International Council on Systems Engineering
A better world through a systems approach

Reclaiming the ***Engineering*** in Model-Based Systems Engineering: Refocusing MBSE on Practical System Engineering Outcomes

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What this session is really about

MBSE success requires a return to system engineering-first thinking.

We risk replacing document-based anti-patterns with model-based ones.

We propose practical strategies to realign modeling with engineering rigor.

Agenda

- The Problem
- The Gap
- The Solution
- The Outcome

Hello from STC AN ARCFIELD COMPANY

Our vision is to build awareness of the power of MBSE and digital engineering best practices.

Kiffin Bryan, CSEP

STC Senior Principal Model-Based Systems Engineer

29-year systems engineering professional dedicated to anchoring MBSE in practical, outcome-driven engineering. I specialize in connecting legacy SE discipline with modern modeling approaches.

Alan Bouchard

STC Principal Model-Based Systems Engineer

18-year defense industry veteran with 10 years in systems engineering. I serve as a 'keystone' bridging traditional SE principles into modern models through my work and mentorship.

Megan Turner

STC Principal Model-Based Systems Engineer

4+ years in defense programs through MBSE and digital transformation. Leads modeling for ground combat vehicle and unmanned air systems. Applies SysML, PLE, and targeted training.

Eric Alexander, CSEP

STC Senior Director, MBSE Services

11 years of systems engineering experience, 9 years in defense industry. Introduced to MBSE in 2016. Currently leading several Army programs within STC’s Armaments & Combat Division.

Acknowledge and Understand the Problem

Reclaiming the Engineering in MBSE

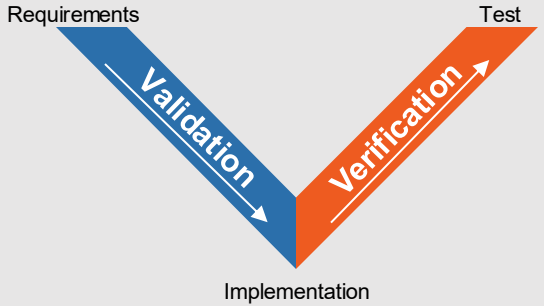
The Evolution of Systems Engineering

From Documents to Models:

- Industry needed a strategic evolution from document-centric processes to model based approaches
  - Modeling addresses real limitations of document-based approaches (increasing complexity, difficulty maintaining traceability, etc.)

The V-Model Foundation:

- Traditional SE centered on answering two critical questions:
  - “Are you building the right thing?” (Validation)
  - “Are you building it correctly?” (Verification)



The Core Engineering Value at Risk:

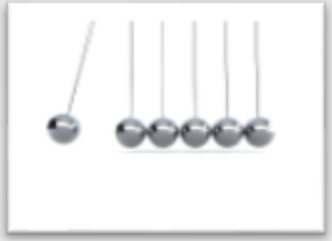
- What these principles provided that we must preserve:
  - Demonstrable evidence that stakeholder needs were understood
  - Clear proof that the system was thoroughly verified
  - Shared understanding across disciplines
  - Engineering transparency throughout the lifecycle

Reclaiming the Engineering in MBSE

The Overcorrection Problem

The Pendulum Effect:

- In solving document-based challenges, we've swung too far in the opposite direction
- MBSE implementation has often overemphasized modeling techniques at the expense of engineering fundamentals



Syntax Over Substance:

- Focus shifted to model perfection rather than engineering outcomes
- SysML compliance and diagram correctness is sometimes valued more than engineering rigor
- Models becoming ends in themselves rather than means to better engineering

Unintended Consequences:

- Engineering decisions obscured by modeling complexity
- Stakeholders struggle to see evidence that we're "building the right thing correctly"
- Documentation of verification and validation less transparent in complex models
- Traditional engineering rigor diluted in pursuit of modeling sophistication
- Reduction in the proposed return on investment of SE

Reclaiming the Engineering in MBSE

The Generational Gap

Skills Imbalance:

- Junior engineers often highly skilled in modeling but disconnected from SE fundamentals
- Technically proficient in SysML syntax but may lack deeper understanding of engineering principles
- Model creation expertise doesn't always translate to engineering judgment

Knowledge Transfer Challenges:

- Traditional engineering wisdom not effectively codified in modeling practices
- Experiential understanding of validation and verification principles difficult to capture in SysML
- The "why" behind engineering decisions gets lost in the transition to model-based approaches

Real-world Consequences:

- Engineering gaps sometimes masked by sophisticated models where verification deficiencies are obscured rather than addressed
- Stakeholders receive impressive visualizations but may miss critical engineering insights
- Decision-making increasingly driven by what can be modeled rather than what should be verified

Reclaiming the Engineering in MBSE

The Core Challenges

The Central Questions:

- Are we upholding rigorous engineering standards while advancing modeling capabilities?
- Can we confidently demonstrate to stakeholders that we are "building the right thing correctly"?
- Are we equipping the next generation to maintain these standards?

Process vs. Purpose:

- When modeling becomes the goal rather than the means to sound engineering
- Completing model artifacts sometimes prioritized over engineering value they provide
- Verification and validation activities adapted to fit modeling constraints rather than engineering needs

Metrics Misalignment:

- Measuring model completeness instead of engineering soundness
- Success defined by model maturity rather than verification coverage
- Quality metrics focused on SysML compliance rather than requirements verification
- Risk of creating "beautiful models of the wrong system"

Reclaiming the Engineering in MBSE

The Path Forward

Bridging Worlds:

- Integrating V-model principles with modern modeling approaches
- Maintaining focus on validation and verification while leveraging MBSE advantages
- Creating clearer connections between models and fundamental engineering questions

Engineering-First Modeling:

- Practical strategies for refocusing on engineering outcomes
- Model-based Systems Engineering Management Plan (SEMP)
- Using models to explicitly demonstrate "building the right thing correctly"
- INCOSE-compliant requirements developed within the model

What You'll Gain From This Session:

- Approaches to create engineering-focused model-based deliverables
- Methods to improve requirements quality in MBSE
- Techniques for using the model to drive technical milestone reviews
- Strategies to close the knowledge gap between modeling and SE fundamentals

Common Scenarios and Strategies to Overcome Model-Focus

Common Anti-Patterns: When Modelers Masquerade as Systems Engineers

Model Focus vs. Product Focus

Problem: High-value programs “Digital Engineering Programs” with aggressive timelines often lead companies to recruit for tool proficiency (e.g., SysML modeling) over engineering depth as they staff up the program(s).

- Results in:
  - Teams of “diagrammers” vs. engineers
  - Models treated as deliverables vs. enablers
  - Silos that weaken collaboration with SMEs and domain experts
  - Reinforced myths that MBSE is “extra” or “inefficient”
- Impact:
  - Systems engineering rigor is diluted across the entire company
  - Design decisions are unsupported by MBSE, trust in the model is depleted
  - Program risk increases, complexity not understood
  - MBSE adoption slows or stalls, gives MBSE a bad-rap

"A fool with a tool is still a fool“ - Grady Booch

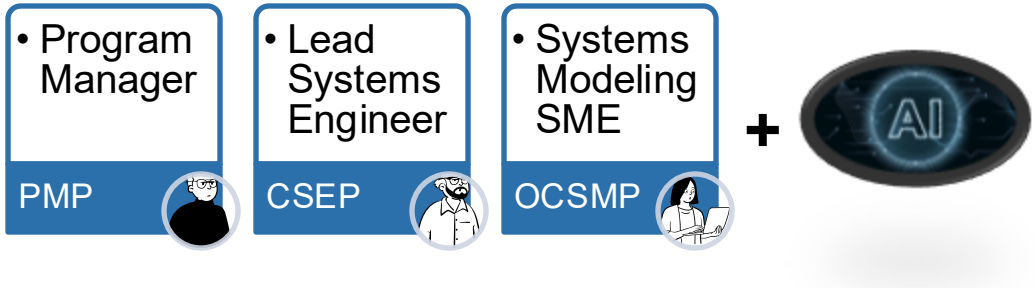
Avoid this anti-pattern at all costs! Classically trained Systems Engineers can be taught SysML much quicker than a modeler can become an effective systems engineer.

The True Role of Models in Engineering

- **Models must be:**
  - A means to an end, not the end itself
  - Integrated with SME inputs and authoritative data
  - Structured to inform design, verify decisions, and align stakeholder intent
  - Scaled to support production, sustainment, and change over time
- **Well-formed models should:**
  - Encode behavior, performance, interfaces
  - Drive requirement validation and risk mitigation
  - Drive architecture decisions before design decisions, reducing integration risk and rework
  - Support modular reuse, obsolescence tracking, and traceability

The Anatomy of a High Performance MBSE Team

Balancing the right ingredients to maintain a product-focus mindset



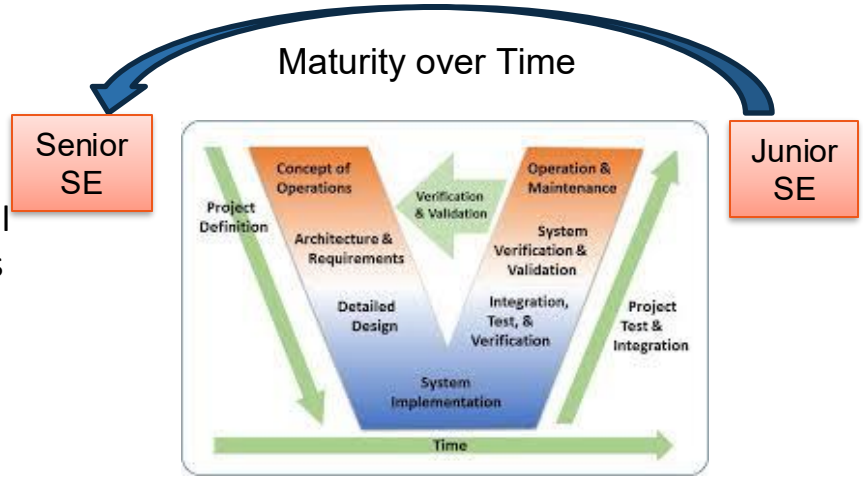
- A blend of program management, SE leadership, and systems modeling expertise is key to maintain in a high performing systemsengineering team that is focused on delivering products, not just models.
- Each of these roles brings something unique to the table, and together they form a product development powerhouse.
  - **PM**: “Lets figure out how to add maximum value to the customer, within cost and schedule constraints”
  - **SE**: “Lets figure out early on how all the pieces fit together to reduce risk on the program and deliver a system that meets its requirements”
  - **Model SME**: “Let’s use the power of integrated systems models to reduce complexity and enhance systems engineering rigor on the program.’
  - **AI**: “let me do things computers are best at, enabling you humans do your higher-level thinking and complex socio-technical problem solving”
- Harness the power of AI today to offload and automate low-complexity model building tasks, or else continue to pay the initially high price of MBSE adoption

Maintain an organizational pattern for blending these skillsets on every project, regardless of the size. If an individual possesses these three skillsets, invest and replicate them!

Practical Strategies to Rebalance Teams

What to do with an influx of modelers in the organization?

- Pair “modelers” with veteran systems engineers
- Junior / entry SE’s should start on the v&v side of the Vee model before trying to produce abstract systems architecture concepts and write requirements
- Use an **SE skills matrix** to guide team composition and career development
- Map **technical experience to lifecycle phases**, not just tool fluency
- Implement internal **mentorship, knowledge management, and onboarding frameworks**
- Understand that **MBSE familiarity ≠ SE passion**—map employees’ **intentions to roles**



Effective MBSE teams blend technical modeling with deep systems thinking—match skills to lifecycle needs, foster mentorship, and align roles with passion, not just tool use.

Leadership Actions for Sustaining Product-Focused MBSE

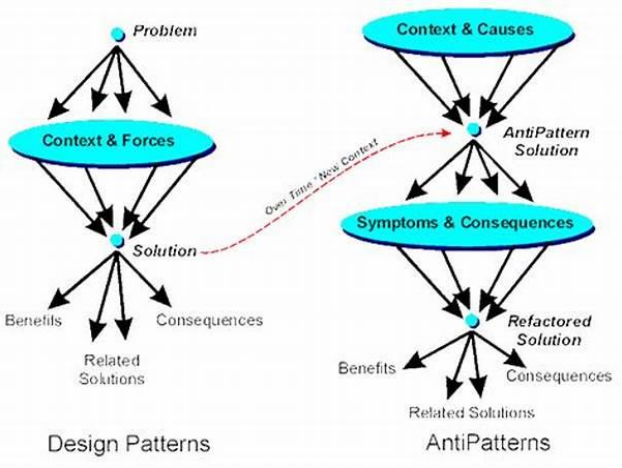
- **Keep the product the north star**—models are only valuable when they contribute to user success
- **Define what good looks like**—via architecture reviews, tradespaces evaluations, validation threads
- **Create a culture of engineering-first, model-enabled thinking**
- **Invest in cross-training, not just tool training**
- **Treat AI as an accelerant, not a replacement for systems engineers**

Model-Based Practical System Engineering Outcomes

Some Practical Examples

- Model Based SEMP
- Technical Reviews
- Processes and more...

Model Based System Engineering Management Plan (SEMP)



Current State of Practice: Static, Sidelined SEMP

***Challenge**:* The Systems Engineering Management Plan (SEMP) is often written early to fulfill contractual requirements and then set aside, losing relevance as the program evolves.

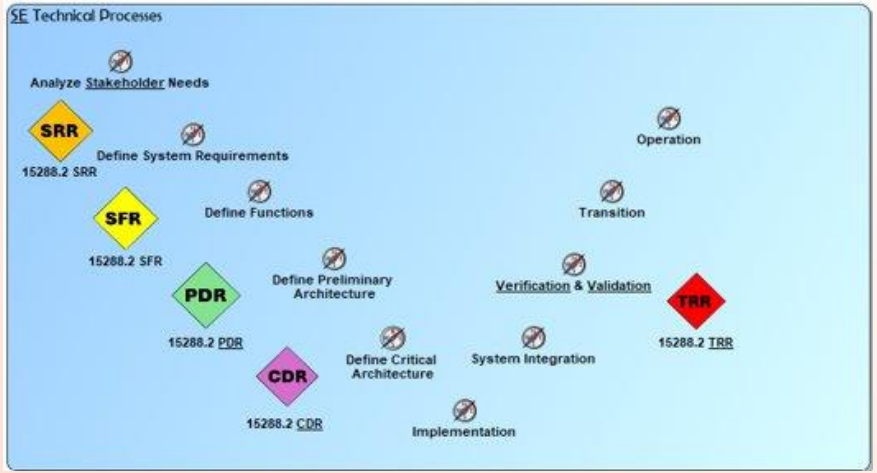
***MBSE Solution**:* Embeds the SEMP directly into the model, transforming it into a *living, model-driven guide* that stays aligned with real-time engineering activities and decisions.

SEMP

#	Id	Name	SEP Template Text	Text	Program Model Artifact
63	2.5	2.5 Design Considerations	As shown in Table 2.5-1, identify the design considerations that are critical to achieving the program's technical requirements. Ensure the design and architectural factors from DoDI 5000.88 are addressed. If additional documentation is required, those documents may need to be embedded/attached in the SEP or located within the program's digital ecosystem. (See SE Guidebook (2022), Design Considerations, for a partial list of design considerations.) Not all are equally relevant or critical ta given program, but all should be examined for relevance.	Design considerations are fundamental concepts that guide trade-off analysis and influence system architecture and development decisions. Some considerations help identify potential design options and trade-offs, while others serve as constraints, boundaries, or limitations. While some constraints may be tailored or negotiated to an extent, many represent fixed elements within the trade space that cannot be changed. According to the SE Guidebook (2022), design considerations encompass a range of factors, and a partial list is provided for reference. In the context of the program, each design consideration will be assessed for its relevance, impact, and criticality within the model-based environment. While not all considerations may be equally applicable or critical to the program, each will be evaluated and modeled as part of the system's requirements, design constraints, or decision criteria to ensure comprehensive coverage of the trade space. These will be captured in a Design Consideration Table.	SE Guidebook Design Considerations
64	2.6	2.6 Technical Certifications	Summarize in table format (Table 2.6-1) the system-level technical certifications obtained during the program's life cycle. Review the following references and add and delete certifications to/from table 2.6-1 as applicable to your program. (See AFPAM 63-128, Attachment 14, AFI 63-101/20-101, para 5.1.5).	Certifications serve as formal acknowledgments by mandatory approval authorities, confirming that the system or program meets specific requirements. Within the program, the certification requirements will be modeled and linked to system elements, ensuring traceability and alignment throughout the development lifecycle. All necessary certifications will be obtained before testing and operational use, with processes in place to maintain them throughout the system's operational life. The MBSE approach will support certification tracking, ensuring compliance with requirements and facilitating updates to the model as certification criteria evolve. Targeted certifications will be tracked in a table with plan and schedule for completion of each; plans will be captured in the IMS.	Technical Certifications
65	3	3 TECHNICAL PROGRAM PLANNING AND CONTROL			
66	3.1	3.1 Organization and Responsibilities			

Alignment Isn't Optional—It's Modeled

Technical Milestone Reviews



Current State of Practice

Engineering Models (CAD, ECAD, Simulation):

- Developed in isolation for specific, narrow purposes
- Shared as screenshots or exported documents, not as live data
- Limited or no traceability to related requirements, behavior, or architecture
- Not integrated into a broader system model or digital thread

Data Sharing & Review Prep:

- Shared via emails, PDFs, printouts, or Teams messages
- Manual effort introduces complexity and risk of inconsistency
- Requires significant time to compile and format review materials
- Lacks centralized configuration management, leading to version confusion

Fragmented Data Across Tools and Formats

***Challenge**:* Artifacts are often dispersed across multiple documents and systems, leading to inconsistencies and duplication.

***MBSE Solution**:* Establishes a *single source of truth* by centralizing information within a unified model, ensuring data integrity and coherence.

Visibility into Milestone Readiness

***Challenge**:* Tracking progress toward milestone completion is often ad hoc and lacks a unified dashboard.

***MBSE Solution**:* Offers *built-in mechanisms to track artifact maturity and review status*, providing clear insight into milestone readiness.

Path to SRR

Review Readiness: Ready for Review | WIP | Not Started | Not Applicable

#	milestoneReview	Name	tailoringRationale	Model Artifact	milestoneReviewRea...	To Do
4	SRR	Updated cost estimate fits within the existing budget	Not available in the model		Not Applicable	
5		Risk Assessment				
6	SRR	Technical risks are identified, and mitigation plans are in place		Opportunity Register Risk Register	WIP	
7	SRR	Initial Mission-Based Cyber Risk Assessment completed			Not Started	
8		System Performance Specification				
9	SRR	Contractor clearly demonstrates an understanding of the system requirements consistent with the Initial Capabilities Document (ICD) and draft Capability Development Document (CDD)		PSPEC to System Spec derivation matrix System to PSPEC Parent Requirement matrix Functional Hierarchy System Function List - System Allocations	Ready For Review	
10	SRR	System requirements, including those generated by the design considerations, are sufficiently detailed and understood to enable functional definition and functional decomposition		L1 - System Specification Function satisfaction of system reqt Reqt flowdown allocation to Subsystem	Ready For Review	
11	SRR	System requirements are assessed to be verifiable (see Chief Developmental Tester in Test and Evaluation (T&E) Enterprise Guidebook (forthcoming))		L1 - RVTM	Ready For Review	
12	SRR	Requirements can be met given the plans for technology maturation		Logical Structure TRL Assessment	WIP	

Readiness Isn't a Guess—It's in the Model

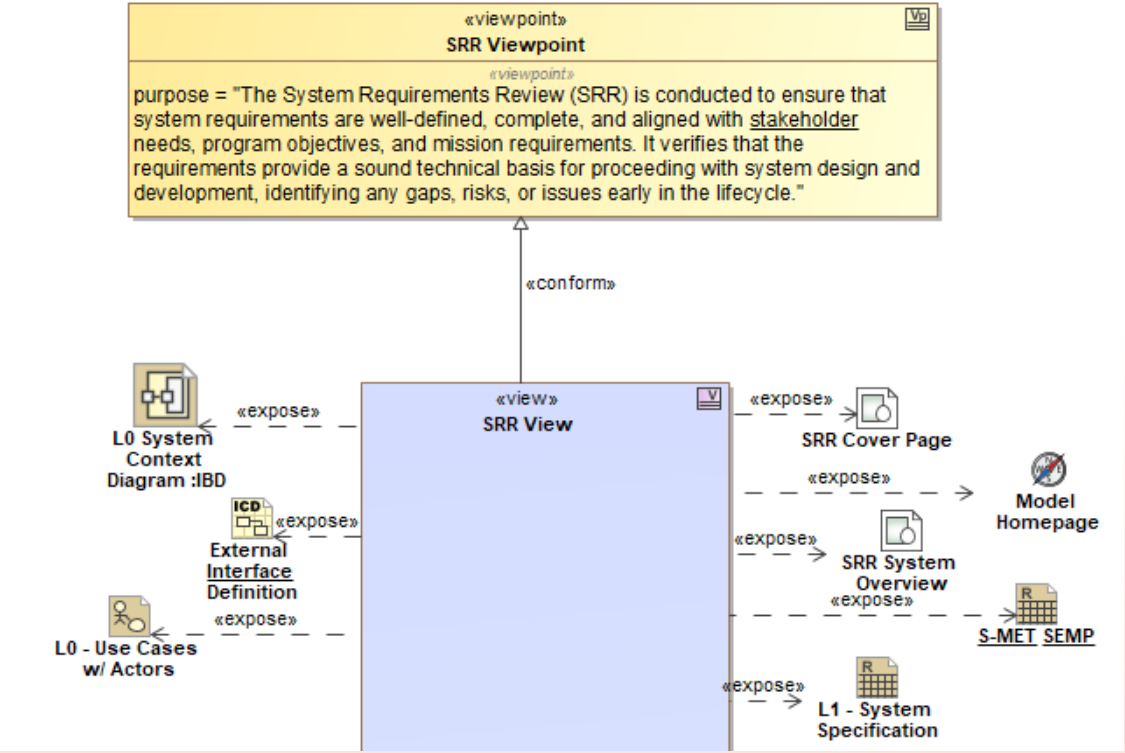
Updates and Reviews

***Challenge**:* Late-stage changes are difficult to incorporate without rework and risk of error.

***MBSE Solution**: Facilitates last-minute updates* within the model, instantly reflecting changes across related views and artifacts.

***MBSE Solution**:* Supports *automated VTL exports* for read-ahead packages, enabling stakeholders to engage with accurate, up-to-date information before the formal review.

SRR Read-Ahead



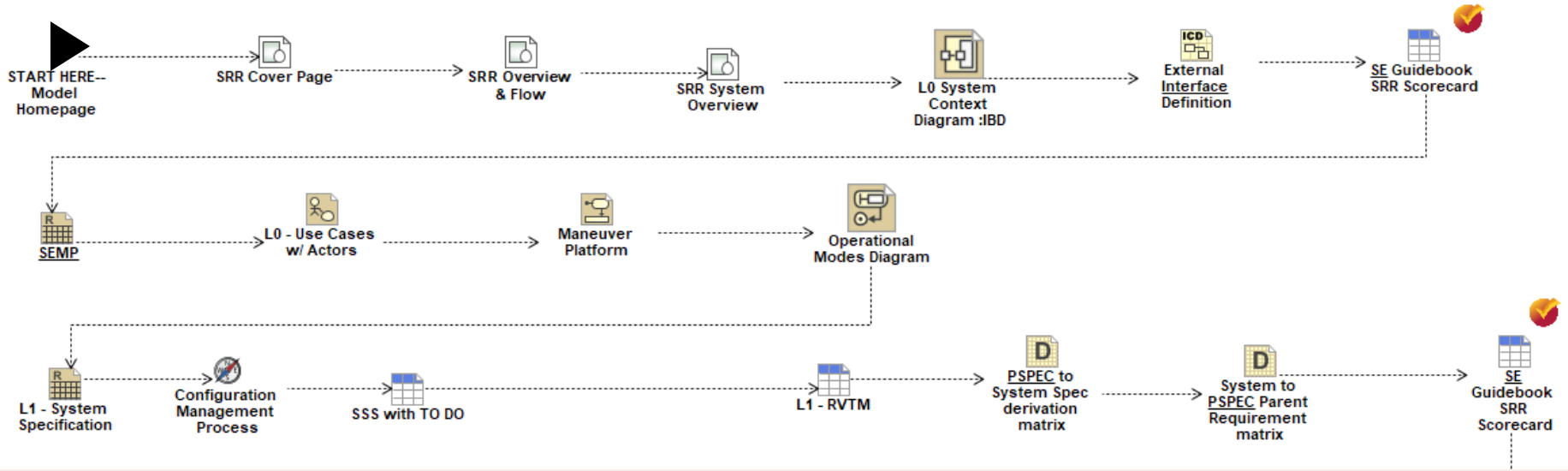
From Model to Slide Deck—In One Click with VTL

Address Real-Time Review Questions Effectively

***Challenge**:* Presenters and Reviewers may lack access to the full context or source artifacts during discussions.

***MBSE Solution**:* Provides *access to all linked model artifacts* in real time, allowing reviewers to trace requirements, behaviors, and structures on the spot.

SRR Presentation



Run the Review from the Source—The Model *Is* the Brief

Review Record-Keeping

***Challenge**:* Critical review metadata (e.g., dates, attendees, decisions) is often captured separately from technical artifacts, risking loss or misalignment.

***MBSE Solution**:* The model can act as the *single authoritative source* for milestone review data—including review date, attendee list, and voting records—ensuring traceability and audit readiness.

SRR Scorecard

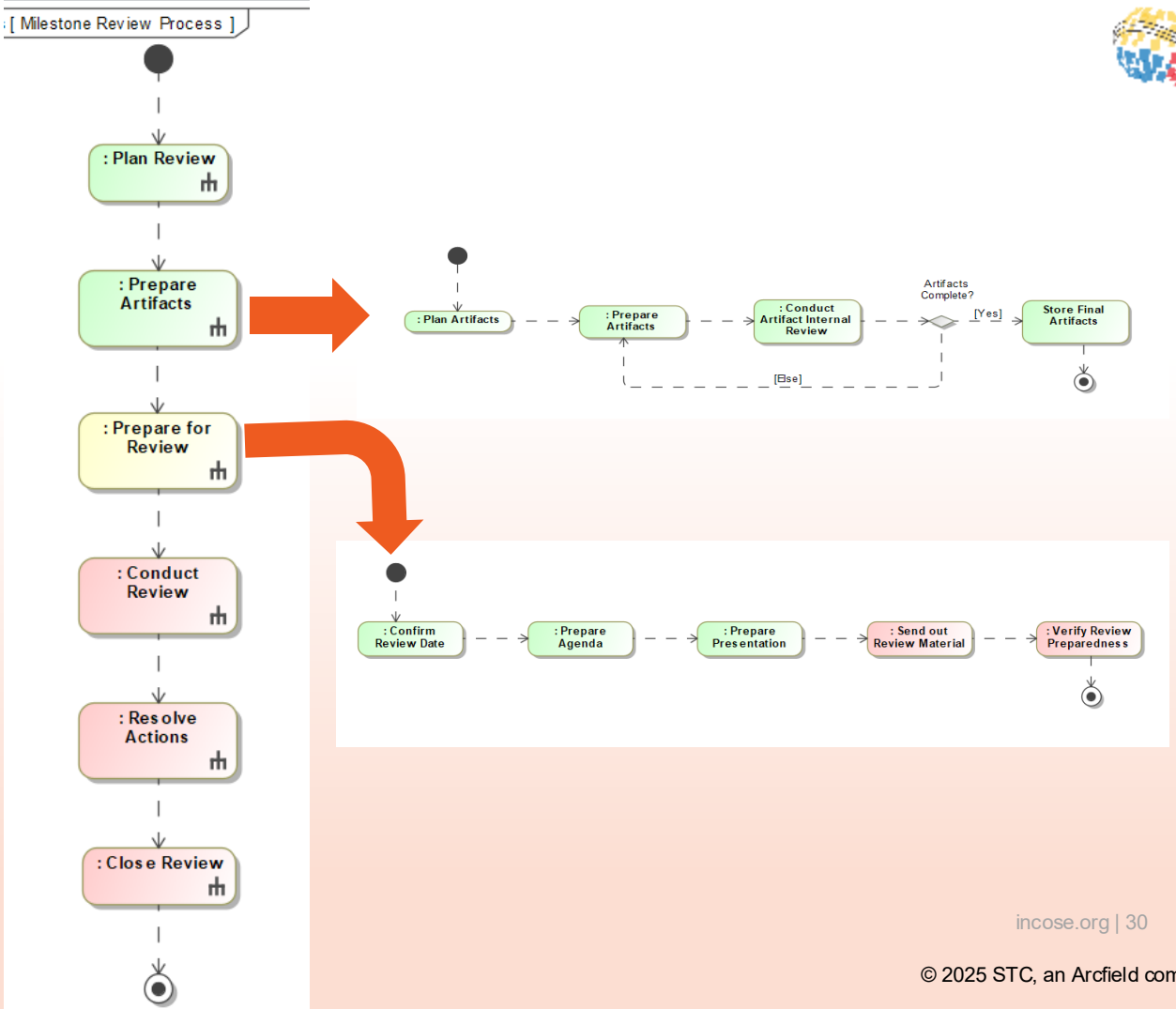
Milestone Review Status: Pass | Partial Pass | Fail | Not Applicable

#	mile...	Name	tailoringRationale	milestoneStatus	Model Artifact	stakeholders	stakeholderVotes	Action Item
4		Preliminary Cost Analysis Requirements Description is consistent with the approved system performance specification	Not available in the model	Not Applicable				
5		Risk Assessment						
6	SRR	Technical risks are identified, and mitigation plans are in place		Partial Pass	Opportunity Register Risk Register	Program Manager Chief Engineer Lead System Engineer Risk Manager	Pass Pass Pass Partial Pass	SRR #2 Add mitigation steps to Risk 4
7	SRR	Initial Mission-Based Cyber Risk Assessment completed		Fail		Cyber Lead	Fail	SRR #1 Need to complete all steps of cyber risk assessement
8		System Performance Specification						
9	SRR	Contractor clearly demonstrates an understanding of the system requirements consistent with the Initial Capabilities Document (ICD) and draft Capability Development Document (CDD)		Pass	PSPEC to System Spec derivation matrix System to PSPEC Parent Requirement matrix Functional Hierarchy System Function List - System Allocations	Program Manager Chief Engineer Lead System Engineer	Pass Pass Pass	
10	SRR	System requirements, including those generated by the design considerations, are sufficiently detailed and understood to enable functional definition and functional decomposition		Pass	L1 - System Specification Function satisfaction of system reqt Reqt flowdown allocation to Subsystem	Program Manager Chief Engineer Lead System Engineer	Pass Pass Pass	
11	SRR	System requirements are assessed to be verifiable (see Chief Developmental Tester in Test and Evaluation (T&E) Enterprise Guidebook (forthcoming))		Pass	L1 - RVTM	Program Manager Chief Engineer Lead System Engineer Test Lead	Pass Pass Pass Pass	

Real-Time Satus. Executive Confidence

Capture Processes in the model

The opportunities are limitless...



Bridging the Knowledge Gap

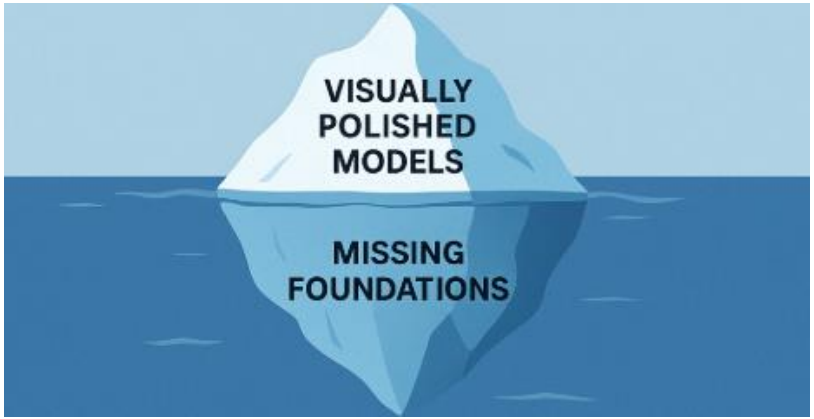
Aligning Modeling Practices with Core Systems Engineering Principles

Identifying the Knowledge Gap

- *Modeling proficiency is rising* — but often lacks foundational **Systems Engineering (SE)** principles.
- *Mastery of SysML syntax* ≠ **Sound engineering judgment** or decision-making.
- *V-model fundamentals are being overlooked*:
  - *Are we solving the right problem?*
  - *Are we solving the problem the right way?*

How the Gap Manifests

- Requirements lack validation traceability, undermining testability and stakeholder confidence
- Verification activities are adapted to fit the model
- Visually polished models that fail technical milestone reviews
- Stakeholders impressed by visuals but left unclear on system completeness



Closing the Gap: Practical Strategies

- **Build SE Fluency** – Train modelers in foundational Systems Engineering: V&V, traceability, lifecycle rigor, and system thinking
- **Embed SE Artifacts into the Model** – Include model-based SEMPs, requirement trace matrices, and verification frameworks
- **Synchronize Models with Reviews** – Align modeling progress with technical milestone reviews and readiness assessments
- **Encourage Professional Certification** – Support CSEP/ASEP pursuit to reinforce standards and elevate practitioner credibility

Strengthening the Next Generation

- **Bridge the Gap with Mentorship** – Pair junior modelers with experienced systems engineers for guided, hands-on learning
- **Use Skills Matrices for Intentional Growth** – Align development plans with core SE competencies and modeling proficiency
- **Institutionalize SE Wisdom** – Create structured mentorship programs focused on engineering tradeoffs and decision-making
- **Promote Experiential Learning** – Involve junior staff in real-world challenges: risk analysis, trade studies, and requirements development

From Mentorship to Mastery

Academic Programs Supporting INCOSE Certification

Stevens Institute of Technology
- **Graduate Certificate —** *12 credits*
- *Online, offered year-round*

University of Detroit Mercy
- **Graduate Certificate —** *15 credits*
- *Fully online*

University of Michigan
- **Master's in Systems Engineering & Design —** *30 credits*
- *Hybrid / Online*

Georgia Tech
- **Professional Master's in Applied SE —** *33 credits*
- *Hybrid, cohort-based*

Johns Hopkins University
- **Part-time Certificate Program**
- **Online, flexible format**

Final Thought: MBSE is Engineering

- MBSE must reclaim its purpose: To enable better engineering decisions – not just better models
- Models are tools, not the goal
- Engineering outcomes remain the standard for success

"The purpose of models is not to fit the data but to sharpen the questions."

(Samuel Karlin, 1983)