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MODEL-BASED ACQUISITION: INCREASING CLARITY, COMPLIANCE AND UNDERSTANDING IN PRODUCT ACQUISITION

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ABSTRACT

The DoD Digital Engineering Strategy [1] released in June 2018 outlined the DoD's strategic goals which "promote the use of digital artifacts as a technical means of communication across a diverse set of stakeholders" In addition to build, test, field and sustainment of defense systems, emphasis was placed on the acquisition and procurement of systems and the importance of digital engineering. This was further reinforced in the Feb 2022 release of the Engineering of Defense Systems Guidebook [2] which contains Digital Engineering sections in each chapter. The norm for Systems Engineering has become Model-Based Systems Engineering (MBSE) in which models are used at all phases of development. To complete the digital thread from concept to disposal, models will be required for the acquisition phase. This paper will describe Model-Based Acquisition (MBAcq), and how it can be used to increase clarity compliance and understanding in Capability Systems and Software Acquisition for ground vehicles.

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1. INTRODUCTION

Digital Engineering is 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. [3] In her presentation at the 20th NDIA SE Conference in October 2017, Ms. Philomena Zimmerman laid out the DoD Digital Engineering Strategy (DES). [3] The five goals of the strategy were to:

1. Formalize the development, integration, and use of models to inform enterprise and program decision making.
2. Provide an enduring, authoritative source of truth.
3. Incorporate technological innovation to improve the engineering practice.
4. Establish a supporting infrastructure and environment to perform activities, collaborate and communicate across stakeholders.

5. Transform the culture and workforce to adopt and support digital engineering across the lifecycle.

The background of the DES was due to

- Dynamic operational and threat environments
- Growth in system complexity and risks

Linear acquisition process that lacks agility

- Cost overruns and delayed delivery of capabilities to the warfighter
- Current practices can't keep pace with innovation and technology advancements.

Ms. Zimmerman also affirmed that Digital Engineering transforms the way that the DoD innovates and operates, and the Authoritative Source of Truth was key to this as shown in Figure 1.

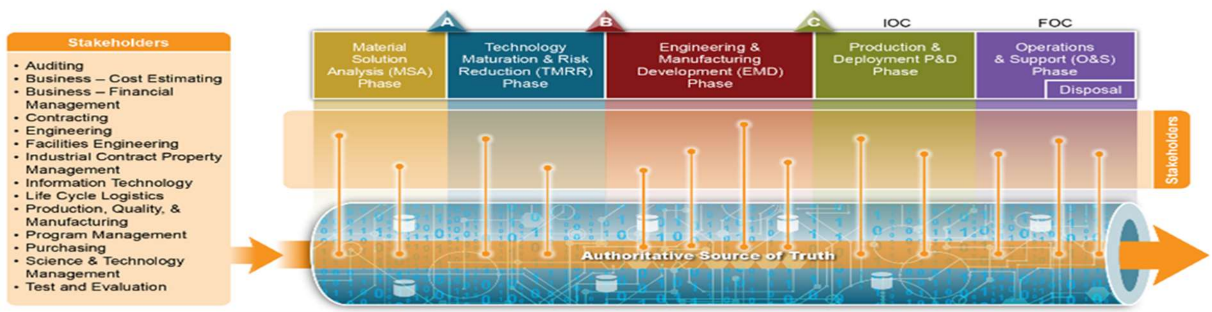

Figure 1: The Scope of the Authoritative Source of Truth.

The Digital Thread of information through the Authoritative Source of Truth enable stakeholders to interact with digital technologies and solve problems in new and groundbreaking ways. Using models is not a new concept. In 1993, "Model-Based Systems Engineering" was coined as a term by Wymore, A. Wayne in his book with the same name.[4] However, digital engineering emphasizes the use of models across the lifecycle.

More pertinent to this paper, Ms. Zimmerman also presented on the Digital Engineering (DE) and Computational Research and Engineering Acquisition Tools and Environments (CREATE). [5] CREATE program develops and deploys validated physics-based High-Performance Computing (HPC) applications to enable DoD engineers to implement and execute the digital engineering paradigm for major DoD platforms (naval, air, & ground vehicles and RF antennas). Includes ability to construct and improve digital product models for weapon platforms. Tools will address all stages of the acquisition process.

1.1. INCOSE Systems Engineering Vision 2035

The purpose of the Systems Engineering Vision 2035 is to inspire and guide the strategic direction of systems engineering across diverse stakeholder communities. [6] The guide provides the global context for systems engineering, summarizes some of the key trends and influencing factors that are expected to drive changes in the practice of systems engineering. It identifies a set of systems engineering challenges, and the high-level roadmaps needed to transition systems engineering from the current state to the future state. It also highlights the need for collaboration among the global systems community to evolve and implement the roadmaps. It addresses the digital transformation and the direction towards a fully model-based systems engineering environment. [6] The section on acquisition defines the current state as follows:

Project needs and requirements are prepared 'in-house' by organizations to inform traditional acquisition processes, with the consequence that the project does not fully leverage the knowledge of the wider enterprise during its earliest and most formative phases. Acquirers possess limited ability to assess technical performance during the systems development process, while contracted parties are not motivated to share information. Reference architectures, when used, are unique to projects and not maintained after delivery of the systems.

In the future, acquiring organizations leverage industry knowledge during the earliest phases of a project, prior to the 'main contract'. They establish multi-organization integrated project teams to perform as 'smart' customers during the entire systems life cycle, able to build upon evolving reference architectures and best practices. Shared digital engineering solutions maximize access to, and enhance the use of, information by all project participants during all phases, including 'smart operations. [6] The section goes on to discuss additional stakeholders and advantages of future acquisition.

Smart Customer

Acquirer draws on their own team, strategic partners and a library of design guidelines and policies to judge system/design fitness, maturity, and risk at all phases of a program. Systems engineering knowledge and competence is available at acquirer site enabling better communication between acquirer and suppliers. [6]

Contract Incentives and Lower Barrier to Entry

Adoption of standards, and access to shared environments and technology will lower the barrier to entry for new and non-traditional organizations.

Better Requirements and Pre-Competitive Preparation

Statement of need and conceptual reference architecture prepared by acquirer in collaboration with potential downstream suppliers and strategic partners, followed by finalization and issue of the tender by the acquirer.

Shared Information and Shared Environments

Maximized access to useful program information by all members of the enterprise, strengthening communication, reducing errors and duplication of assets. Shared digital engineering solutions, with mature configuration and variant management, allows the enterprise to work in highly iterative, short steps/phases, providing the agility and flexibility needed to manage large and complex systems, supported by dynamic "dashboards" and high degree of automation, while still supporting fair protection of intellectual property of all enterprise members.

Shared Management of Risks

All stakeholders share and collectively manage program risks. This arrangement leverages the greater knowledge of the enterprise, and shared access to information across the life cycle by the acquirer and supplier, to address risks, and reduces surprises and issues leading to conflict.

Smart Operations

Operations will be integrated across projects and through the trusted supply chain, leveraging digital twins, pervasive health monitoring, and predictive maintenance, to achieve a completely optimized life cycle up to controlled disposal. [6] One of the key elements to this future vision is access to models and digital models and information throughout the acquisition lifecycle. Reference architectures are a key part of this.

1.2. Reference Architectures

In the future, the enterprise has regular access to and maintains a proven and evolving catalogue of applicable architecture patterns and frameworks matched to the needs and phase of the program. [6] A Reference Architecture is an authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple architectures and solutions. Reference Architectures serve as a reference foundation for developing solutions and may also be used for comparison and alignment purposes. [7]

The primary purpose of a Reference Architecture is to guide and constrain the instantiations of solution architectures as depicted in Figure 2. Based on this, a Reference Architecture is considered an organizational asset:

- Providing common language for the various stakeholders
- Providing consistency of implementation of technology to solve problems
- Supporting the validation of solutions against proven Reference Architectures
- Encouraging adherence to common standards, specifications, and patterns

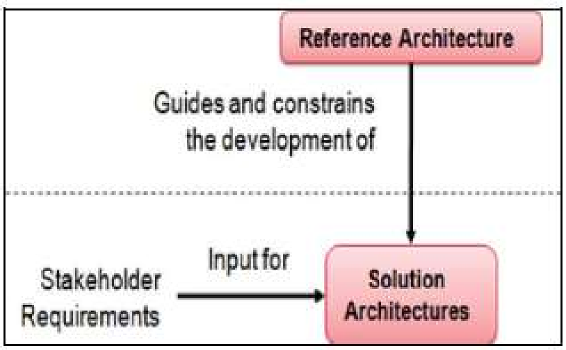

Figure 2: Reference Architecture Purpose

Other relevant terms used in the definitions include "patterns" and "solution architectures". Patterns are models of architecture representations at a level of generality that provides some degree of reuse. The DoD Architecture Framework (DoDAF) [9] defines Solution Architecture as a framework or structure that portrays the relationships among all the elements of something that answers a problem. It describes the fundamental organization of a system, embodied in its components, their relationships with each other and the environment, and the principles governing its design and evolution. Solution architecture instantiations are guided and constrained by all or part of a Reference Architecture where the generalized and logical abstract elements of the Reference Architecture are replaced by real world, physical elements according to the specified rules, principles, standards, and specifications. [8]

2. Model Centric Research

M Blackburn, et al [10] led a research project looking at Transforming Systems Engineering through Model-Centric Engineering A013 Final Technical Report. The project found that the "expected capability of MCE and more broadly Digital Engineering (DE) can enable mission and system-based analysis and engineering that reduces the typical time by at least 25 percent from what is achieved today for large-scale air vehicle systems." The project used model-based techniques throughout the development of the Skyzer system as part of a NAVAIR project. Models included:

- Project Planning Model for Skyzer
- Surrogate Mission Model for Skyzer
  - Parts of mission model provided as Government Furnished Information (GFI)
- Surrogate System Model for Skyzer
  - Parts of system model provided as GFI
- Surrogate Acquisition Model Skyzer, includes models for:
  - Statement of Work
  - Technical Evaluation Criteria formalized as a model to support source selection
  - Surrogate Contractor System RFP model for Skyzer
  - Surrogate contractor assessed, refined and extended GFI system model
  - Traces back to Government Skyzer System and Mission models
- Surrogate Contractor Design models for Skyzer
  - Design models address aspects of multi-physics analysis and design

  - Links disciplines-specific design back to Surrogate Contractor system, which traces back to Government Skyzer System and Mission models
- View and Viewpoints for DocGen and other Libraries
  - Used to generate the specifications from the models based on stakeholder views
- Collaboration Environment for the Authoritative Source of Truth

Other projects have also adopted MBAcq techniques, but the results have not yet been published.

3. Acquisition Reference Models

L Hart [11] presented at Ascend 2020 on the topic of Model-Based Systems Engineering (MBSE) & The Acquisition Reference Model (ARM) Lowering the Barrier to Gov MBSE Adoption. The ARM is a set of reusable model templates and guidance used to structure a model-based RFP based on the Unified Architecture Framework (UAF) [12] standard to support data driven decisions beginning with acquisition which can be maintained throughout the complete lifecycle of program. The ARM helps to create a precise RFP, respond to RFP, evaluate RFP response including contractor self-evaluation, government evaluation, and contractor execution after award. Finally, the resulting matured model can be used to maintain the technical baseline. As it evolves over time it represents the technical baseline. [11]

The Model-Based RFP Process involves an ARM template, Government Reference Model (GRM) and the Model-Based RFP Model. Models are used throughout the acquisition process. The RFP would be generated from the RFP model and would include operational context, capabilities, requirements, constraints, etc. Evaluation criteria would include MOSA, certification properties, data rights, KPPs, IP, etc. Guidance would be provided to the RFP response regarding modeling conventions, traceability, format, etc. Data rights, GFE, GFSW, GFI would be tagged in the model.

As detailed in [7], the RFP response would include a solution model with traceability to the requirements and model elements within the GRM. This would comply with the guidance provided with the GRM. As part of the evaluation by the government, for compliance and scoring, evaluators would use the built-in evaluation criteria. Other aspects would use criteria and data in accordance with the domain, context, and use. These criteria would provide an objective means of performing analysis or alternatives and compliance. Again, any required documents would be generated from the models and could be further specified in the ARM [11]

During contract execution, the government would use the models to collaborate with suppliers, monitor progress and maturity and assess change impact and manage risks. [11]

4. Model-based Acquisition Concepts

Many concepts have been defined so far in this paper with descriptions and relationships confined to their specific domain. To get the large picture, a concept diagram has been created in Figure 3. It defines the concepts in a simple, solution-independent notation without specifying which model elements will implement them. Expressing the concepts in this way provides the larger picture of how the different concepts will work together. The lines with arrows represent directed relationships, the triangles specify types and subtypes, the open diamond represents aggregation, and the black diamond represents composition. The following sections describe the elements in the diagrams as well as their major relationships. Elements on the diagram are capitalized to help identify them.

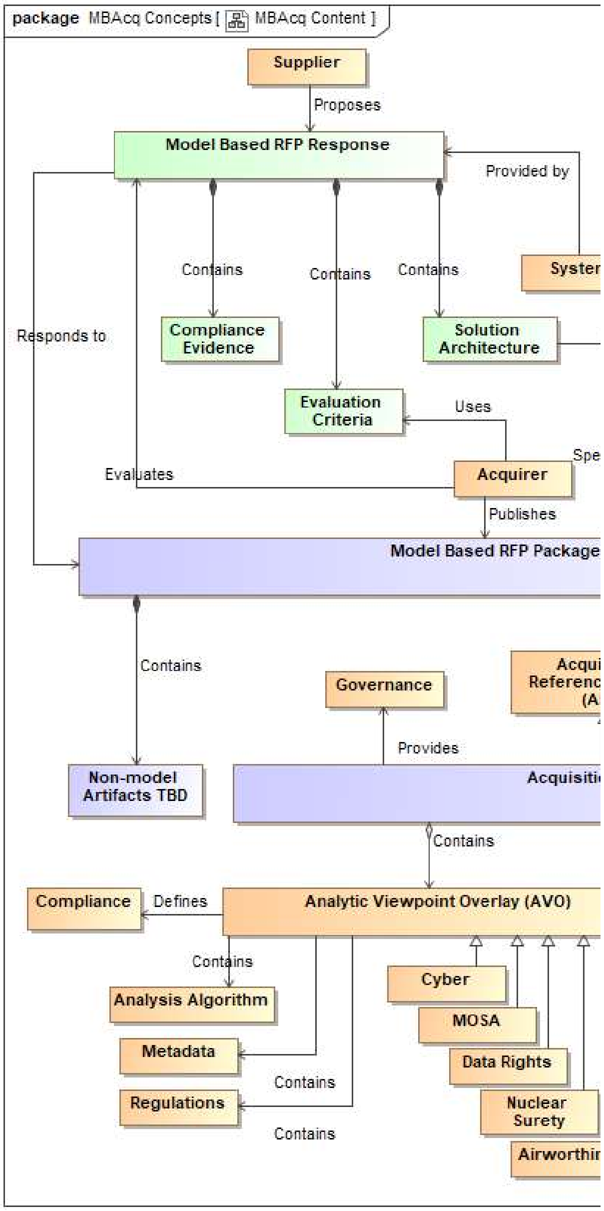

Figure 3: Model-Based Acquisition Concept Map

The Acquirer Publishes a Model-Based RFP Package that specifies the desired System. The Model-Based RFP Package is made up of Non-Model Artifacts, an Acquisitions Reference (ARM) and a Government Reference Model (GRM). The ARM is a type of Acquisition Reference Library (ARL) and provides Governance. The ARM Template provides model structure for RFP content and evaluation tools. The ARM contains Analytical Viewpoint Overlays (AVO), Data Item Descriptions (DID) Templates and Schemas, and the Uniform Contract Format (UCF). Of particular interest in the UCF are Section K – Representations, Certifications and Other Statements of Offerors, Section L – Instructions, Conditions, And Notices to Offerors, and Section M – Evaluation Factors For Award. The GRM is a descriptive model containing the program requirements, & constraints, High level Capabilities, mapped to Operational scenarios, traced to requirements (e.g., CDD, SRD, Conops, Technical performance measures (i.e., KPPs, KSAs, MOEs…). The GRM and TPM can be expressed in the Systems Modeling language (SysML) [12], the Unified Architecture Framework (UAF) [13], or other modeling language.

An AVO is a collection of constructs needed to support analysis for a domain specific concern using a standardized approach. Typical construct elements include:

- A set of regulations, constraints, rules…. driving the analysis (i.e., MOSA, safety, certification, airworthiness, Space …)
- A set of Data/Metadata required to address or support analysis, compliance or fit for purpose. Implementation example (Domain model/profile)
- Logic/algorithm needed to perform analysis using the metadata and regulations. [14]

The characteristics of these AVOs:

- Usually have associated regulations, governance that can be treated as standards-based requirements or constraints
- Cross cutting both viewpoints/rows & aspects/columns
- Supports specific analysis associated with a Domain Specific concern
- Can be created independent of a specific solution architecture description
- Can be applied or removed from a specific architecture description without impacting the AD, hence an overlay

The AVO defines compliance in its variety of ways, depending on which is the most appropriate.

The Supplier Proposes a Model Based RFP Response that will Provide a System. The RFP Response contains Compliance Evidence, Evaluation Criteria, and a Solution Architecture that is Compliant With the GRM.

5. MBAcq and Ground Vehicle Acquisition

The Digital Engineering Strategy [1] spelled out five goals of the strategy as shown in Figure 4.

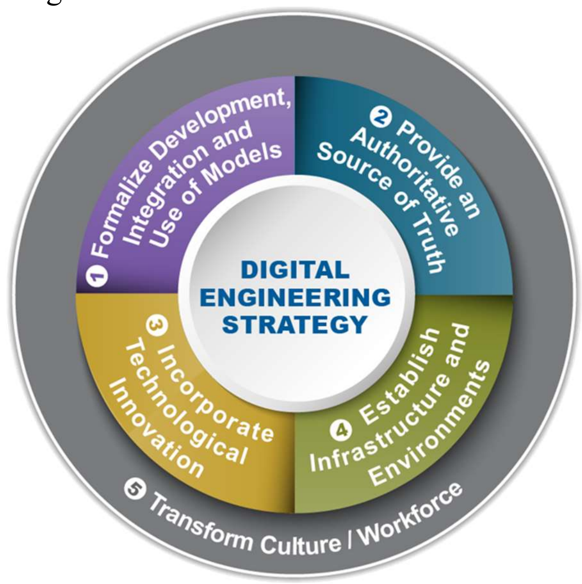

Figure 4: Digital Engineering Strategy

In addition to being goals, they also define the tasks that an organization needs to perform to implement the strategy. Implementation of the strategy will be both iterative and incremental.

1. Formalize the development, integration, and use of models to inform enterprise and program decision making. Existing processes will need to be examined to determine where and how model-based techniques can be inserted and adopted. Processes will need to be prototyped to determine which work best.

2. Provide an enduring, authoritative source of truth. Configuration management of models needs to be maintained throughout the product development lifecycle to ensure consistent information. This needs to be maintained as well as to support ongoing operations and maintenance. Otherwise, the models will need to be rebuilt from scratch with corresponding loss of IP and knowledge. In addition, best practices, patterns,

components, libraries can be harvested and reused in future projects.

3. Incorporate technological innovation to improve the engineering practice. Most important, training will need to take place at all levels of the organization in accordance with exposure and use of models. This will include influencers, reviewers, and modelers. Engagement with standards and industry bodies to share ideas will also be useful.

4. Establish a supporting infrastructure and environment to perform activities, collaborate and communicate across stakeholders.

Model-based Acquisition is not just SysML or UAF models. It involves the digital thread across a set of development tools. This includes requirements management tools, Product Lifecycle Management (PLM) tools, physics-based evaluation tools, testing tools, configuration management tools, etc. This infrastructure needs to be developed in conjunction with industry, standards bodies, and tool vendors to ensure interchange and connectivity.

5. Transform the culture and workforce to adopt and support digital engineering across the lifecycle. Successes and failures will need to be shared within the organization to learn from both good and bad experiences. Feedback to processes, standards, modeling techniques, need to be captured and documented. Output from models need to be adapted to the expertise and purpose in accordance with the intended audience. Overly technical output should not be presented to high level decision makers. Otherwise, this risks turning them off.

6. Future Research and Development

We are seeing an increase in the number of RFPs requiring the use of MBSE as well as the use of models during the acquisition process. The challenge to both the supplier and provider is the lack of standardization in the approach resulting in a learning curve for every proposal as well as response. To address this concern, the OMG UAF MBAcq WG was formed to survey the current landscape with participation from government, industry and SE and Architecture standards such as SysML and UAF. The WG will access, recommend, vet, and implement SE and Architecture standards updates and create process guidance for both the engineering and acquisition professional. Future papers and presentations will be written on the progress being made.

7. Conclusion

Model-Based techniques have become ubiquitous in engineering and development of systems. This has been driven by best practice in industry as well as government initiatives such as the DES. The next natural evolution of Model-Based techniques is their use during acquisition. This will not be simple, and lessons will need to be learned and publicized. Initial projects will need to provide additional time and resources to projects to accommodate false starts and iteration. Learning to communicate in a new language always takes time. Learning to communicate using modeling languages is just as difficult time consuming. Standardization of the MBAcq grammar, vocabulary, graphical notation, process, semantics, and best practice is essential to ensure that we are all speaking a common language and communicating efficiently. This will help ensure success and the adoption of these techniques.

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