A Proposed Community Roadmap for Advancing the Practice of Model-Based Systems Engineering in Government Programs and Enterprises

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Introduction and Background

- Model-Based Systems Engineering (MBSE) is an emerging paradigm for improving the practice of systems engineering
- Integrated sets of system models are the focal point for knowledge management, technical communication, and data interchange

MBSE is the future of SE

Benefits of MBSE for Government Enterprises

- Improved collective understanding of system capabilities, requirements, composition, functionality, behavior, interdependencies, and performance
- Better organization of technical information across system life cycles
- Less-ambiguous communication of requirements across contractual boundaries and organizational interfaces
- Improved efficiency in evaluating performance of architectural options
  - *System models are a starting point for initializing analytical models in less time with less risk of error, and for organizing the results of trade studies*
- Improved traceability and more efficient transition from early concept studies and capability-based assessments through all subsequent life cycle activities
- Ability to perform rapid, comprehensive impact assessment crossing architectural layers and organizational stovepipes
- Strengthened ability to architect enterprise-wide and cross-enterprise solutions by integrating knowledge and insight across the enterprise

MBSE improves insight to improve acquisition and sustainment decisions

Problem Statement

- The MBE/MBSE government/contractor community is large, varied, and each is working to address their own set of challenges
- Various professional societies (e.g., INCOSE, NDIA), technical workshops (e.g., GSAW) and consortia (e.g., OMG) recognize the challenges and are contributing in niche areas
- The interested organizations could benefit from a community roadmap that would define a series of achievable progressive steps to further advance and coordinate the accomplishments
- The community roadmap is proposed without “ownership,” funding, or due dates but these can be added as the content is refined

Focus Areas for Advancing MBSE

- Evolving Enterprise Systems Engineering
  - *Enhance decision-making, improve enterprise capabilities and resilience, and architect enterprise-wide solutions, by better integrating knowledge across the enterprise and its constituent programs*
- Improving System Acquisition and Execution Outcomes
  - *Reduce risk of delays, cost overruns, and underperformance in acquisition programs by improving the quality of systems engineering*
- Institutionalizing Evolved Systems Engineering
  - *Accelerate adoption of MBSE by addressing key cultural, organizational, and infrastructure challenges*
- Advancing the State of MBSE Tools
  - *Improve quality and capability of system modeling tools, particularly to address the unique needs of Government programs*

Four focus areas for advancing MBSE for Government needs

Purpose of the Proposed Community Roadmap

- This Roadmap is a proposed starting point for planning investment and collaboration activities to advance the practice of MBSE in Government acquisition and sustainment
  - *Focus is on goals, not on tasks*
- Aerospace's Model-Based Engineering Community of Interest created a similar MBSE Roadmap to inform near-term investment and collaboration
  - *Resulted in positive outcomes, including this Systems Engineering Forum*
- Community input is requested to identify high-priority areas for which near-term collaboration should begin
  - *What areas should we focus on?*
  - *What are the best mechanisms for collaborating to make progress?*
  - *What organization takes the lead on an item? When can it be accomplished?*
- We hope that collaboration within this Community results in a consensus Roadmap that can unify our individual efforts toward common goals

This Roadmap is just a starting point for community collaboration

Timeframes in the Roadmap

- Four timeframes have been identified in the Roadmap
  - *Work to Date*
    - Captures the typical progress made to date in Government application of MBSE
  - *Near-Term Goals*
    - Identifies near-term objectives the community should strive to achieve in the next year or two
  - *Long-Term Goals*
    - Identifies more challenging objectives the community should attempt to address once significant progress has been made in near-term goals
  - *End-State*
    - Represents the desired state of MBSE in Government practice for which we no longer need to consider MBSE to be something different than SE
    - When all SE is MBSE

Timeframes selected to inform strategic planning efforts

A Roadmap for Advancing the Practice of Model Based Systems Engineering

	Work to Date	Near Term	Longer Term	End State
Enabling Enterprise Systems Engineering	• DoDAF products built as models in modeling tools, not just pictures • Modeling pilots provide valuable experience in building models and using modeling tools • MBSE initiatives are largely stovepiped, not well coordinated	• Demonstrate & document value in MBSE transition projects • Develop interoperable methods, including common metamodels, to enable model sharing at enterprise and system levels • Improve quality and speed of engineering and technical baseline change processes	• Integrate enterprise architecture with system models to provide multi-level insight • Manage technical baselines entirely from model; documents extracted from model • Enterprise CM is model-centric • Standard metamodel enables improved model interoperability	• Improved enterprise situational awareness through federated enterprise and system models • Decisions made based on holistic assessment of impacts across all interfaces and stakeholder perspectives
Improving System Acquisition and Execution Outcomes	• Contractors deploying MBSE more frequently in Government development programs • Aerospace ATR and Workshop on MBSE Guidance for Government-Acquired Programs	• Demonstrate & document MBSE value to near-term development and acquisition programs • Develop approaches to improve mission assurance via MBSE • Refine leading indicators for proactive application of MBSE • Refine practice of model-based SE reviews and audits	• Models facilitate concurrent engineering analysis throughout life cycle to support trades • Broaden application of MBSE across portfolio of programs • MB RFPs and proposals, and MB source selections • Tight integration with specialty engineering models	• Models used as primary means to capture and communicate knowledge across life cycle • Models serve as requirements and deliverables for acquisitions • Modeling eliminates SE escapes, resulting in better, more affordable systems
Institutionalizing Evolved Systems Engineering	• Growing interest in MBSE pilot and demonstration projects provide experience in using multiple tools and methods • Improving stakeholder awareness of benefits of MBSE	• MBSE training at multiple levels • Disciplined processes for MBSE transition effort planning • Reusable framework for MBSE tool evaluation and selection • Collect metrics on MBSE value • Publicize positive experiences to build community confidence	• Standardized metamodel for improved model interoperability • Tools to facilitate model use & updates by non-modelers • Improved visual appeal of model views for non-technical stakeholders • Update IEEE 15288 to better align with MBSE practice	• SE and MBSE are synonymous • Models are used by all as the Single Source of Truth • Interoperable models enable knowledge synergy across domains and organizations • Models are transparent to users • Update IEEE 15288 to reflect MBSE as standard SE practice
Advancing the State of MBSE Tools	• Community effort largely driven by other industries • Shortfalls of existing tools becoming more apparent • Model and data interoperability between tools is still limited	• Improve federation of models with analytical and simulation tools • Improve interoperability of models between MBSE tools • Address classification, information compartmenting, and IP issues	• Model use and updates mostly done by non-model-experts • Data exchanges are largely automated with consistent semantics	• Tool selection driven more by tradeoffs of features than tradeoffs of limitations • Seamless data exchange via common data standards and collaborative frameworks

A Roadmap for Advancing the Practice of Model Based Systems Engineering

Enabling Enterprise Systems Engineering

Work to Date	Near Term	Longer Term	End State
• DoDAF products built as models in modeling tools, not just pictures • Modeling pilots provide valuable experience in building models and using modeling tools • MBSE initiatives are largely stovepiped, not well coordinated	• Demonstrate & document value in MBSE transition projects • Develop interoperable methods, including common metamodels, to enable model sharing at enterprise and system levels • Improve quality and speed of engineering and technical baseline change processes	• Integrate enterprise architecture with system models to provide multi-level insight and improve performance, robustness, and resiliency • Manage technical baselines entirely from models; documents extracted from models • Enterprise config. management is model-centric, not document-centric • Standard metamodel enables improved model interoperability	• Improved enterprise situational awareness through federated enterprise and system models • Decisions are made based on holistic assessment of impacts across all interfaces and stakeholder perspectives • Optimize enterprise performance, robustness, and resiliency through enterprise-wide insight provided by MBSE

A Roadmap for Advancing the Practice of Model Based Systems Engineering

Improving System Acquisition and Execution Outcomes

Work to Date	Near Term	Longer Term	End State
• Contractors deploying MBSE more frequently in Government development programs • Aerospace ATR and Workshop on MBSE Guidance for Government-Acquired Programs	• Demonstrate & document MBSE value to near-term development and acquisition programs • Develop approaches to improve mission assurance via MBSE • Refine leading indicators for proactive application of MBSE • Refine practice of model-based SE reviews and audits	• Models facilitate concurrent engineering analysis throughout life cycle to support trades • Broaden application of MBSE across portfolio of programs • MB RFPs and proposals, and MB source selections • Tight integration with specialty engineering models • Reuse of components and patterns from model libraries is the norm rather than the exception	• Models used as primary means to capture and communicate knowledge across life cycle • Models serve as requirements and deliverables for acquisitions • Modeling eliminates SE escapes, resulting in better, more affordable systems • Achieve DoD vision for Digital Thread & Digital Twin

A Roadmap for Advancing the Practice of Model Based Systems Engineering

Institutionalizing Evolved Systems Engineering

Work to Date	Near Term	Longer Term	End State
• Growing interest in MBSE pilot and demonstration projects provide experience in using multiple tools and methods • Improving stakeholder awareness of benefits of MBSE	• MBSE training at multiple levels • Disciplined processes for MBSE transition effort planning • Reusable framework for MBSE tool evaluation and selection • Collect metrics on MBSE value • Publicize positive experiences with MBSE to build confidence in value of MBSE	• Standardized metamodel for improved model interoperability • Tools to facilitate model use & updates by non-modelers • Improved visual appeal of model views for non-technical stakeholders • Update IEEE 15288 to better align with MBSE practice	• SE and MBSE are synonymous • Models are used by all as the Single Source of Truth • Interoperable models enable knowledge synergy across domains and organizations • Models are transparent to users • Update IEEE 15288 to reflect MBSE as the standard SE practice

A Roadmap for Advancing the Practice of Model Based Systems Engineering

Advancing the State of MBSE Tools

Work to Date	Near Term	Longer Term	End State
• Community effort largely driven by other industries • Shortfalls of existing tools becoming more apparent • Model and data interoperability between tools is still limited	• Improve federation of models with analytical and simulation tools • Improve interoperability of models between MBSE tools • Address security classification, information compartmenting, and intellectual property protection limitations of tools	• Model use and updates largely accessible by non-model-experts • Data exchange between data stores and analyses largely automated and not hampered by human misinterpretation	• Tool selection driven more by tradeoffs of features than tradeoffs of limitations • Seamless data exchange between Government agencies and contractors through the use of common data standards and collaborative frameworks

Mechanisms for Collaboration

- Mission Assurance Improvement Workshop (MAIW)
  - *FY17 topic related to MBSE (Mission Assurance Considerations for MBSE)*
- NDIA Systems Engineering Modeling and Simulation Working Group
  - *Developing the Model-based RFP*
- INCOSE Working Groups
  - *Space Systems WG, Model-Based Conceptual Design WG, etc.*
- Object Management Group (OMG)
  - *Domain-specific standards extending SysML, UPDM to improve interoperability of models*
- Ground System Architectures Workshop (GSAW)
- Others?

Many potential opportunities to foster collaboration within existing frameworks and organizations

Proposed Next Steps

- Feedback from you on the roadmap in 2 weeks
- Identify organizations to refine roadmap steps and commit to them
- Report out progress

Conclusion

- Again, this Roadmap is intended to serve as a starting point to seed the discussion

- We’re looking for inputs from Government and Industry of the high-priority areas to focus near-term collaboration efforts
  - *What areas should we focus on?*
  - *What are the best mechanisms for collaborating to make progress?*

- We hope to initiate collaboration within this Community to develop a consensus Roadmap that can unify our individual efforts toward common goals of achieving mature MBSE capabilities in Government acquisition and sustainment programs and enterprises

BACKUP

Mission Assurance Considerations in Model Based Engineering for Space Systems

Team (Traditional Topic)	Problem Statement	Examples
Team Leads • Dave Gianetto (RTN) • TBD (Harris) • Marilee Wheaton (Aerospace) Team Members • Michael Chory (MIT/LL) • Al Hoheb (Aerospace) • Aliki Loper-Keddy (SSL) • Chris Schreiber (LM) • Bill Sharp (Boeing)	Traditional systems engineering methods where requirements baselines, hardware/software models, and product assurance criteria are all managed independent of solution architectures are insufficient to address the demands for resilient systems at lower price points and faster fielding. An approach for integration of these typically disparate elements is needed to leverage developments in model based engineering (MBE) into an effective execution framework. Any such approach, where models and software based systems and tools can replace documentation in the V&V flow, must retain mission assurance through the program lifecycle. Moreover, historical document-based V&V artifacts (vs models & software based systems and tools) can impede timely change management and trade studies throughout the system lifecycle.	Simulations, like Matlab, do not link to performance requirements in execution systems resulting in models that may not agree with provided hardware. A legacy NSS program has experienced delays in configuration change management and system upgrades due in part to lack of integration of multiple SV configurations, diverse user requirements, and a document-based V&V baseline.
Stakeholders	**Charter**	**Products**
SC Champions: • Mark Baldwin, Raytheon • Anne Ramsey, Harris **October 13, 2016, incorporating Co-lead comments**	1. Define an approach for executing MBE while retaining essential mission assurance processes and deliverables. 2. Determine how mission assurance execution and output/reporting may change when using a MBE approach. Consider several program execution MA processes in TOR-2011(8591)-21 (e.g. Requirements Analysis, Reliability, Configuration Management) as part of an essential set. 3. Identify a minimum set of model capabilities required to execute the MA processes. 4. Stretch task: Investigate how the roles of quality assurance and inspection might change in an environment where traditional paper outputs and physical inspection may be replaced by models and virtual inspection embedded into manufacturing processes.	1. Produce a guidelines and/or best practices document for executing model based engineering in concert with essential MA processes and deliverables on a typical space segment program. In addition to the charter elements, include the following; • Basic description of MBE. • Six MA Selected Process Areas: Requirements Analysis and Validation; Design Assurance; Reliability Engineering, System Safety; Configuration/Change Management, Independent Reviews • Identify any new developments or roadblocks to implementation. 2. Create an addendum to TOR-2011(8591)-21 that summarizes charter item #2 for each MA process evaluated.