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A Roadmap for Advancing the State of the Practice in MBSE in Government Acquisition

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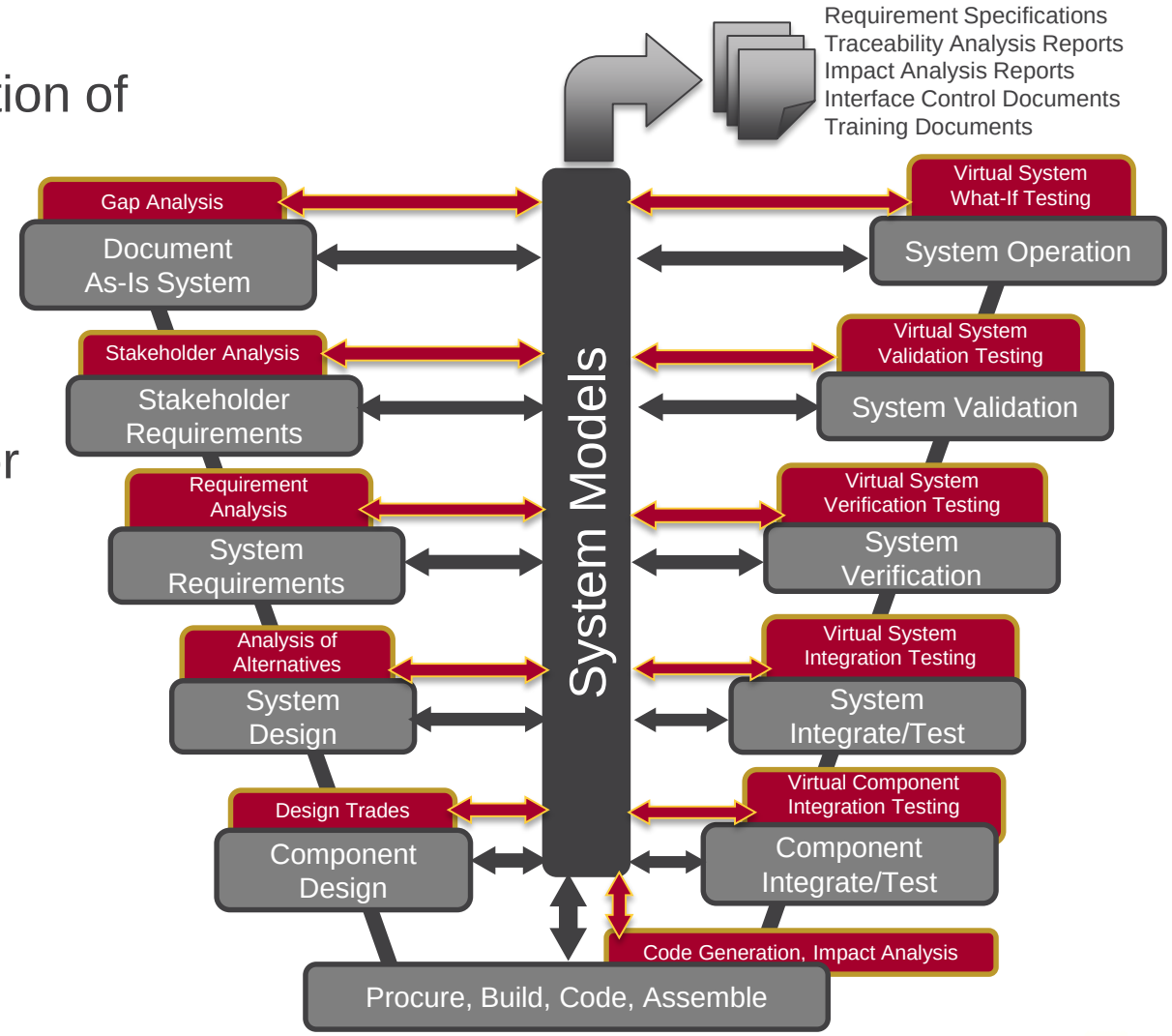
Why MBSE?

- Increasing system **complexity**
  - More **escapes** with greater impacts → program delays, cancellations
  - Many **legacy** systems and interfaces → constrains system evolution
  - **Spiral and agile** development → multiple requirement/design baselines
- Increasing information **stovepipes**
  - Organizational, structural, temporal, projects, etc.
  - Knowledge lost between lifecycle phases
- Ambiguous representation results in **inconsistent mental models**
  - Lack of a “common systems engineering picture”
  - Misinterpretation is common
- Documents and stove piped models are **brittle** artifacts
  - Difficult to keep synchronized and consistent
  - Difficult to capture complex and numerous interrelationships
  - Difficult to find disconnects

MBSE

- System models are **central** to the execution of SE processes
  - Traceability analysis
  - Impact analysis
  - Gap analysis
  - Virtual I&T
  - “Single source of truth”
- System models provide the foundation for **knowledge capture** and **information sharing**…
  - … among technical disciplines
  - … between organizations
  - … spanning life cycle phases
- System models improve the **speed and quality of SE execution**
  - Reduced human error
  - Reduced data inconsistency
  - Reduced miscommunication

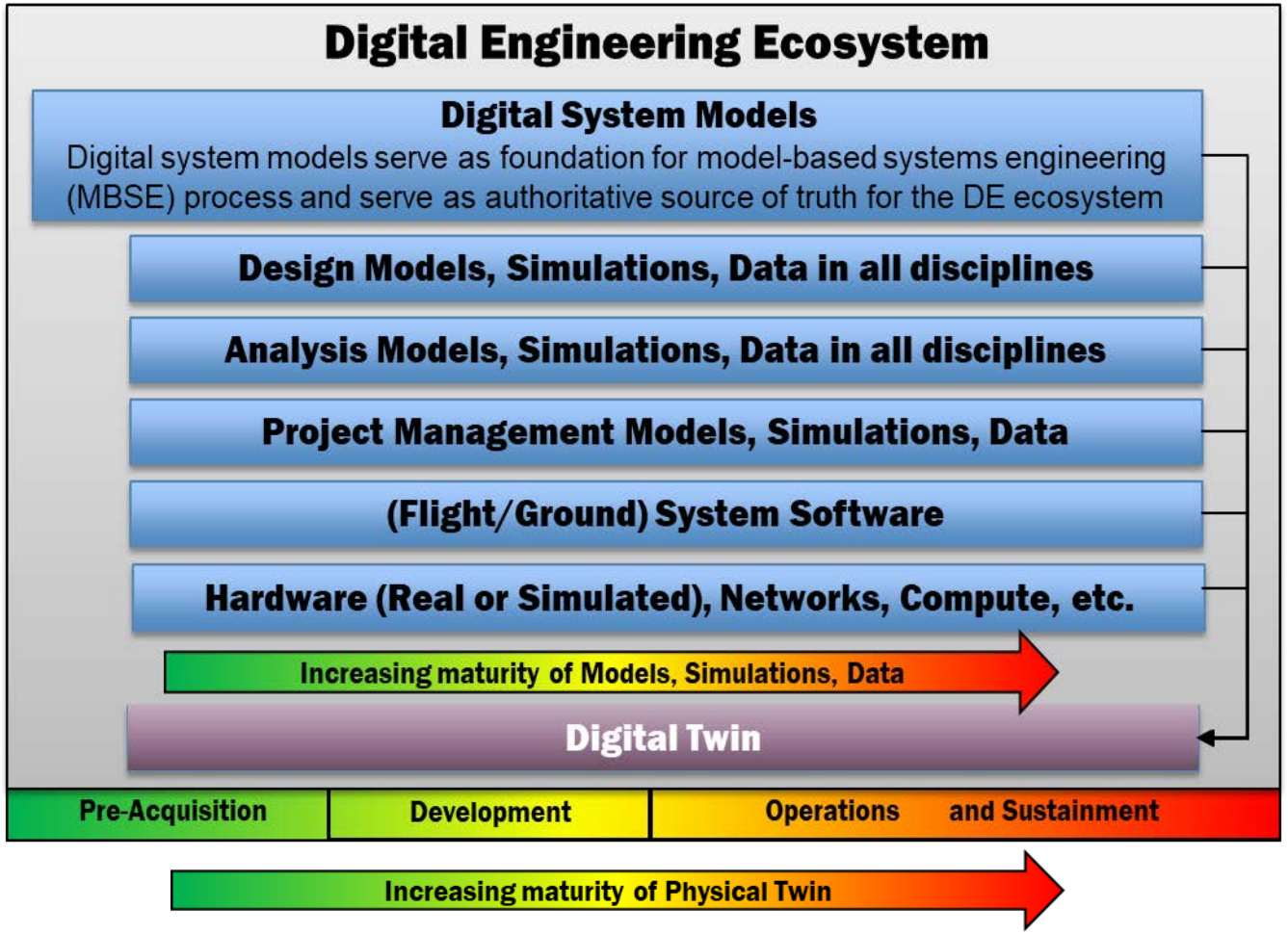


Benefits of MBSE

- Improved **collective** understanding of system capabilities, requirements, composition, functionality, behavior, interdependencies, and resilience
- Better **organization** of technical information across system life cycle phases
- Less-ambiguous **communication** across contractual, organizational interfaces
- Improved **efficiency** in evaluating architectural options
- Better **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's portfolio

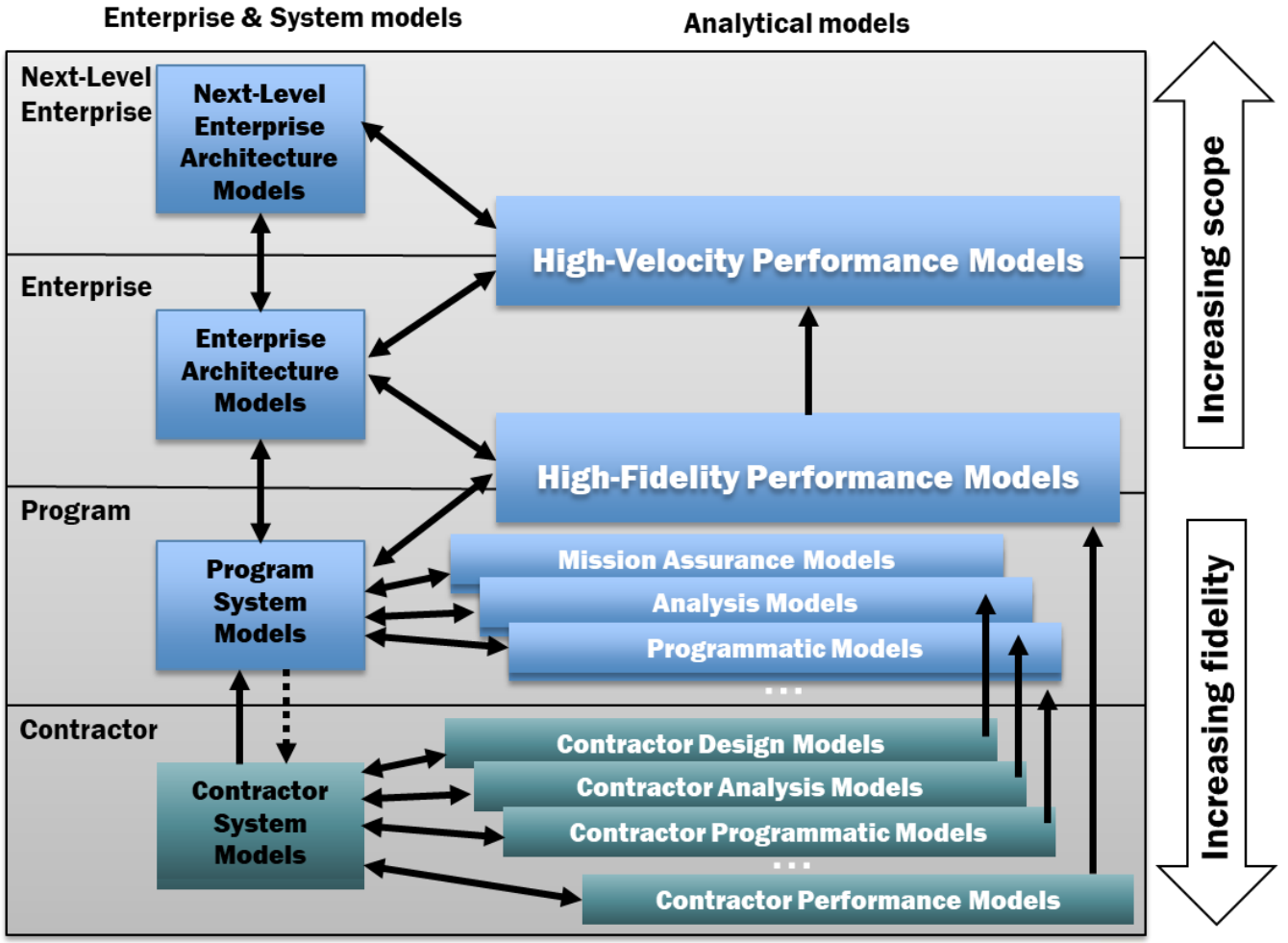
The Digital Engineering Landscape

- Digital Engineering (DE) **ecosystem** includes all models, simulations, and data across all disciplines
- Digital system models (DSM) are central to MBSE implementation
- Digital Twin integrates models, simulations, and data across all disciplines and incorporates unit-specific characteristics
- Digital Twin evolves to keep pace with the Physical Twin



Layered Hierarchy of Integrated Models

- Decisions at all levels are informed by comprehensive knowledge of impacts and dependencies
- Models at each layer of the organization are loosely coupled with models in adjacent layers
- Sharing of models reduces duplication of work
- Synchronization of models enforces concept of authoritative source of truth
- System models provide definitive inputs to other models



Introducing the Roadmap

- A Roadmap was created to serve as a point of departure for discussions and planning of investment and collaboration activities
- Presented initially at a Systems Engineering Forum sponsored by The Aerospace Corporation
- An update highlighting progress made since that time was presented at a subsequent Systems Engineering Forum
- The Roadmap stimulated much discussion and collaboration in advancing the state of the practice of MBSE in Government service

Focus Areas for Advancing MBSE

- **Enabling 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

Timeframes

- *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

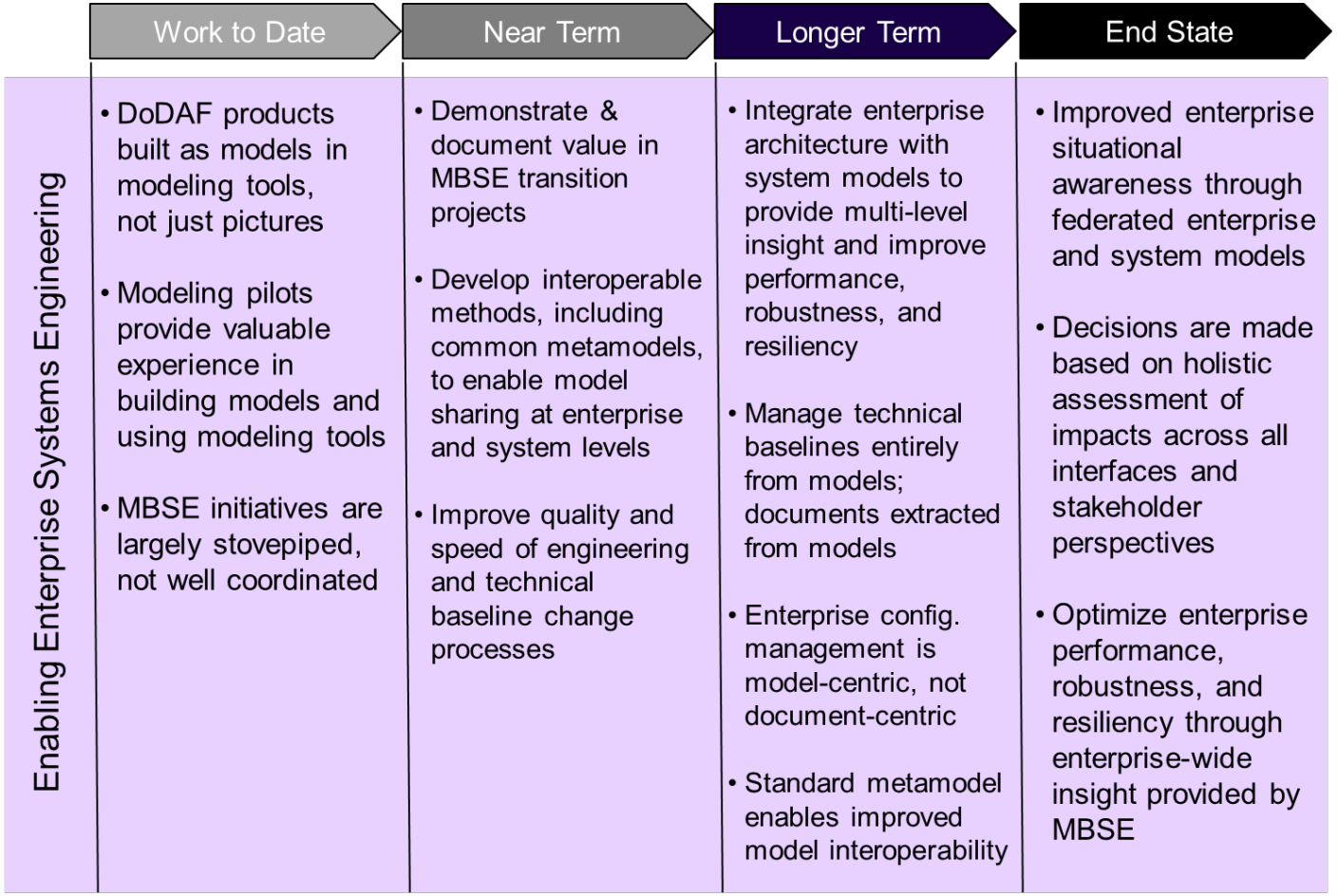
A Roadmap for Government Application of MBSE

	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 the enterprise • Enterprise performance and resilience are optimized through enterprise-wide insight
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 • Model reuse is the norm	• 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 • Digital Thread/Twin vision realized
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

Enabling Enterprise Systems Engineering

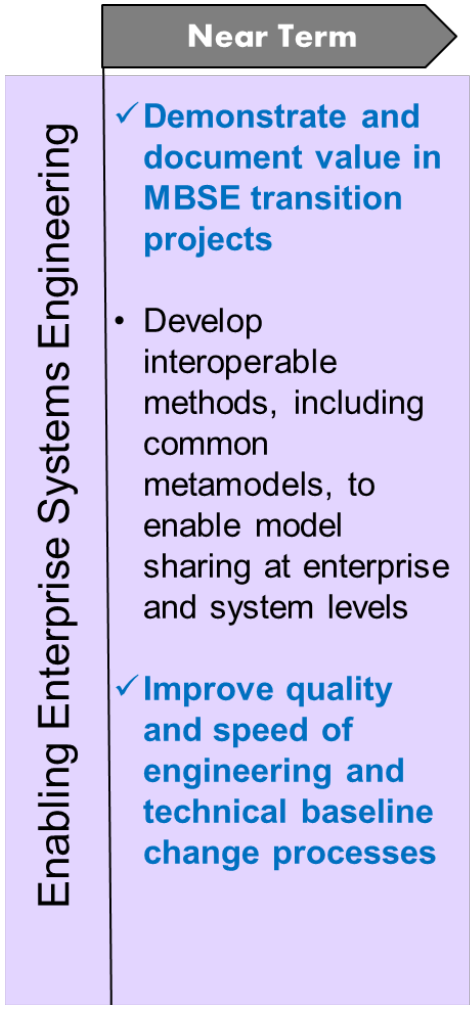
- Enterprises are growing in complexity
  - Organization, business processes, systems, drivers, etc.
- MBSE methods can be used to improve the execution of enterprise systems engineering processes
  - Enhance enterprise decision-making
  - Improve program decision-making through better understanding of impacts and dependencies
  - Enable better enterprise-wide solutions
- Key challenges with enterprise application of MBSE include the greater complexity of integration/federation of models and data from many different stakeholders

Enabling Enterprise Systems Engineering



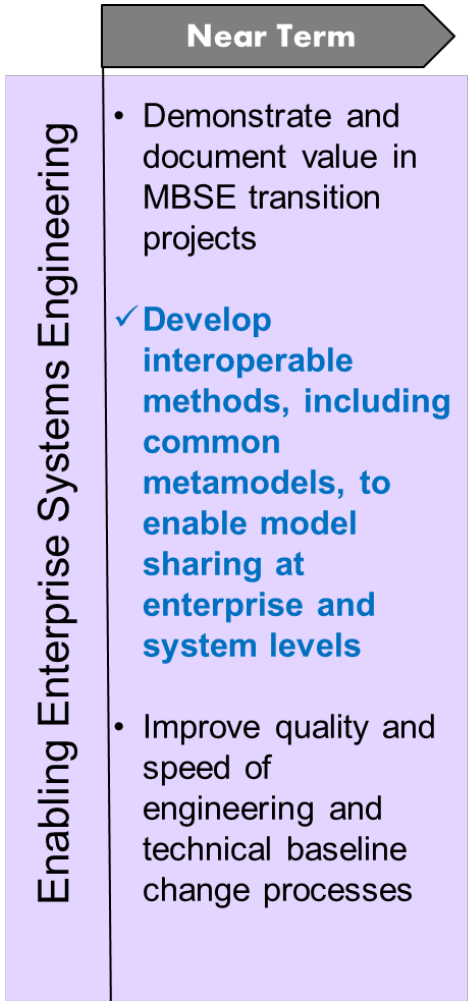
- MBSE is a critical enabler for implementation of disciplined practice of enterprise systems engineering

Enabling Enterprise Systems Engineering



- Supporting enterprise-level MBSE pilot efforts at several Government agencies
  - Advising on strategy and priorities
  - Using problem framing workshops to define and refine understanding of MBSE needs to drive scope of pilots
  - Prototyping MBSE methodologies
  - Advising model implementation teams on model structure and modeling practices
  - Piloting approaches for executing model-based enterprise-level systems engineering reviews and audits

Enabling Enterprise Systems Engineering



- Leading multiple enterprise-level architecture modeling efforts and coordinating to improve interoperability
  - Coordinating among modeling teams to develop interoperable models across multiple programs, enterprises
    - Incorporating best-practice methods and modeling patterns
  - Prototyping data- and model- interoperability mechanisms to improve information exchange among agencies
  - Exploiting Portfolio Decision Support Tool (PDST) for interactive visualization of programmatic interdependencies across an enterprise

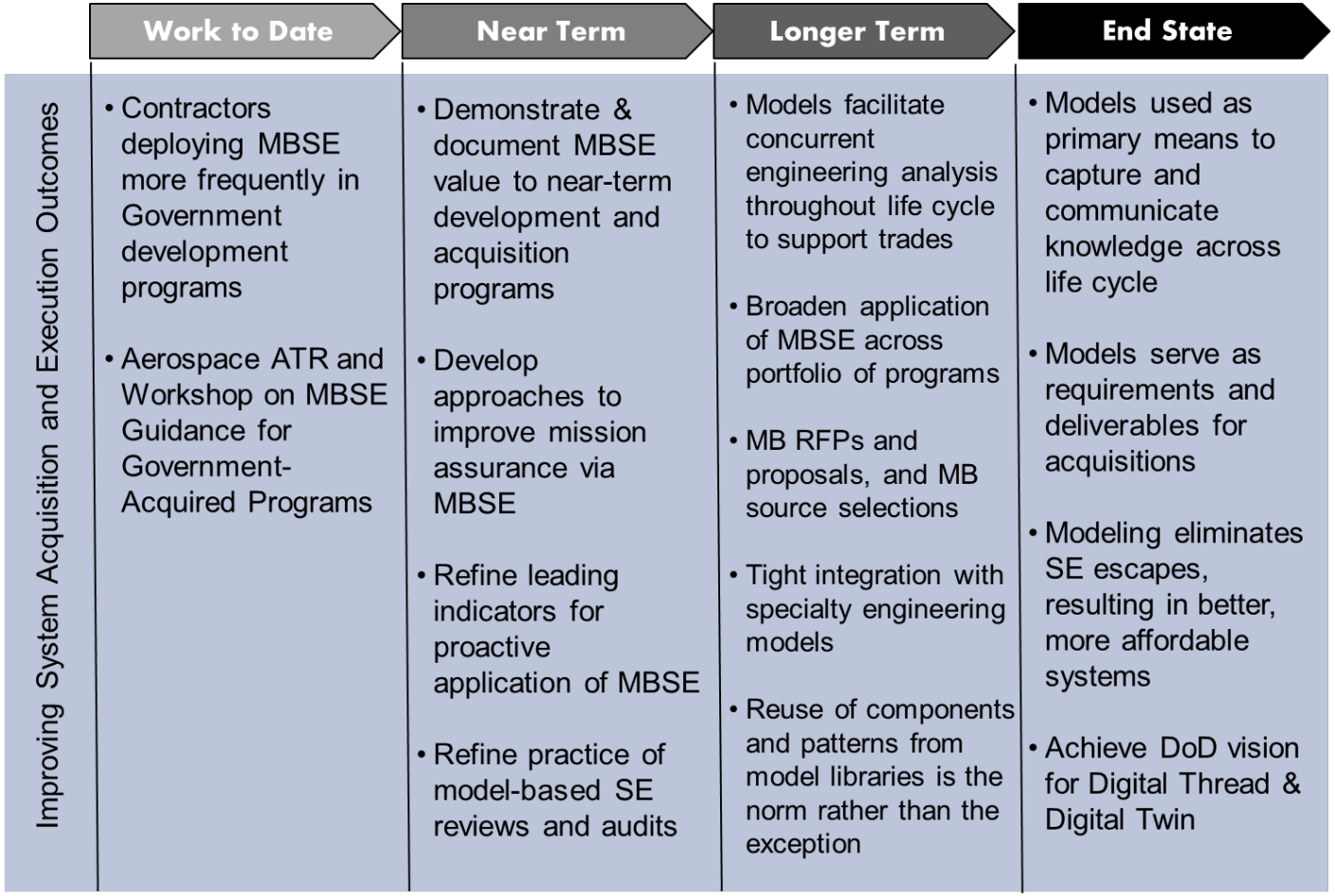
Improving System Acquisition and Execution Outcomes

- MBSE has been successfully used by system developers to improve the quality of those development efforts

- Government agencies responsible for acquiring those systems can also use MBSE to improve their processes
  - Requirements development
  - Architectural trades
  - Communication (two-way) with contractors
  - Assurance and oversight activities (e.g., V&V, milestone reviews)
  - Integration, esp. where the Government is the System Integrator

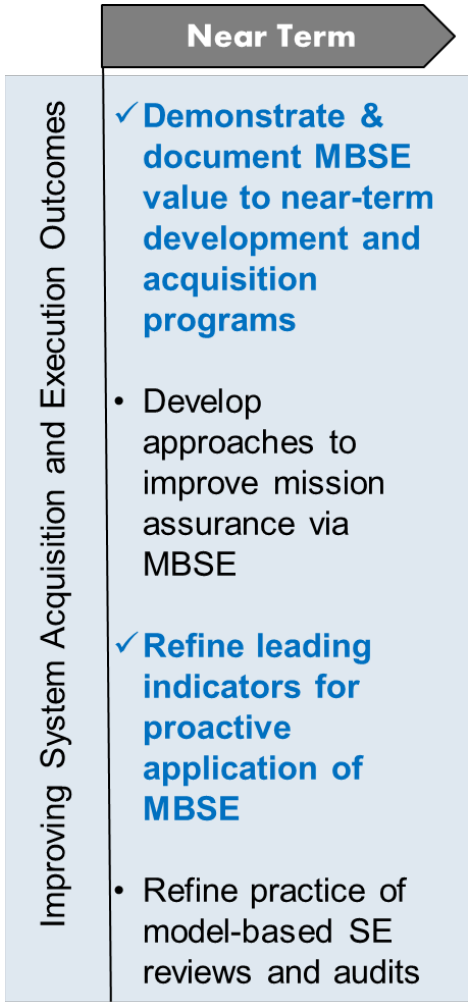
- MBSE can also provide enduring value to system users/operators and maintainers long after the system has transitioned to the Operations and Sustainment phase
  - Enable “what if?” exercises, aid in impact analyses, and inform development of tactics, techniques, and procedures (TT&P)

Improving System Acquisition and Execution Outcomes



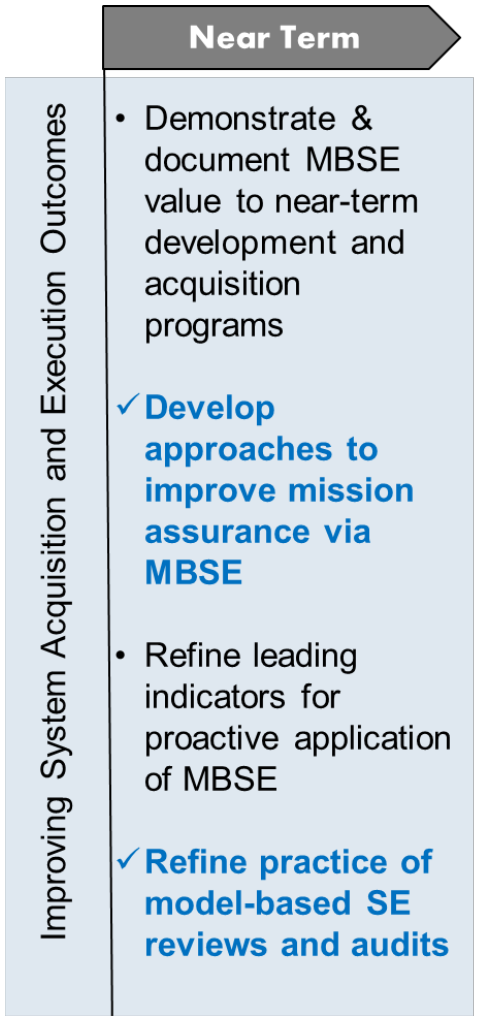
- MBSE is a critical enabler for improved system acquisition and execution outcomes

Improving System Acquisition and Execution Outcomes



- Supporting MBSE pilot efforts for several Government acquisition programs
  - Defining requirements for MBSE processes and model-based deliverables as Data Item Descriptions (DIDs) for use in Contract CDRLs
- Piloting MBSE on in-house prototype system development projects
  - Accelerated system life cycle enables rapid learning and adaptation
- Demonstrating use of system models in executing system design reviews

Improving System Acquisition and Execution Outcomes



- Community collaboration developed a 2018 Mission Assurance Improvement Workshop product
  - *Mission Assurance Considerations for MBE for Space Systems*
- Developing unique methodologies for executing mission assurance in a model-based world
  - Software Model Assurance Levels methodology
  - Model-Based Integration Risk methodology
  - Adapting MBSE methods for agile development

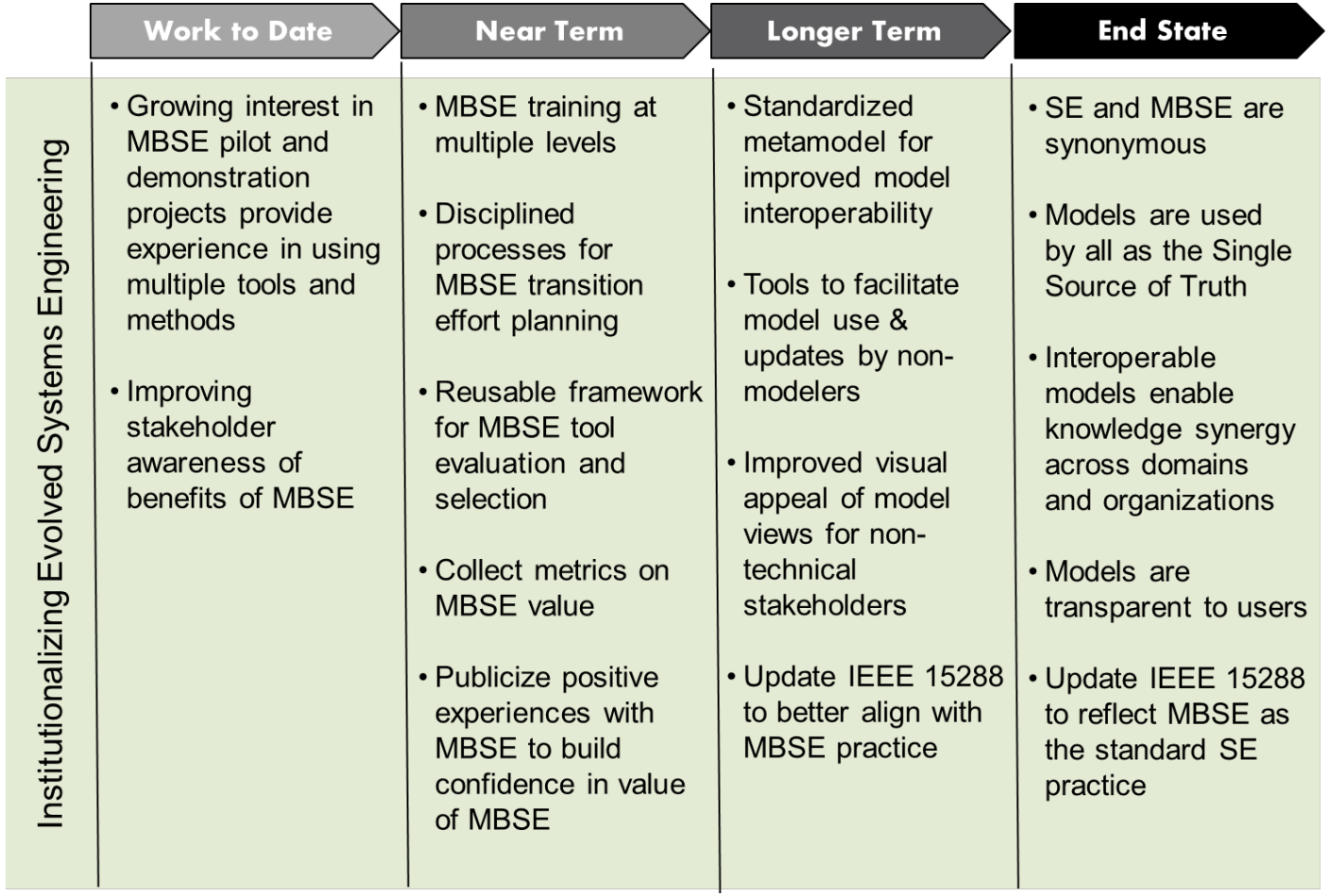
Institutionalizing Evolved Systems Engineering

- Transitioning from traditional SE implementation to more modern practices is far from trivial

- While some of the challenges are technical…
- Government organizations often have greater cultural, political, and financial impediments to rapid, substantive change

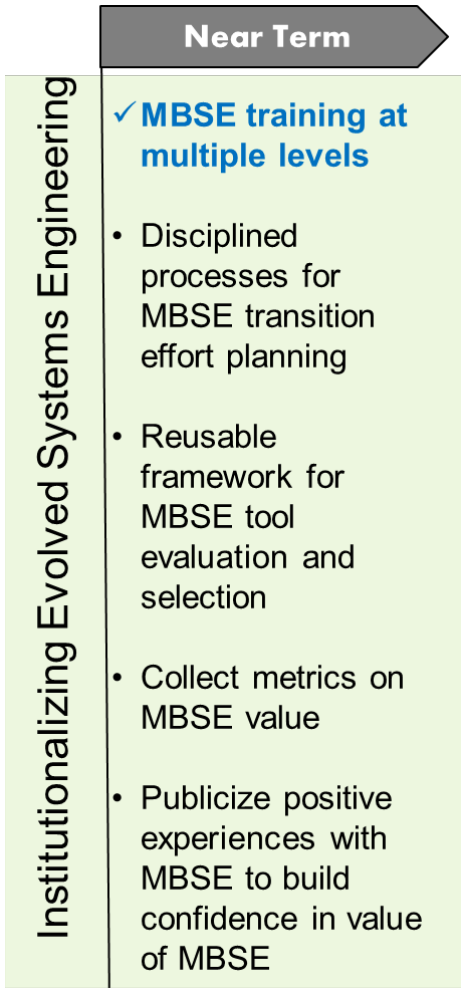
- Need to overcome these obstacles through communication, education, leadership, and publicized demonstrated success

Institutionalizing Evolved Systems Engineering



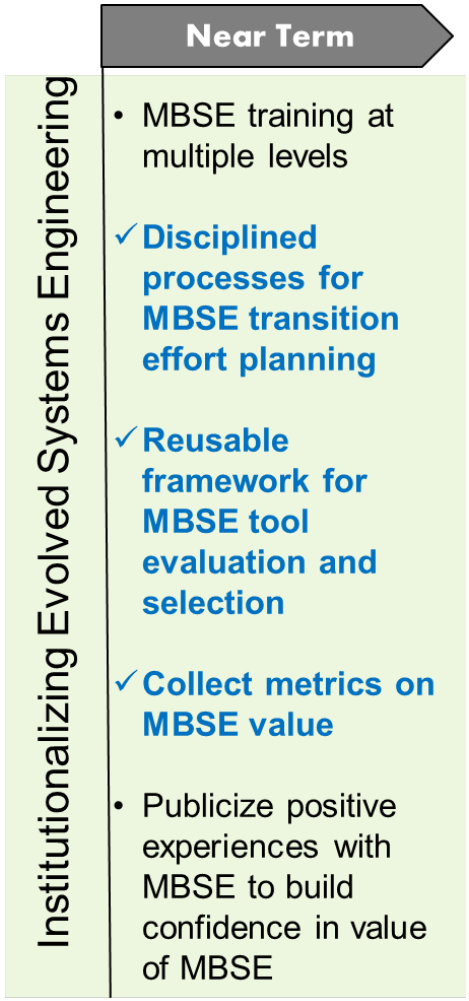
- MBSE adoption requires significant attention to overcoming human and organizational obstacles
- **This isn't Rocket Science; it's Brain Surgery**

Institutionalizing Evolved Systems Engineering



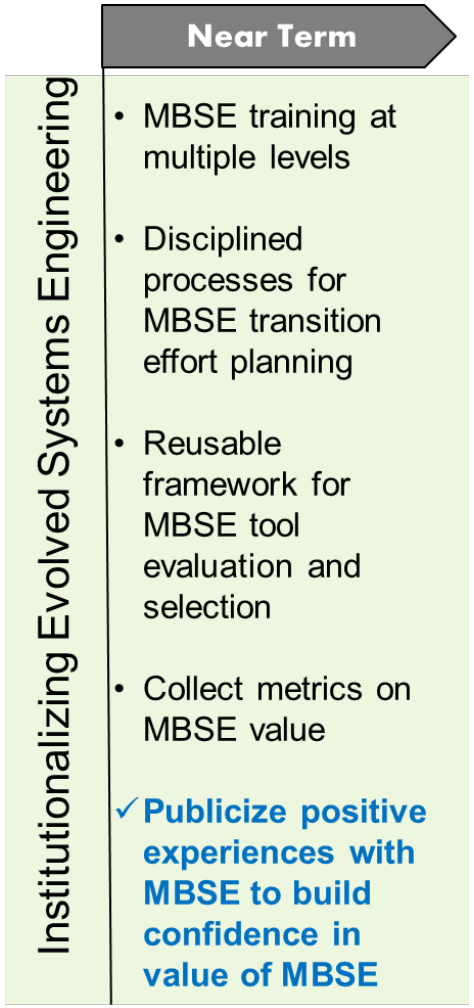
- Developing and executing multiple tiers of workforce training in MBSE principles, practices, and techniques
  - MBSE familiarization training
  - SysML modeling training
  - Enterprise architecture modeling training
  - User Groups for sharing lessons learned and best practices
- Growing the cadre of experienced modelers and MBSE-savvy systems engineers through training and hands-on experience

Institutionalizing Evolved Systems Engineering



- Developing disciplined processes for executing transitions to MBSE
  - Providing guidance for Government MBSE transition efforts
  - Model Based Enterprise Capabilities Matrix
  - Readiness assessment framework for MBE “technologies”
- Modeling tool evaluations/demonstrations
  - Comparing and contrasting modeling tools
- Collecting lessons learned and metrics to address questions of ROI for MBSE

Institutionalizing Evolved Systems Engineering

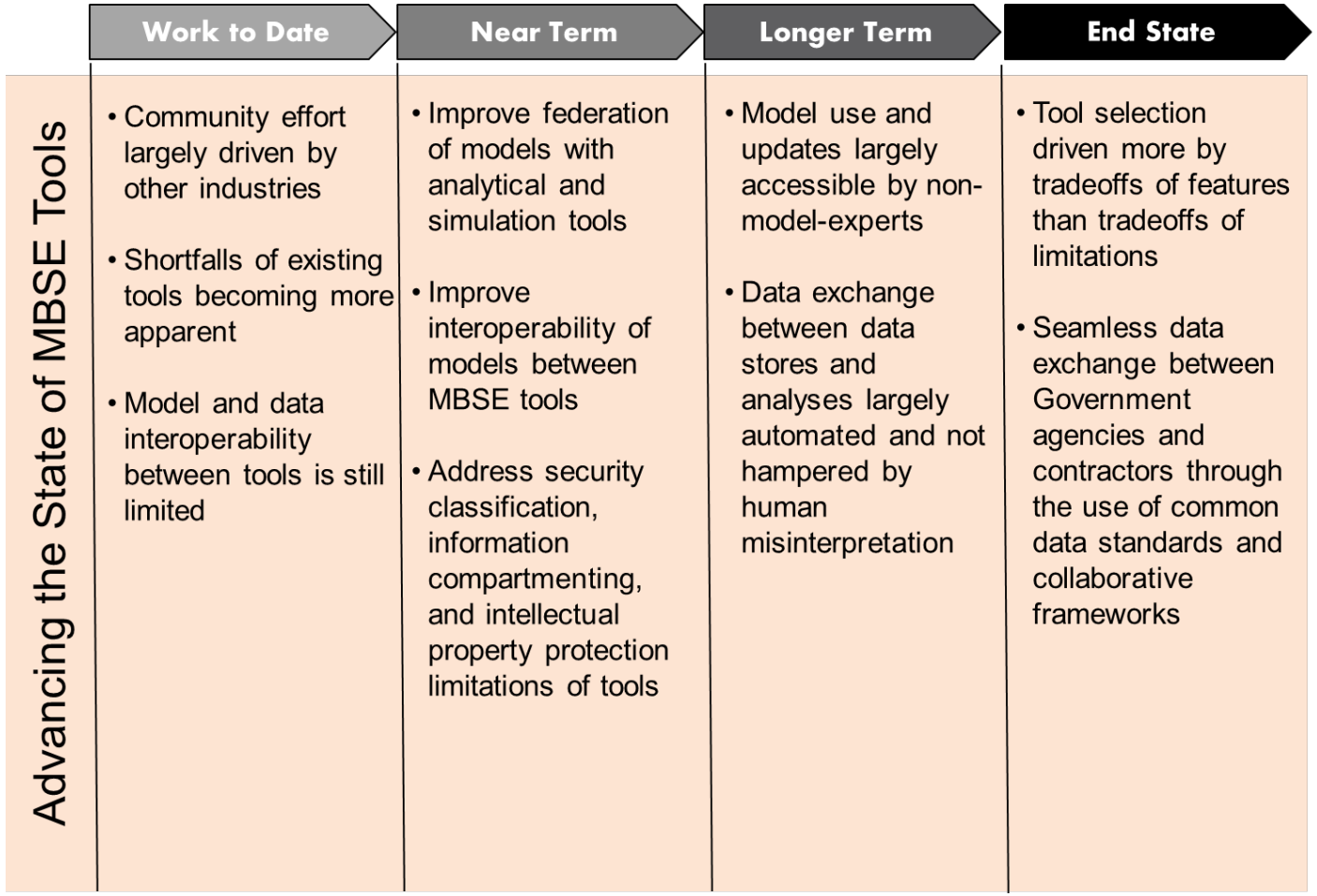


- Exploding interest in collaboration and sharing of lessons learned across the community of practitioners
  - MBE Community of Interest
  - MBSE Collaboration workshops among multiple Government agencies
  - DoD Digital Engineering Working Group
  - New INCOSE Challenge Teams
    - Model-Based Engineering Capabilities Matrix
    - Digital Engineering
  - Systems Engineering Forums

Advancing the State of MBSE Tools

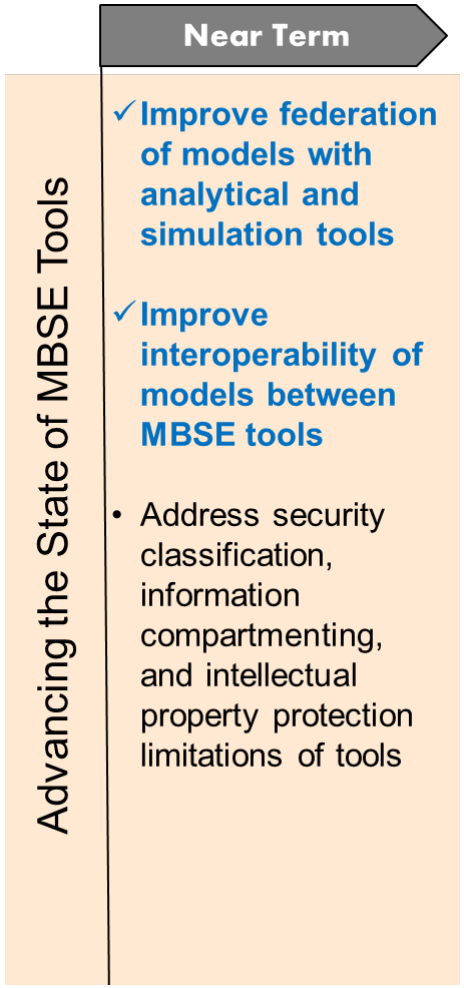
- These include:
  - Modeling languages
  - Modeling frameworks, templates, standards
  - Software tools (not just model authoring tools)
  - Model and data interoperability mechanisms
  - Model and data visualization mechanisms
  - etc.
- While the worldwide market is working to advance the state of the art in all of these areas, some of the unique needs of Government enterprises may need greater attention
  - Complexities associated with security classification
  - Enforcement of authoritative source of truth across multiple security enclaves
  - Interoperability between many tools in a heterogeneous ecosystem consisting of numerous contractors and partner agencies

Advancing the State of MBSE Tools



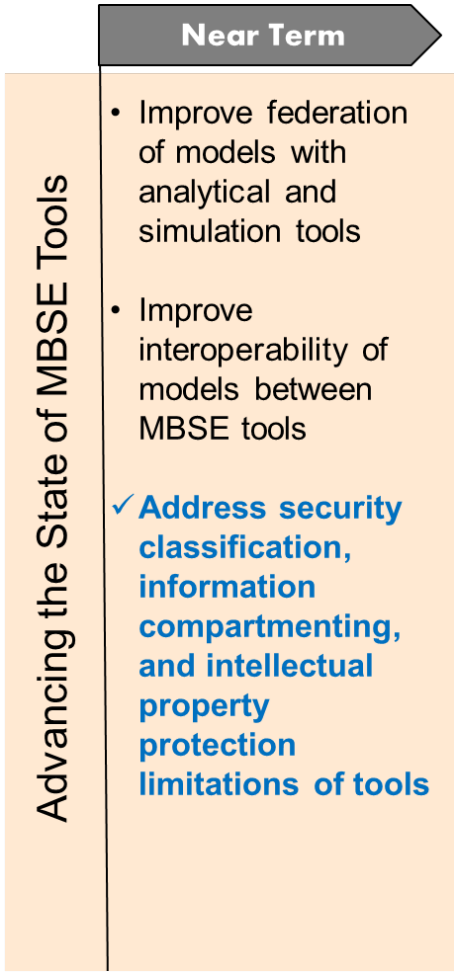
- MBSE toolset is expanding, but some Government-driven use cases may not be getting enough attention

Advancing the State of MBSE Tools



- Advancing data interoperability strategy and enabling infrastructure for integrating M&S tools
- Interoperability testing and demonstration of tool capabilities to exchange model data between tools
  - Descriptive modeling tools
  - Analytical M&S tools
  - Portfolio Decision Support Tool (PDST)

Advancing the State of MBSE Tools



- Participating in international standards development to contribute defense Government enterprise perspective to emerging standards
  - System Modeling Language (SysML) v2
  - Unified Architecture Framework (UAF)
  - New ISO/IEC/IEEE 42020, 42030 (Architecture Processes, Architecture Evaluation Framework)
  - Update of ISO/IEC/IEEE 42010 (Architecture Descriptions)
- Piloting model configuration management spanning multiple security enclaves

Conclusions

- This roadmap was created to establish a starting point for a shared vision
- Was successful in driving discussions and collaboration among the Government acquisition community
- Four focus areas are being addressed through efforts being sponsored by many Government agencies
- We hope to continue to leverage interest and investment across the community to advance the state of the practice of MBSE in Government applications

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