INCOSE Model-Based SE Transformation
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Background on INCOSE and SE Transformation

• Relatively young professional society (28 years) and SE practice/discipline (~60 years), growing.
• Evolving SE discipline and INCOSE vision+plan: *A World in Motion: SE Vision 2025.*
• Early roots mil/aero, later shifted heavily to commercial automotive, energy, medical, communications, information systems, advanced manufacturing, consumer products, others.
• Other engineering disciplines (ME, EE, CE,…) rooted in connected physical sciences—but for systems engineering, this theoretical foundation is only now deepening, enabled by transition to models.
• INCOSE Board of Directors Objective: “INCOSE accelerates the transformation of systems engineering to a model-based discipline.”
# Stakeholders in a Successful MBSE Transformation

## Model Consumers (Model Users):
- Non-technical stakeholders in various Systems of Interest, who acquire / make decisions about / make use of those systems, and are informed by models of them. This includes mass market consumers, policy makers, business and other leaders, investors, product users, voters in public or private elections or selection decisions, etc.

## Model Creators (including Model Improvers):
- Product visionaries, marketers, and other non-technical leaders of thought and organizations
- System technical specifiers, designers, testers, theoreticians, analysts, scientists
- Students (in school and otherwise) learning to describe and understand systems
- Educators, teaching the next generation how to create with models
- Researchers who advance the practice
- Those who translate information originated by others into models
- Those who manage the life cycle of models

## Complex Idea Communicators (Model "Distributors"):
- Marketing professionals
- Educators, especially in complex systems areas of engineering and science, public policy, other domains, and including curriculum developers as well as teachers
- Leaders of all kinds

## Model Infrastructure Providers, Including Tooling, Language and Other Standards, Methods:
- Suppliers of modeling tools and other information systems and technologies that house or make use of model-based information
- Methodologists, consultants, others who assist individuals and organizations in being more successful through model-based methods
- Standards bodies (including those who establish modeling standards as well as others who apply them within other standards)

## INCOSE and other Engineering Professional Societies:
- As a deliverer of value to its membership
- As seen by other technical societies and by potential members
- As a great organization to be a part of
- As promoter of advance and practice of systems engineering and MBSE
Background on INCOSE and SE Transformation

• INCOSE includes Leadership, ~44 Working Groups (WGs), plus numerous external partnerships and collaborations:
  – https://www.incose.org/ChaptersGroups/WorkingGroups

• The INCOSE Transformation requires heavy collaboration and partnering across both internal INCOSE Working Groups as well as external collaborators and partners:
  – The size and inter-dependent networked nature of this SE Transformation means that collaboration is essential—we seek global community collaboration.
  – We suggest same is true for any organization with a similar goal.

• For example, . . .
**Partnering Example:**

**Patterns WG**

INCOSE MBSE Patterns Working Group: Joint 2017-2018 activities, interests, collaborations, conversations, project partners
Transformation as a Systems Engineering Problem

Traditional Systems Engineering Emphasizes Process

MBSE Increases Relative Emphasis on Information
Transformation as a Systems Engineering Problem

Traditional Systems Engineering Emphasizes **Process**

MBSE Increases Relative Emphasis on **Information**

Information Consumed → **Engineering Process (Iterative)** → Information Produced

Information Passing Through **Engineering Process**

Life Cycle Management Process (Iterative)

Information Passing Through Life Cycle Processes

Transformation
Transformation as a Systems Engineering Problem

Traditional Systems Engineering Emphasizes Process

MBSE Increases Relative Emphasis on Information

Process & Procedure

Engineering Process (Iterative)

Information Consumed

Information Produced

Transformation

Information Passing Through Engineering Process

Life Cycle Management Process (Iterative)

Information Passing Through Life Cycle Processes

Models
Transformation as a Systems Engineering Problem

- We are not just converting previous information to model-based form and stopping there . . .
- The STEM revolution sprang from **smallest effective representation**:  
  - Discovery and exploitation of physical laws and principles expressed in **model-based patterns** compressing a complex world.  
  - Distilling discovered learning into its simplest form.
- Unlike other engineering disciplines, SE has only begun to arrive at model-based representation.
- SE foundations are still being explicated, and are much more than just modeling languages.
- Science also builds on what is **verifiably learned**, with managed and transferable credibility, by **applying, not rediscovering, trusted knowledge**.
What is the smallest effective model content (not language) for SE, across whole life cycle?
What is the effective exploitation of recurring model-based patterns?

What is the smallest effective model content (not language) for SE, across whole life cycle?
INCOSE ASELCM Reference Pattern

(Used in INCOSE Agile SE Life Cycle Model Discovery Project, descriptive, not prescriptive.)

- **System 1**: Target system of interest, to be engineered or improved.
- **System 2**: The environment of (interacting with) S1, including all the life cycle management systems of S1 (engineering, production …, including learning about S1).
- **System 3**: The life cycle management systems for S2, including learning about S2.

(Substantially all the ISO15288 processes are included in all four Manager roles)
• System 1: Target system of interest, to be engineered or improved.
• System 2: The environment of (interacting with) S1, including all the life cycle management systems of S1 (engineering, production …, including learning about S1.
• System 3: The life cycle management systems for S2, including learning about S2.

(Substantially all the ISO15288 processes are included in all four Manager roles)
3. System of Innovation (SOI)

2. Target System (and Component) Life Cycle Domain System

1. Target System

LC Manager of Target System

Learning & Knowledge Manager for Target Systems

Life Cycle Manager of LC Managers

Learning & Knowledge Manager for LC Managers of Target System

Target Environment

(Substantially all the ISO 15288 processes are included in all four Manager roles)

4. How do we trust and effectively apply, not rediscover, learned patterns?

3. How do we learn, verify, validate, and quantify uncertainty in models?

• Agile software methods emphasized individual learning.
• Effective group learning is the prize.
• Systems engineers are still eager to model from scratch.

• Information Debt, not just Technical Debt
• Capitalization of System Patterns as IP
COMPARATIVE ROI

Benefits to Users of System Descriptions
(Recurring Benefit Per Project)

Investment Per Project
(Recurring Cost Per Project)

Cost to Support Methodology
(Small group per Enterprise, not Project Recurring)

ROI: Ratio of Benefits (below) to Investment (below)
(Recurring ROI Per Project)

"Learn to Model"
(MBSE)

"Learn the Model"
(PBSE/MBSE)

QUALITATIVE ANALYSIS

Benefits to Users of System Descriptions
(Recurring Benefit Per Project)

Investment Per Project
(Recurring Cost Per Project)

Cost to Support Methodology
(Small group per Enterprise, not Project Recurring)

Models Improve Understanding Within Projects

Patterns Continuously Improve Understanding and Content Across Projects and Enterprise

Model Creators Must Create and Validate Model (possibly also learning to model)

Model Creators Need Only Configure Model from Pattern

Methodology Governance Must Accommodate Modeling Rules

Pattern Creators Must Manage IP Portfolio Asset

“Learn to Model”
(1X Scale)

“Learn the Model”
(10X Scale)
Sample Activities, and Transformation Products

Example Products & Other Deliverables

INCOSE Transformation Plan Developed (Reported Already):
1. Stakeholder Community Identification
2. Strategy & Action Plan
3. Enablers & Roadblocks

Pilot Products Developed and Available for Beta Test Use:
1. MB Roadmap Planning and Assessment Tool
2. Model Features Planning and Packaging Framework

Products Under Development
1. Model Based Exemplars
2. Requirements for VVUQ of Credible Models
3. INCOSE MBSE Primer
4. Value Briefing / Case Studies / ROI
5. Webinar
6. IS2018 MBSE Workshop

Emerging Activities, Partners We’re Supporting:
1. OMG SysML 2.0
2. ASME Model VVUQ Effort
3. SE Ontology Effort with SERC, JPL, et al.
4. Two New MBSE Challenge Teams:
   - Digital Artifacts
   - Augmented Intelligence for Systems Engineering
Example Transformation Products, for Beta Test Use: MB Roadmap Planning and Assessment Tool

- **Product Concept**: Drive “one level below” the declaration that “we want to start using Model-Based Methods”, or the assertion that “we already use Model-Based Methods”:
  - Drills down “one level”, to the granularity level of the ISO15288 processes, but not lower than that
  - Provides a **light-weight tool** for (a) making a plan to incorporate Model-Based Methods, or (b) overviewing the relative perceived extent of Model-Based Method use and its degree of impact, challenge
  - Not a detailed maturity model
    - Meant to be easy to use, but more challenging than “we are going to use model based methods”, or “we already do”
    - Resulting display instrument suitable for use in leadership briefings as well as technical audiences.

- **For use by**:
  - An enterprise
  - A project
  - An individual person
  - A multi-company team
  - A trade group
  - And especially by . . . CAB members!
**Product Concept:** What are the stakeholder features of the model we are planning, the model we are building, the model we are using? Is it fit for its intended use?

A more detailed, but entirely stakeholder-level, framework for describing the full spectrum of stakeholder issues, expectations, and outcomes for the full life cycle (development through use, maintenance, retirement) of any type of model.

Explicitly connected to the ISO15288 process areas, but drills further into what stakeholders expect and actually receive.

Tied to the joint effort with ASME on Computational Model Credibility (Model VVUQ) guidelines and standards, supported by INCOSE.

Tied to (separate tool) Model Requirements to follow separately, as the basis for determining the credibility of models.

Resulting data is suitable for creating views bridging from business stakeholders to technical practitioners.

For use by:
- An enterprise
- A project
- An individual person
- A multi-company team
- A trade group
- And especially by . . . CAB members!
INCOSE invites and practices internal and external partnering and collaboration on SE Transformation and related activities:

- **Example**: Newly formed INCOSE MBE Capabilities Assessment Challenge Team Project (led by Al Hoheb, Aerospace Corp., and Joe Hale, NASA).
- Related and complementary to the INCOSE MB Roadmap Planning and Assessment Project and Model Features Planning and Packaging Framework (VVUQ Pattern)—a natural partnership.

We invite additional collaborations with public and private sector partners.

Hear more about, collaborate on, these and other activities at the INCOSE International Symposium IS2018 in Washington, DC, July 7-12:

- Including an MBSE Workshop on Saturday, July 7
- Including a collaborations panel on Patterns in the Public Square, with FAA, FDA, DoD, INCOSE, ASME, SAE

[https://www.incose.org/symp2018/home](https://www.incose.org/symp2018/home)
Discussion
References

1. INCOSE Model-Based Transformation web site: https://www.incose.org/about/strategicobjectives/ transformation
   https://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf
3. “INCOSE MBSE Transformation Planning & Assessment Framework: Beta Test”: 
References

8. INCOSE Patterns Working Group, “MBSE Methodology Summary: Pattern-Based Systems Engineering (PBSE), Based On S*MBSE Models”, V1.5.5A, retrieve from: http://www.omgwiki.org/MBSE/doku.php?id=mbse:pbse


Supplemental Information
SE Transformation

Objective:

INCOSE Accelerates the transformation of systems engineering to a model-based discipline.

Build a broad community that promotes and advances model-based engineering and the role that model-based systems engineering plays in it.

Accelerate the transformation to a model-based discipline:

- Advance and mature the MBSE Practice
- Mainstream Model Based Systems Engineering
- Evolve to a cohesive MBSE language, applicable to multiple domains
- Promote and advance the role of MBSE in global Model Based Engineering (MBE)
- Connect to other MBE cross domain standards like Building Information Modeling (BIM)
- Get authoritative information on MBSE out to practitioners and the broader community
- Infuse MBSE into SEBoK
- Align with SE Vision 2025 (see page 38-39)

From:

- Model-based systems engineering has grown in popularity as a way to deal with the limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAM

To:

- Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The use of internet-driven knowledge representation and interactive technologies enable highly efficient and shared human understanding of systems in a virtual environment that spans the full life cycle from concept through development, manufacturing, operations and support.

Questions:

strategicobjectives@incose.org
Strategy Notional Timeline

- Mission Areas
- Internal Short Wave
- External Mid Wave
- Advancing Long Wave
- Waves Run Concurrently
- Activities build on each other
<table>
<thead>
<tr>
<th>Mission</th>
<th>Systems Engineering is acknowledged as a model based discipline</th>
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**Mission Area #**

<table>
<thead>
<tr>
<th>Mission Area</th>
<th>Infuse INCOSE</th>
<th>Engage Stakeholders</th>
<th>Advance Practice</th>
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<tbody>
<tr>
<td>What can INCOSE Do?</td>
<td>Engage stakeholders to assess the current state of practice, determine needs and values of model based methods</td>
<td>Advance stakeholder community model based application and advance model based methods.</td>
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<td>Goals</td>
<td>Inclusion of model based content in INCOSE existing/new products (Vision, Handbook, SEBoK, Certification, Competency Model, etc.)</td>
<td>Identify, categorize and engage stakeholders and characterize their current practices, enablers and obstacles</td>
<td>Increase awareness of and about stakeholders outside SE discipline of what is possible with model based methods across domains and disciplines (tech/mgmt)</td>
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<td>Objective 1</td>
<td>Expand reach within INCOSE of MBSE Workshop; highlight and infuse tech ops activities with more model based content (products, WGs etc.)</td>
<td>Build a community of Stakeholder Representatives to infuse model based advances into organizations practicing systems engineering.</td>
<td>Initiate, identify and integrate research to advance systems engineering as a model based discipline</td>
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<td>Objective 2</td>
<td>Outreach: Leverage MOUs to infuse model based content into PMI, INFORMS, NAFEMS, BIM, ASME and others, sponsoring PhD Students, standardization bodies, ABET</td>
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<td>Objective 3</td>
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<td>Objective 4</td>
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<td>Objective Assessment/Roadmap</td>
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Transformational Working Groups

Transformational Enablers

Home / Chapters & Groups / Working Groups / Transformational

Transformational Enablers - Troy Peterson

Working Groups with public content pages managed on the INCOSE public site:

- Agile Systems & SE
  - Lean Systems Engineering
    - MBSE Initiative
    - MBSE Patterns
  - Model Based Concept Design
  - Object-Oriented SE Method
  - Very Small Entities (VSE)
- Systems Science
  - Tool Integration and Model Lifecycle Management
  - INCOSE-NAFEMS Collaboration
  - Ontology

http://www.incose.org/ChaptersGroups/WorkingGroups
Systems engineering will lead the effort to drive out unnecessary complexity through well-founded architecting and deeper system understanding.

A virtual engineering environment will incorporate modeling, simulation, and visualization to support all aspects of systems engineering by enabling improved prediction and analysis of complex emergent behaviors.

Composable design methods in a virtual environment support rapid, agile and evolvable designs of families of products. By combining formal models from a library of component, reference architecture, and other context models, different system alternatives can be quickly compared and probabilistically evaluated.

From: Model-based systems engineering has grown in popularity as a way to deal with the limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAE.

To: Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The use of internet-driven knowledge representation and immersive technologies enable highly efficient and shared human understanding of systems in a virtual environment that span the full life cycle from concept through development, manufacturing, operations, and support.
INCOSE MBSE Initiative as an Incubator and Transformation Agent

- MBSE Patterns Challenge Team: (Started 2013, graduated to INCOSE Working Group in 2016)
  - Transforming model-based methods through the leverage of recurring learned patterns

- Digital Artifacts Challenge Team:
  - Identifying and characterizing MBSE digital artifacts across the lifecycle

- Production and Distribution Systems Challenge Team
  - Connecting models across the lifecycle – Industry 4.0, Supply Chain, Logistics

- V&V of models (Potential Collaboration ASME, INCOSE, NAFEMS)
  - Verification and Validation of Models – tied to ASME VV50 standards project

- Augmented Intelligence in Systems Challenge Team
  - How can machine learning and AI aid systems engineering in the innovation process

- MBSE/MBE Capabilities Assessment Challenge Team
  - Developing self-assessments and gap analysis, strategic planning, project progress aids