DE) transformation initiatives aimed at accelerating the delivery of fully integrated digital engineering capabilities designed, developed, and sustained in a model-based digital environment. The aerospace and defense industries are responding with their own initiatives and investments to develop innovative MBSE capabilities to create digital threads and "digital twins" for systems they develop and services they provide.

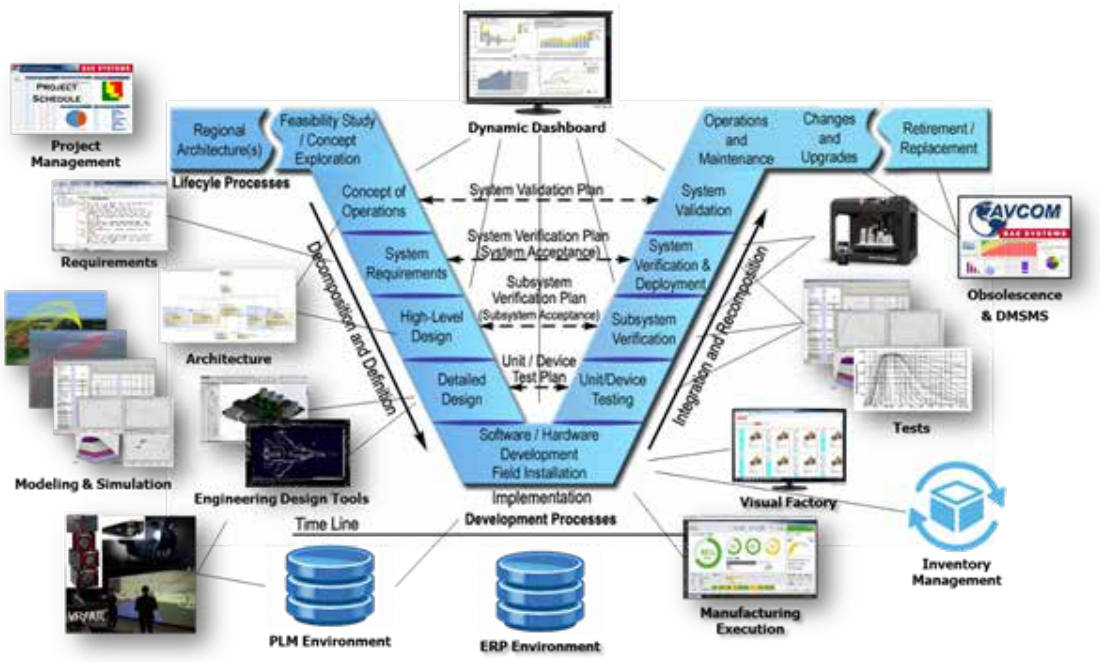
ADAMS™ Reference Architecture

In order to fulfill this vision, BAE Systems is developing an Advanced Integrated Data Environment for Agile Manufacturing, Integration and Sustainment Excellence (ADAMS) - a model-based, digital engineering environment that allows our engineers to perform end-to-end system design, development, integration, maintenance, and sustainment activities. The ADAMS Reference Architecture is a technology blueprint for the incremental development, implementation, and deployment of such an environment to our programs. At its core, ADAMS implements an Integrated Data Environment (IDE) by deploying a suite of integrated system architecture modeling tools, engineering design tools, a Product Lifecycle Management (PLM) system, an Enterprise Resource Planning (ERP) system, as well as project management tools.

It will provide a single, configuration controlled, logical data repository and that interconnects the system data across five domains throughout the system life cycle:

- System Integration, an environment that integrates a master schedule, project plans, and project risk register with a set of project management workflows that drives work breakdown structure (WBS) elements, work packages, and risk mitigations through the life cycle
- Systems Engineering, an MBSE environment that captures the system requirements and the logical and functional architecture applying a system modeling approach
- Software Engineering, an integrated software development environment consisting of software development tools, source code version control, and automated workflows that drive software requirements, issues, and bugs through the lifecycle
- Product Lifecycle Management (PLM), a hardware-centric configuration control environment that supports physical design and product definition and integrates 3D Computer-Aided Design (CAD) modeling and other engineering design tools, as well as 3D printing for additive manufacturing
- Supply Chain Management, an integrated Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES) environment that implements an interconnected and digitalized supply chain and automated manufacturing process (the "digital shop floor")

BAE Systems, Inc.
Intelligence & Security
www.baesystems.com



These five domains span multiple functional disciplines and support integrated operations for system development and sustainment projects across the entire system life cycle/Systems Engineering V through model integration and process automation.

We take an incremental approach to develop the ADAMS architecture and deploy it on major programs to meet their individual MBSE requirements and champion customers' DE objectives. We have developed a unique methodology to manage the IDE in both classified and unclassified environments, enabling us to leverage technical expertise across the organizations in order to solve complex technical problems while protecting sensitive and classified technical information.

Applications and Examples

BAE Systems has applied MBSE to ongoing programs and new acquisitions with the complex interdependencies associated with heritage and legacy processes and systems. Examples include the following:

Our Intercontinental Ballistic Missiles (ICBM) team has demonstrated the expertise to translate "paper-based" legacy and heritage design documents into interconnected, cross-domain digital models that "own" constantly evolving technical baselines. The application of these skills realizes the cost, schedule, and performance benefits of DE for new and legacy programs. When mature, it virtually eliminates single point failures associated with Subject Matter Expert (SME) "tribal knowledge" by democratizing that knowledge through the exchange of models and their underlying data.

On the U.S. Navy (USN) AEGIS Technical Representative program, our team uses a model-based test and evaluation approach for Independent Verification and Validation (IV&V), using system models to manage the requirement baseline and architecture traceability, change impact analysis, verification testing, and to automate the system and software testing process.

On the USN's Strategic Systems Program (SSP), our team is developing an integrated SysML-based system modeling and PLM approach to perform two mission-critical functions, managing the change process for the interface requirements and the interface requirement data sets, including all Contract Data Requirements List (CDRL) items.

Our Digital Engineering (DE) Lab provides an IDE in a classified environment for the weapons system technical baseline. It deploys the state-of-the-art Virtual Reality (VR)/Augmented Reality (AR) technology that delivers connected, immersive visualizations that mimic the real world and provide the ultimate customer experience in collaborative engineering, critical design reviews, and architecture and design decision-making.

BAE Systems, Inc.
Intelligence & Security
www.baesystems.com

Our Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) programs are utilizing the ADAMS IDE-enabled cross-domain digital thread and developing an integrated C4I system-of-systems architecture for next generation surface ships to provide architectural design trade space for new ship designs.

We developed the Visual Factory™, a specialized Manufacturing Execution System (MES) application, and deployed it to our systems integration and manufacturing facilities in Summerville, SC and Lexington Park, MD. At these facilities, integration teams installed and delivered thousands of military and Special Forces vehicles, boats, and surface crafts, and kitted assemblies of C4ISR systems.

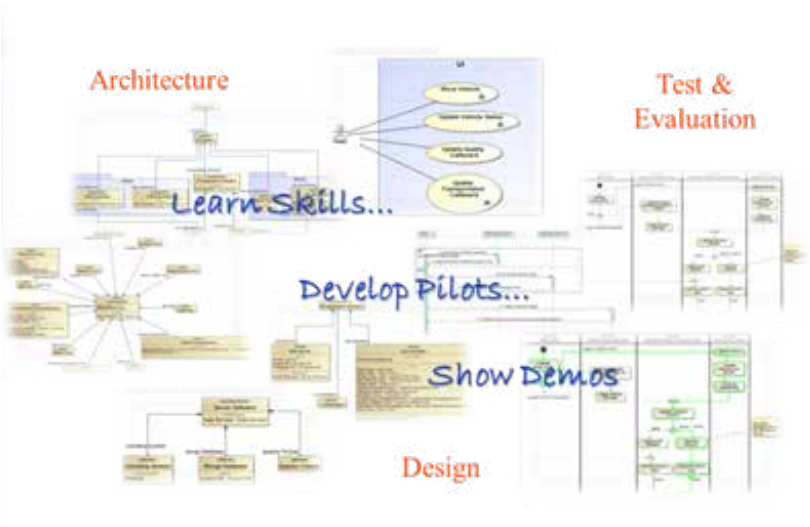
With our FAST Lab team's focus on emerging Undersea Warfare requirements and technologies, a significant Internal Research and Development (IRaD) investment was made to demonstrate a recently purchased capital AUV (Riptide 2MP) during the Navy's ANTX-19 experiment. The team used MBSE as a design and development tool resulting in significantly more capability to be fielded, in a shortened time period and using fewer personnel than traditional methods.

Developing Workforce Talent

In order to cultivate a MBSE-capable workforce, we launched the MBSE Catalyst Program to train employees in specialized MBSE skills, particularly in system modeling and architecture-based design. The Catalyst Program aims to develop: a) new skills – develop architecture and modeling skills and product domain knowledge; b) pilot projects – apply learning into practice and develop hands-on experience with a real-world problem; and c) system demonstrations - gain customer and stakeholder acceptance and program support.

Designed much like a university certificate program, the Catalyst Program consists of four steps:

1) Self-learning - basic concepts in MBSE or systems engineering in preparation for the hands-on stages;
2) Hands-on training and labs - weeklong, professional trainers led classroom training in system modeling;
3) Pilot projects - apply use cases derived from real-world programs; and
4) Stakeholder acceptance – demonstrate use cases to internal and customer stakeholders.



Over time, these pilot use cases become the starting point or the "catalyst" for new requirements and scope of work under contract. More importantly, this program has produced and is continuously providing a new cadre of hands-on system architects and the critical human capital that will lead our DE enterprise transformation.

BAE Systems, Inc.
Intelligence & Security
www.baesystems.com

Cultivating Cultural Change

BAE Systems views the DE strategy as a critical enabler for our businesses, our teams, and our customers. Adopting a DE culture, on the other hand, will require a comprehensive change in how we do business and perform multidisciplinary engineering, which may be the most difficult challenge we face as we adopt this new methodology. To cultivate the necessary culture change, we are adopting the following multipronged approach:

- Engage stakeholders, especially at the senior management level, to drive a high degree of organizational adoption, as well as the commitment of required funding and resources. We organized focused workshops and invited industry-leading experts to conduct special management training.
- Make DE relevant to program and customer challenges by solving their problems and demonstrating the benefits of adoption (for example, from design reuse), and by developing MBSE-based solutions for business captures and proposals as key differentiators
- Provide workforce training. We have developed the "MBSE Pathway," a special self-learning curriculum for training MBSE knowledge and skills, offered to employees as part of their professional development.
- Communicate about MBSE, its benefits and strategic potentials, frequently and effectively, especially from senior executives. Link DE to business growth strategy and convey how it can change the organization through new business winning and the gains of productivity and efficiency.

Implementation and Deployment

As a systems integrator, we support a broad base of customers and missions, each with different requirements for the engineering and development environment. Our strategy is to implement and deploy a customized IDE tailored to the nature of the work and the type of mission requirements. We have taken an incremental approach – crawl, walk, run – as a preferred strategy that seeks small successes early and often. At a tactical level, we develop use cases that lead to stakeholder engagement and demonstrating problem solving techniques, while helping to build the confidence and credibility.

We view ADAMS as a critical enabler for our businesses, our teams, and our customers that offers the following business benefits:

- Cost Reduction/Take-out. Moving the right side of the system V to the left enables early system understanding and architecture tradeoffs, detecting defects early in the design process and reducing transaction cost throughout the system life cycle
- Cycle Time Reduction. Enabling systematic design reuse, change impact analysis, early requirement verification and validation, and early design decisions
- Improved System Integrator Capabilities for Customers. Improved ability of owning the technical baseline and change management, better requirement definition and traceability, integrated system analysis and modeling and simulation capabilities, and rapid engineering and response capability for greater fleet readiness posture
- Knowledge Transfer. Codifying system designs and product knowledge in models and institutionalizing intellectual property (IP), trade secrets, and enterprise knowledge management
- Empowered Teams. Equipping engineers and project teams, particularly millennials, with advanced architecture modeling and engineering design tools, and digital technology capabilities for the information age

Ultimately, our mission as a prime systems integrator and trusted partner to our customers is to deliver better systems and increased capabilities to the end users and warfighters at highest level of quality, lower cost, and at a faster pace. We are committed to supporting our customers' digital engineering mandates and to continuously improving mission assurance for the systems and programs we support.

BAE Systems, Inc.
Intelligence & Security
www.baesystems.com

About BAE Systems

BAE Systems, Inc. and its 33,600 people are part of a global defense, aerospace and security company with 85,800 employees worldwide. We deliver products and services for air, land, sea and space, as well as advanced electronics, security, information technology solutions, and customer support and services. Our dedication shows in everything we create and deliver—from advanced electronic systems to cyber operations and intelligence analysis, from combat vehicles to naval weapons, and from ship maintenance and modernization to vehicle upgrades and services. We push the limits of possibility to provide a critical advantage to our customers where it counts.

For more information:

Tisha Wright
Director, Government Relations
BAE Systems, Inc.

T: +1 703 312 6975; M: +1 571 329-1737

E: tisha.wright@baesystems.com

1101 Wilson Blvd, Suite 2000
Arlington, VA 22209