V1.3.2

International Council on Systems Engineering

Bill Schindel, INCOSE Fellow, Member of INCOSE Transformation Lead Team

INCOSE Model-Based SE Transformation

Aerospace Corporation System Engineering Forum, May 2, 2018

schindel@ictt.com

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- Transformation as a Systems Engineering Problem
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- Organization, Partnering, Collaboration, Invitation
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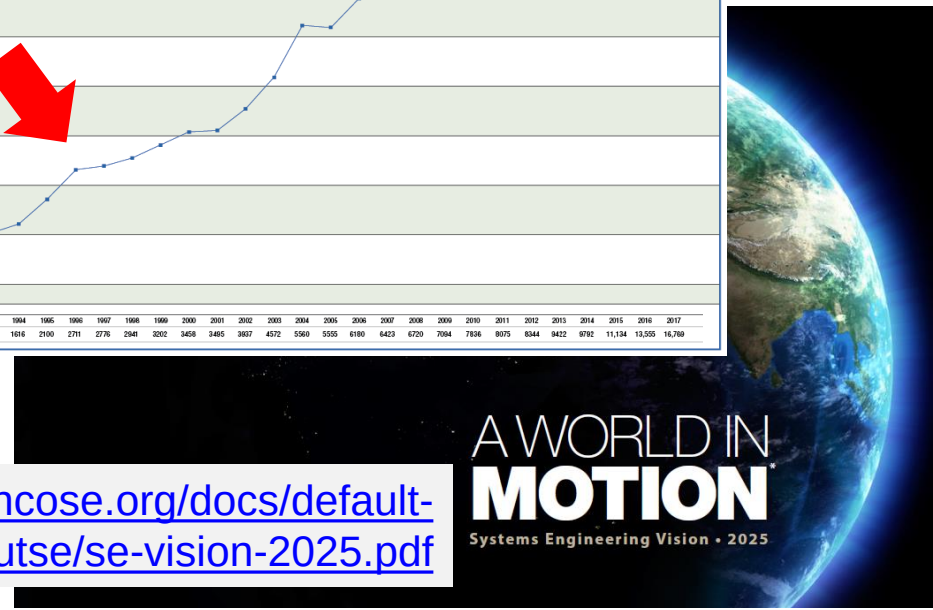
Background on INCOSE and SE Transformation

- 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.*"



https://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf

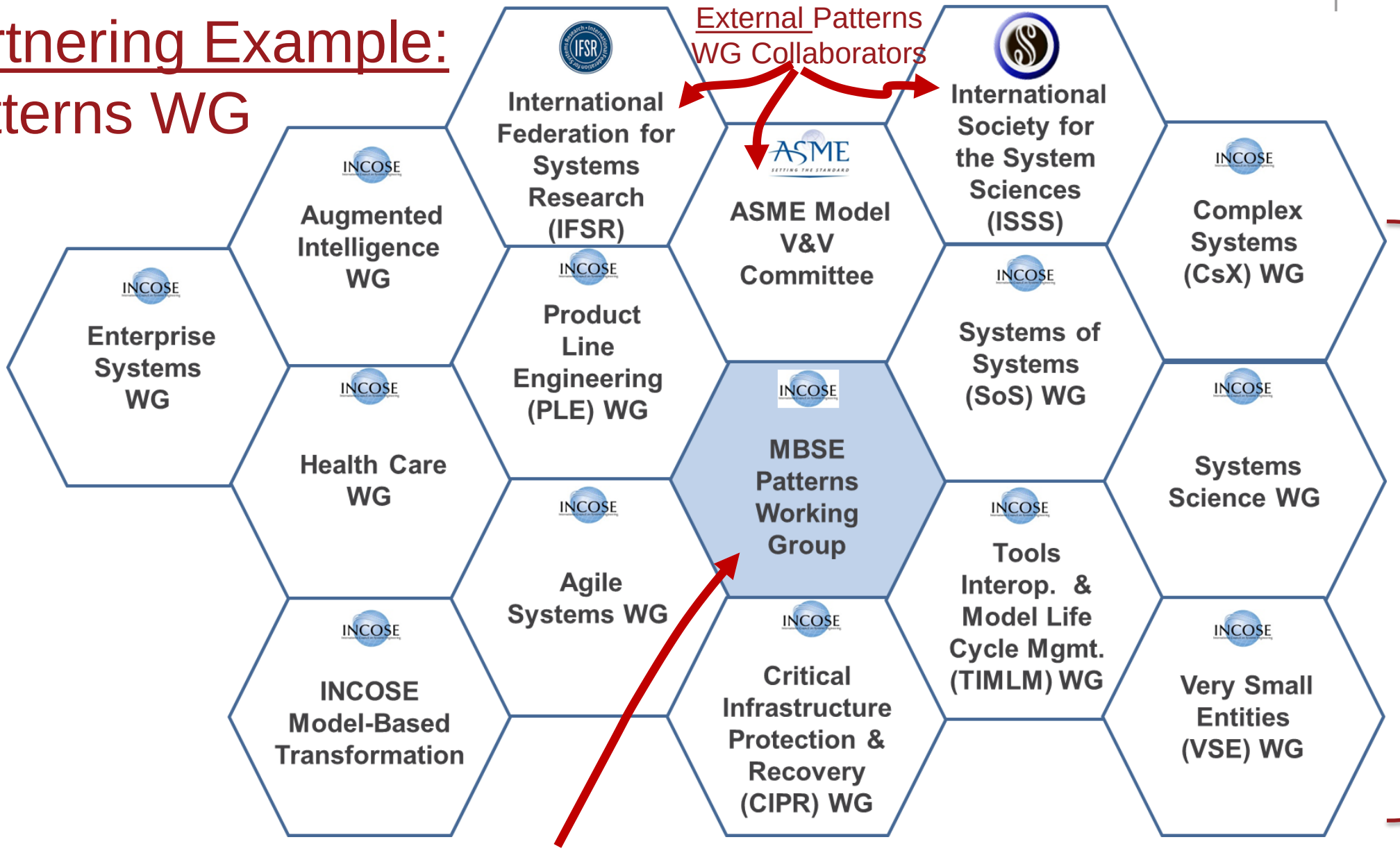
Background on INCOSE and SE Transformation

Population <-- Size (Log)	Stakeholders in A Successful MBSE Transformation (showing their related roles and parent organizations)	Industry & Gvmt. Initiatives	Orgs. Internalizing MBSE, Incl Gvmt Contractors & Commercial	Vendors of MBSE Tooling and Services	Academia and Researchers	Technical Societies, Other Non-Technical Organizations	
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.	X	X			X	
**	Technical model users, including designers, project leads, production engineers, system installers, maintainers, and users/operators.	X	X			X	
*	Leaders responsible to building their organization's MBSE capabilities and enabling MBSE on their projects	X	X			X	
Model Creators (including Model Improvers):							
*	Product visionaries, marketers, and other non-technical leaders of thought and organizations	X	X		X	X	
*	System technical specifiers, designers, testers, theoreticians, analysts, scientists	X	X		X	X	
*	Students (in school and otherwise) learning to describe and understand systems				X	X	
*	Educators, teaching the next generation how to create with models	X	X		X		
*	Researchers who advance the practice		X	X	X		
*	Those who translate information originated by others into models	X	X		X	X	
*	Those who manage the life cycle of models	X	X		X	X	
Complex Idea Communicators (Model "Distributors"):							
**	Marketing professionals	X	X	X		X	
**	Educators, especially in complex systems areas of engineering and science, public policy, other domains, and including curriculum developers as well as teachers	X	X	X	X		
**	Leaders of all kinds	X	X	X	X	X	
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			X			
*	Methodologists, consultants, others who assist individuals and organizations in being more successful through model-based methods	X	X	X	X		
*	Standards bodies (including those who establish modeling standards as well as others who apply them within other standards)	X				X	
INCOSE and other Engineering Professional Societies							
*	As a deliverer of value to its membership					X	
*	As seen by other technical societies and by potential members					X	
*	As a great organization to be a part of					X	
*	As promoter of advance and practice of systems engineering and MBSE					X	

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, . . .

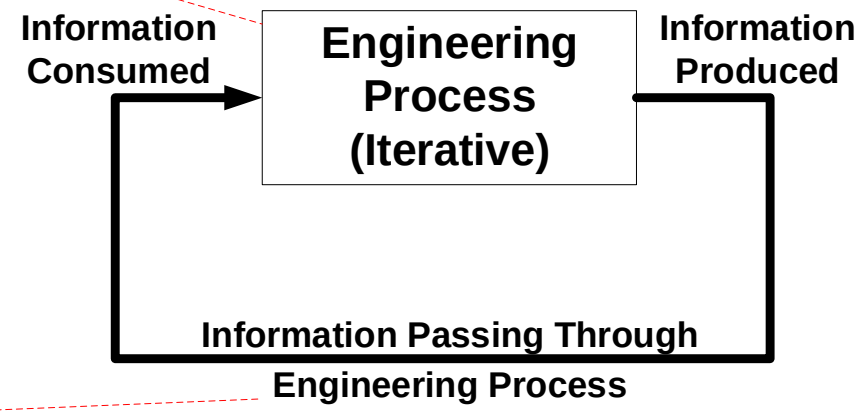
Partnering Example: Patterns WG



INCOSE MBSE Patterns Working Group: Joint 2017-2018 activities, interests, collaborations, conversations, project partners

Transformation as a Systems Engineering Problem

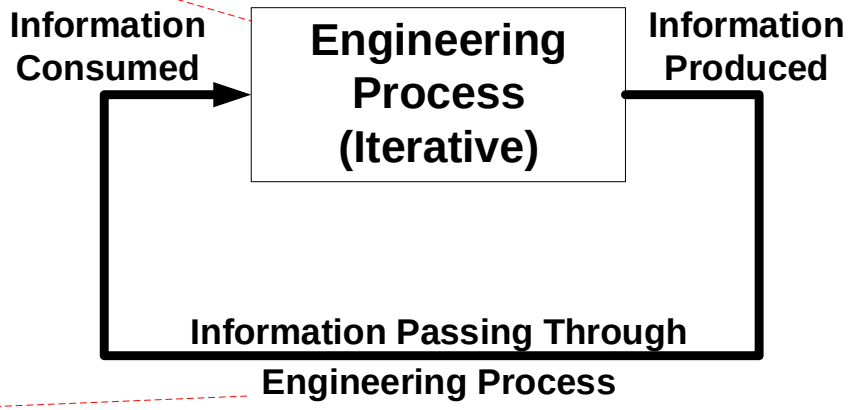
Traditional Systems Engineering Emphasizes ***Process***



MBSE Increases Relative Emphasis on ***Information***

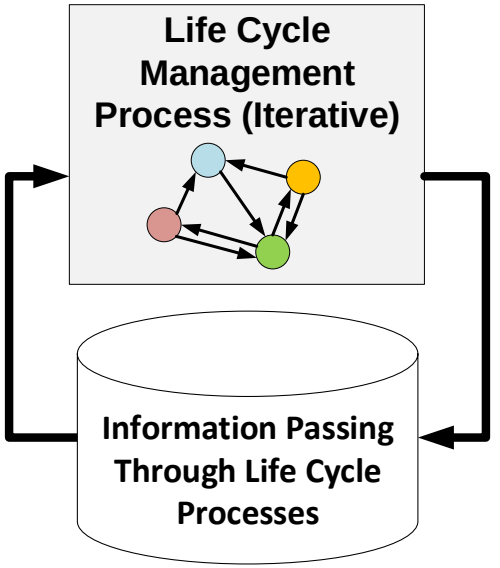
Transformation as a Systems Engineering Problem

Traditional Systems Engineering Emphasizes ***Process***



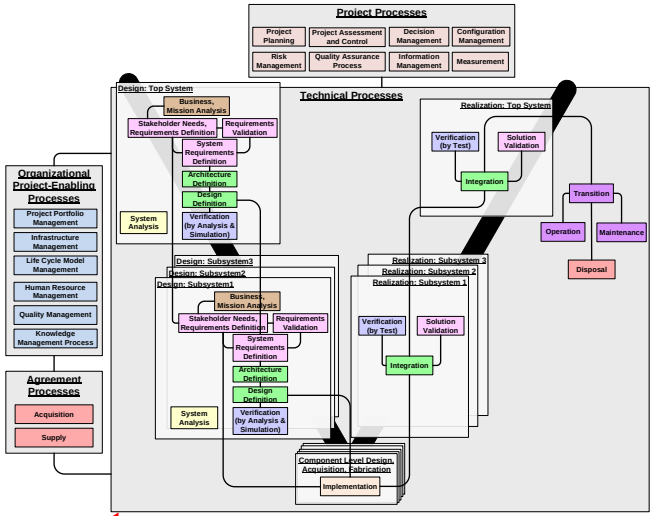
MBSE Increases Relative Emphasis on ***Information***

Transformation



Transformation as a Systems Engineering Problem

Process & Procedure



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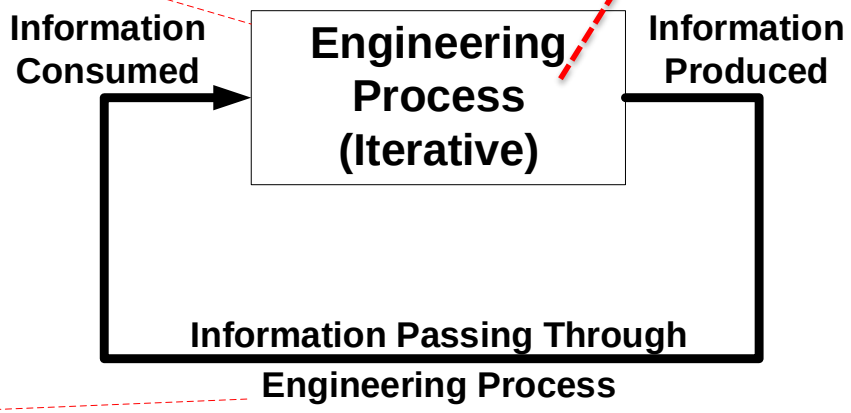

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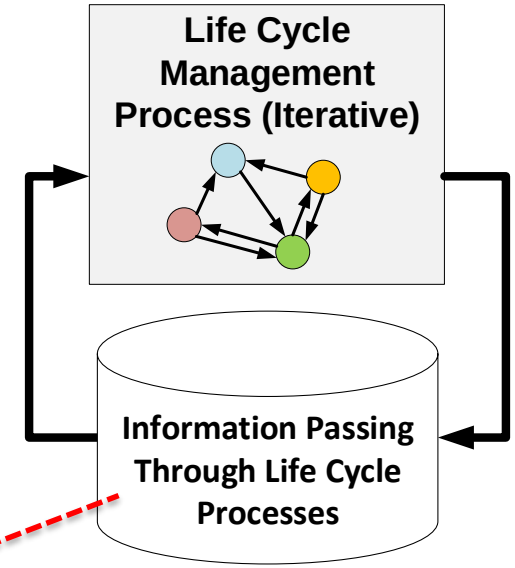
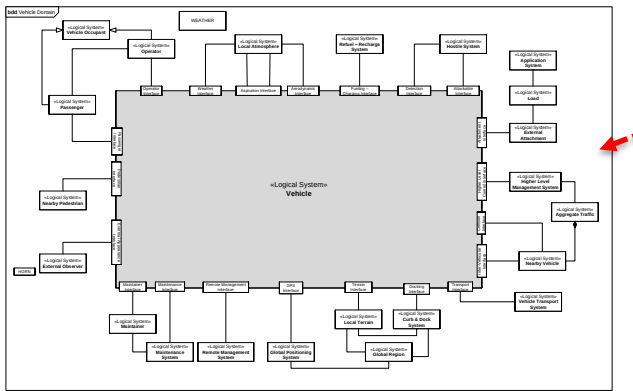


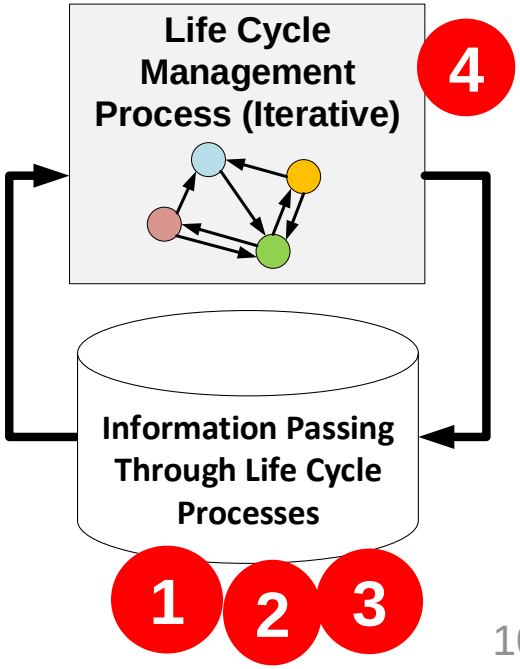


Models

Transformation as a Systems Engineering Problem

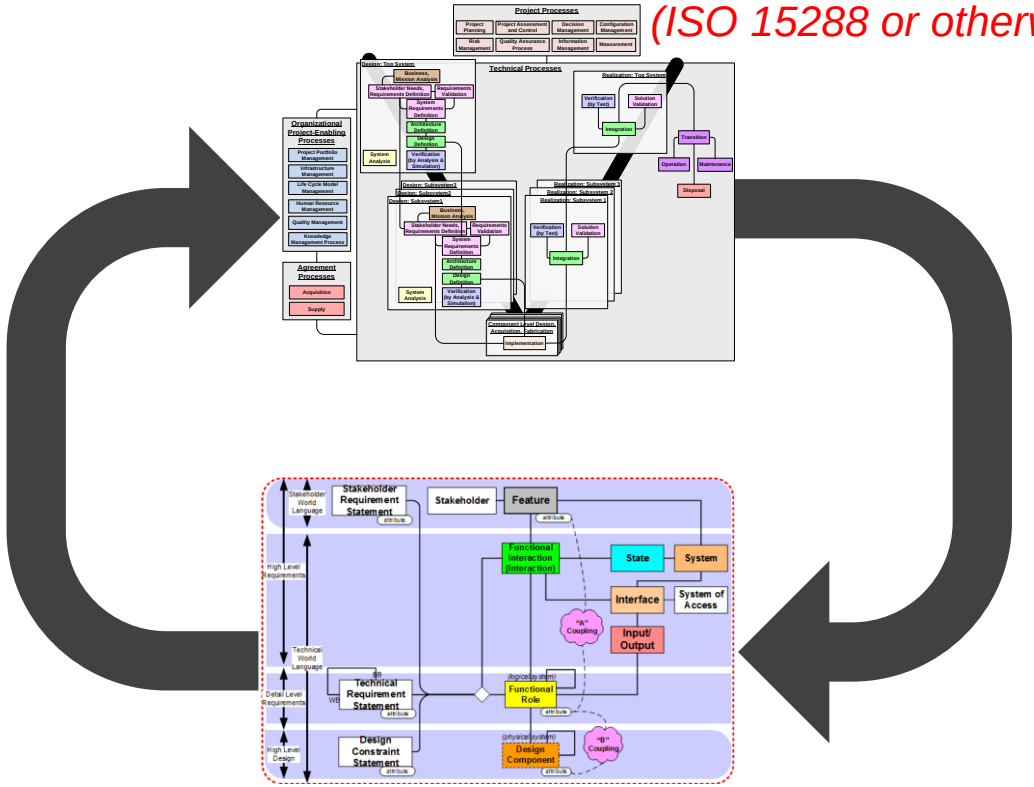
- We are not just converting previous information to model-based form and stopping there . . .
- The STEM revolution sprang from smallest effective representation:
  - Discovery and exploitation of physical laws and principles expressed in model-based patterns compressing a complex world.
  - Distilling 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.



Process & Procedure

(ISO 15288 or otherwise)

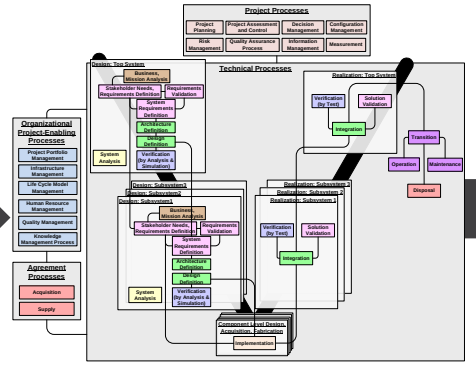


Model-Based Information

1

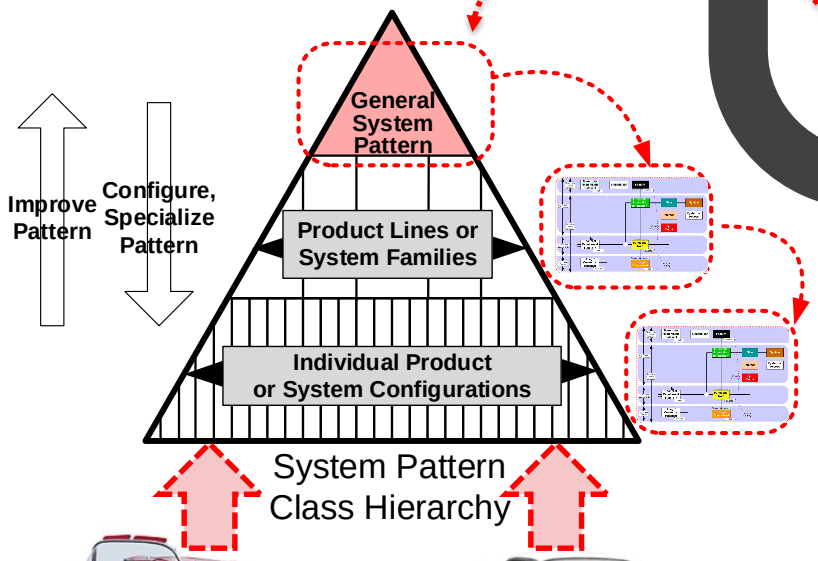
What is the *smallest effective* model *content* (not language) for SE, across whole life cycle?

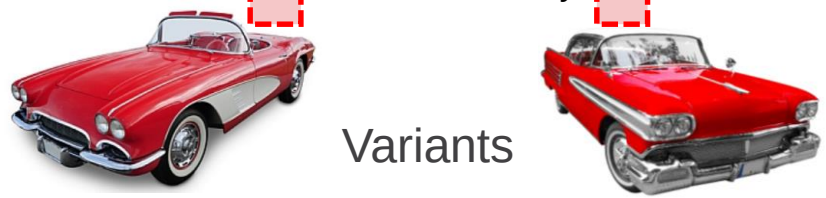
Process & Procedure



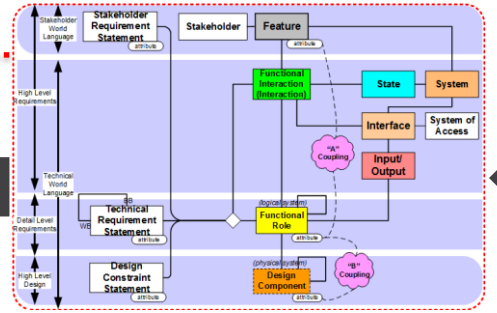
What is the effective exploitation of *recurring model-based patterns*?

2





Variants



Model-Based Information

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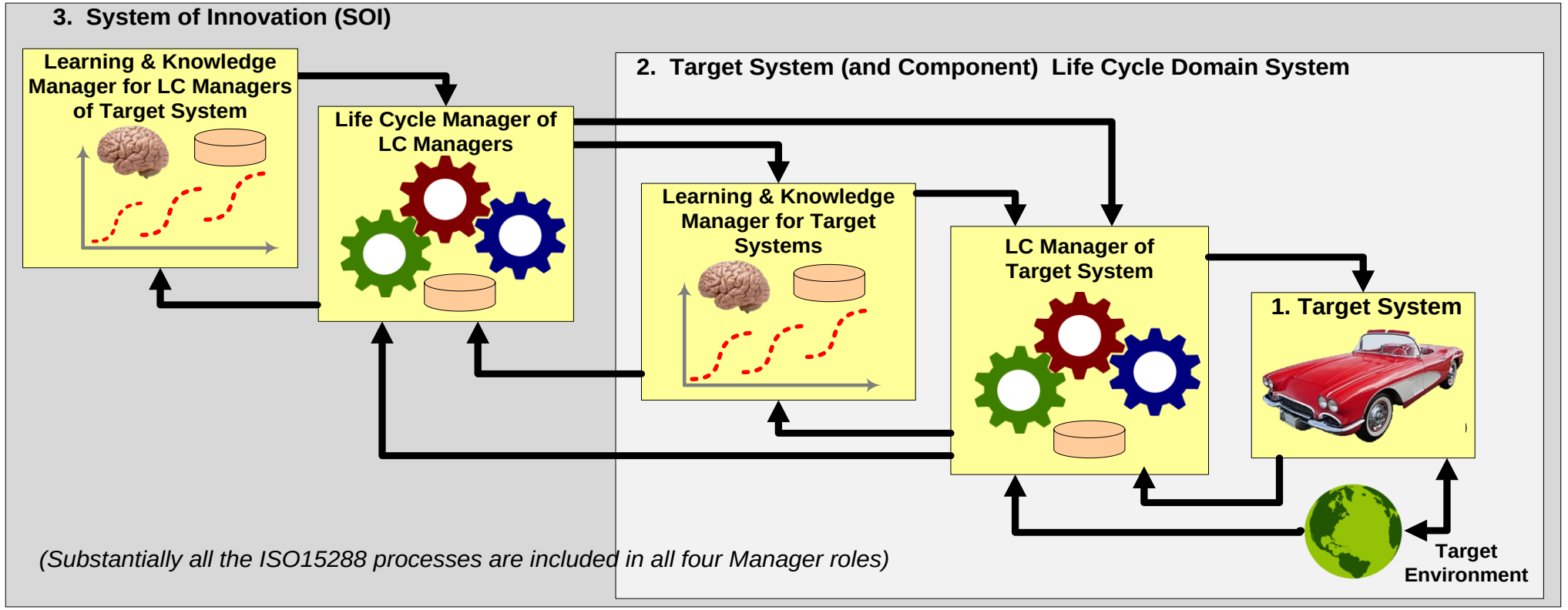
INCOSE ASELCM Reference Pattern

(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.

INCOSE ASELCM Reference Pattern

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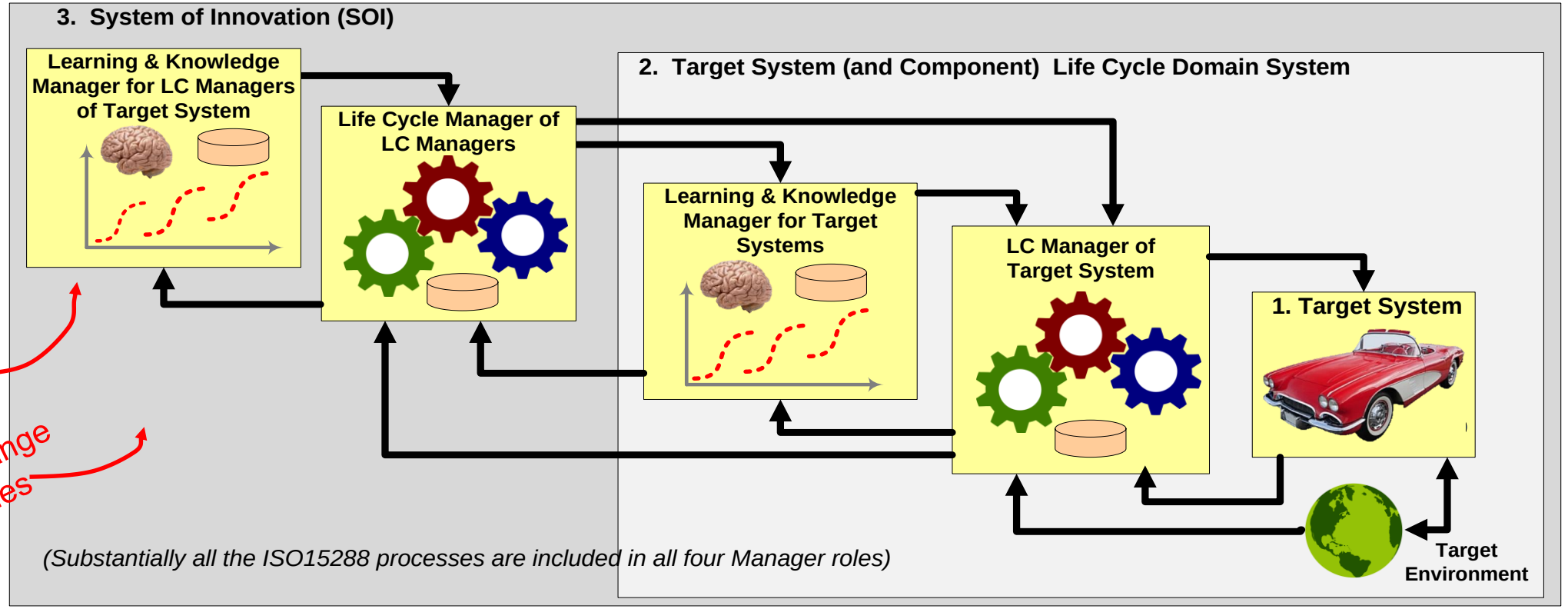

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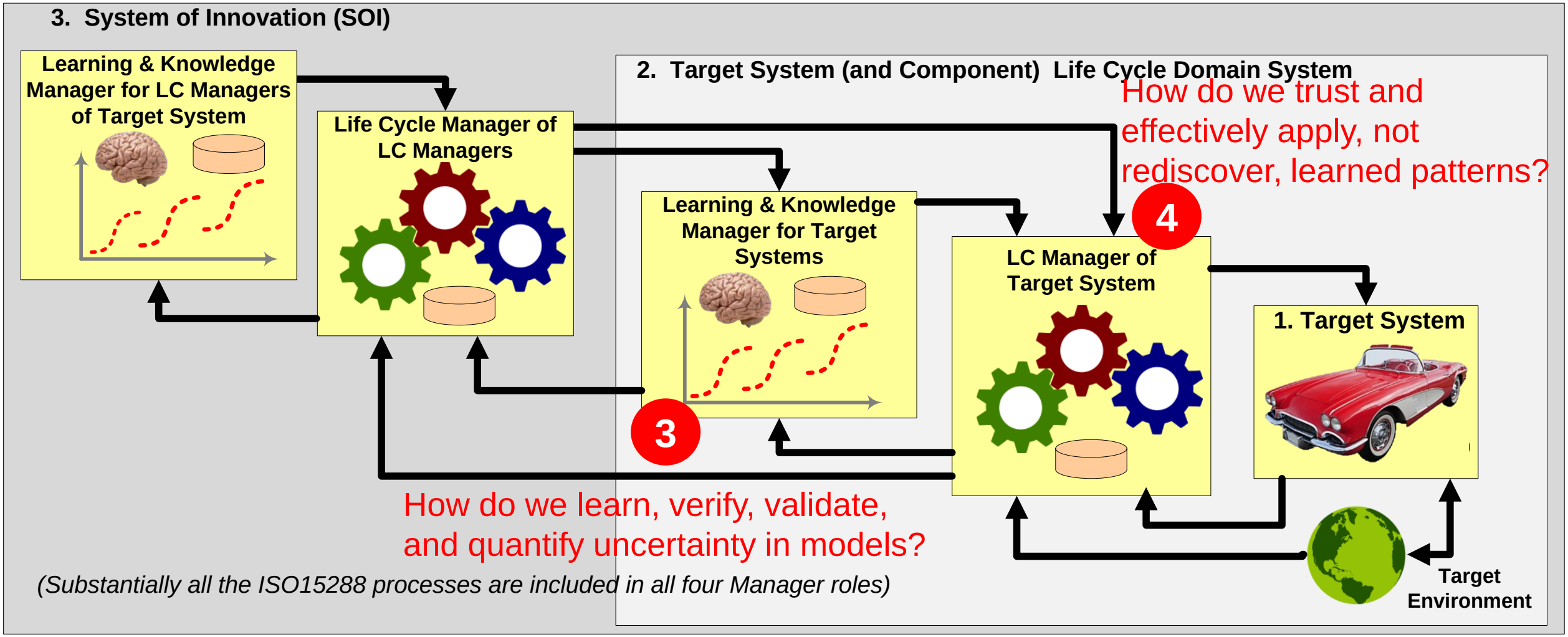
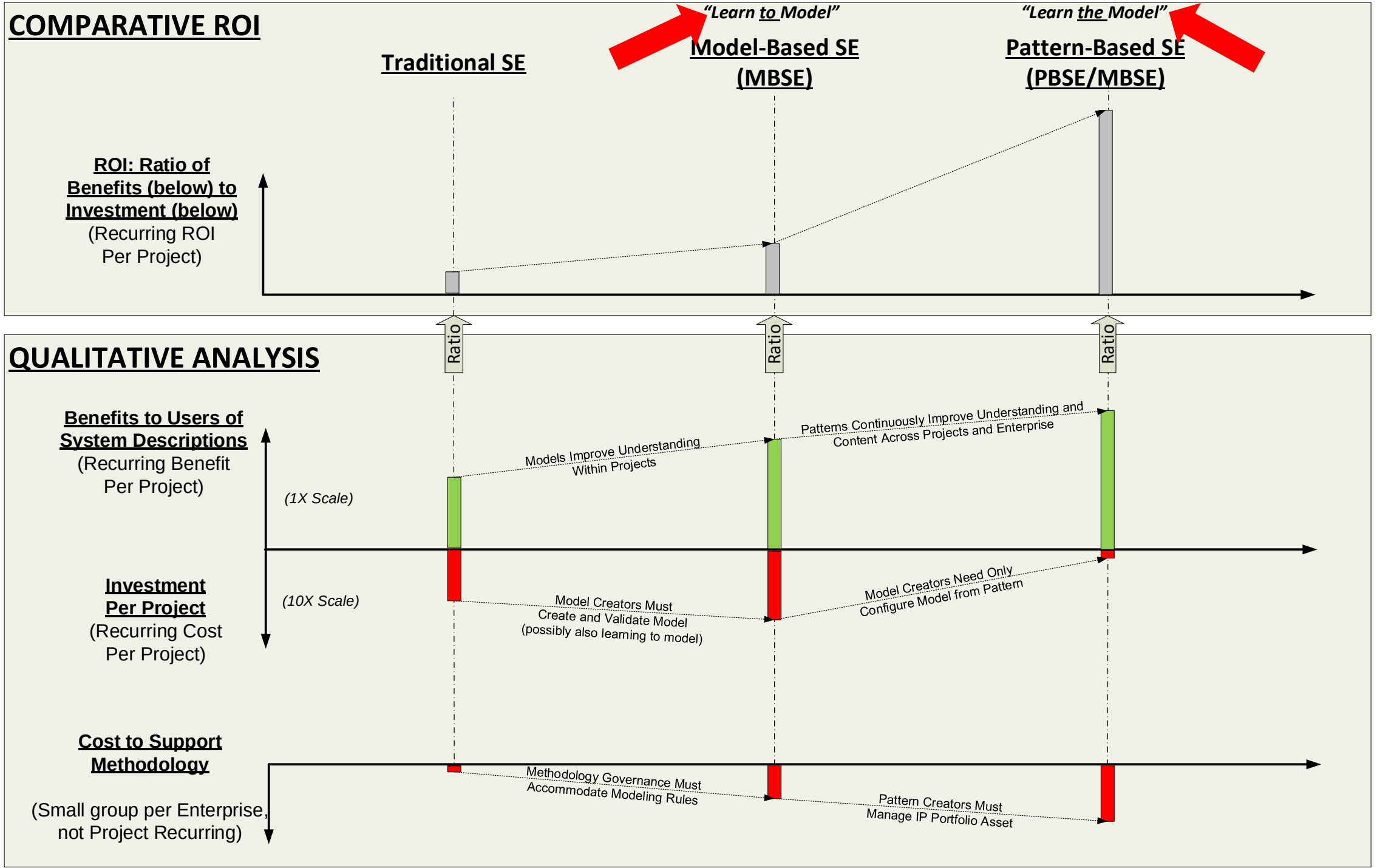


- Agile software methods emphasized individual learning.
- Effective group learning is the prize.
- Systems engineers are still eager to model from scratch.

- Information Debt, not just Technical Debt
- Capitalization of System Patterns as IP


COMPARATIVE ROI
Traditional SE
"Learn to Model"
Model-Based SE (MBSE)
"Learn the Model"
Pattern-Based SE (PBSE/MBSE)
ROI: Ratio of Benefits (below) to Investment (below)
(Recurring ROI Per Project)
Ratio
Ratio
Ratio
QUALITATIVE ANALYSIS
Benefits to Users of System Descriptions
(Recurring Benefit Per Project)
(1X Scale)
Models Improve Understanding Within Projects
Patterns Continuously Improve Understanding and Content Across Projects and Enterprise
Investment Per Project
(Recurring Cost Per Project)
(10X Scale)
Model Creators Must Create and Validate Model (possibly also learning to model)
Model Creators Need Only Configure Model from Pattern
Cost to Support Methodology
(Small group per Enterprise, not Project Recurring)
Methodology Governance Must Accommodate Modeling Rules
Pattern Creators Must Manage IP Portfolio Asset

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:

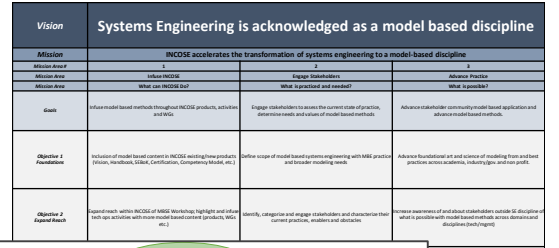
1. MB Roadmap Planning and Assessment Tool
2. Model Features Planning and Packaging Framework

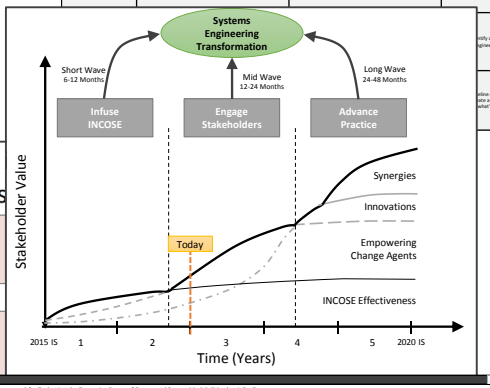
Products Under Development

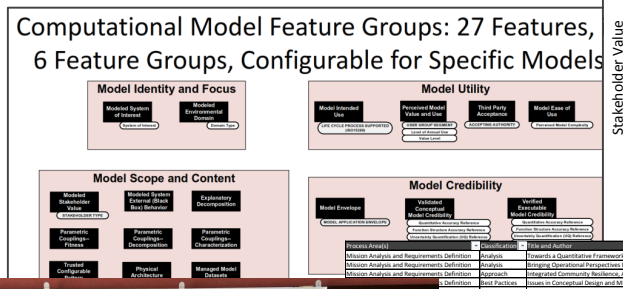
1. Model Based Exemplars
2. Requirements for VVUQ of Credible Models
3. INCOSE MBSE Primer
4. Value Briefing / Case Studies / ROI
5. Webinar
6. IS2018 MBSE Workshop

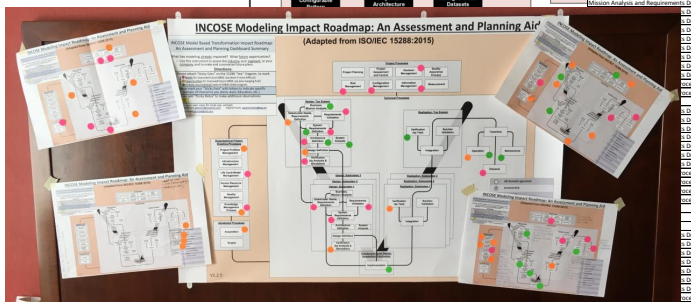
Emerging Activities, Partners We're Supporting:

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

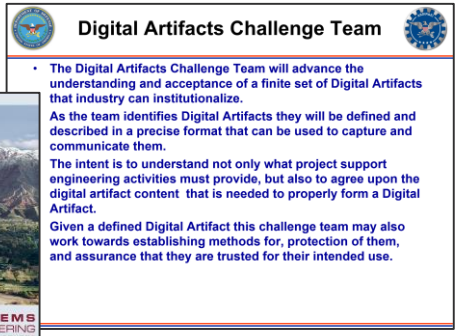






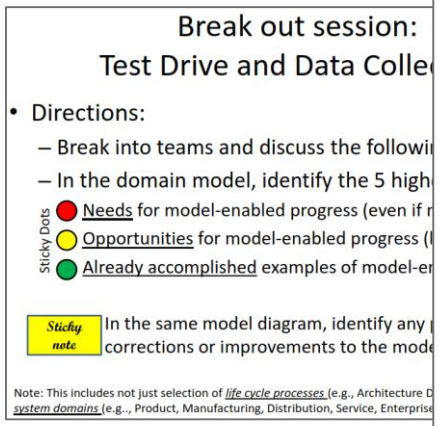


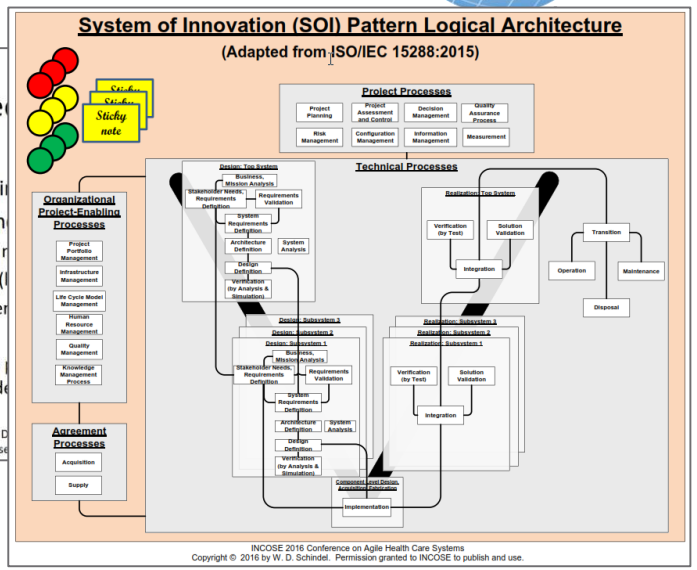
Process Area(s)	Classification	Title and Author	Domain	Citation
Mission Analysis and Requirements Definition	Analysis	Towards a Quantitative Framework for Evaluating the Expressive Power of Conceptual System Models (Mordecai, Dori)	Industry Agnostic	IS 2016
Mission Analysis and Requirements Definition	Analysis	Bringing Operational Perspectives Into The Analysis of Engineered Resilient Systems (Sitterle, Freeman, Ender, Brimhall, Balestrini-Robinson, Goerger)	Aerospace & Defense	IS 2016
Mission Analysis and Requirements Definition	Approach	Integrated Community Resilience, A Model Based Systems Engineering Approach (McDermott, Nadolski)	Infrastructure	IS 2016
s Definition	Best Practices	Issues in Conceptual Design and MBSE Successes: Insights from the Model-Based Conceptual Design Surveys (Morris, Robinson, Harvey, Cook)	Industry Agnostic	IS 2016
s Definition	Approach	Using Visual Diagrams and Patterns for Consistent and Complete Requirements (Lempia, Schindel, Hrabik, McGill, Graber)	Industry Agnostic	IS 2016
s Definition	Analysis	Modeling-Simulation-Analysis-Looping: 21st Century Game Changer (Marvin, Schmitz, Reed)	Energy	IS 2016
s Definition	Case Study	Case Study: A Model Based Systems Engineering (MBSE) Framework for Characterising Transportation Systems Over the Full Life Cycle (Scott, Arabian, Fullelove, Campbell)	Transportation	IS 2016
s Definition	Approach	Making Smart Cities Smarter – MBSE Driven IoT (Hause, Hummel)	Infrastructure	IS 2016
s Definition	Approach	A Framework for Small Satellite Architecture Design (Cianar, Ryan, Tuttle)	Space	IS 2016
s Definition	Approach	Applying Model-based SE Techniques for Dependable Land Systems (Payne, Fitzgerald, Bryans, Winthorpe)	Aerospace & Defense	IS 2016
s Definition	Analysis	Evaluation of Illustrative ConOps and Decision Matrix as tools in concept selection (Sokl, Muller)	Energy	IS 2016
ccess Areas	Approach	Getting Started With MBSE in Product Development (Kass, Kobas)	Industry Agnostic	IS 2016
ccess Areas	Foundations	MBSE++ – Foundations for Extended Model-Based Systems Engineering Across System Lifecycle	Industry Agnostic	IS 2016
	Best Practices	Insights from Large Scale Model Based Systems Engineering at Boeing (Malone, Friedland, Herrold, Fogarty)	Aerospace & Defense	IS 2016
s Definition	Case Study	Creating an A3 Architecture Overview; a Case Study in SubSea Systems (Muller, Wee, Mobarg)	Energy	IS 2015
s Definition	Approach	A Layered Requirement Development Model for Railway Infrastructure Development (Maarschalkerweerd, Bosma)	Transportation	IS 2015
s Definition	Foundations	Ontology for Systems Engineering as a base for MBSE (van Ruijven)	Industry Agnostic	IS 2015
s Definition	Case Study	The Use of MBSE in Infrastructure Projects – An MBSE Challenge Team Paper (Hause, van de Ven, Buitelear, Burgers)	Transportation	IS 2015
s Definition	Foundations	Model-based Engineering of Emergence in a Collaborative SoS: Exploiting SysML & Formalism (Ingram, Payne, FitzgeraId, Couto)	Transportation	IS 2015
s Definition	Best Practices	From Asking Forgiveness to Saying "You're Welcome!" – Introducing Requirements Engineering to Medical Device Development (Medina, Fuenti	Healthcare	IS 2015
s Definition	Approach	Model Based Systems Engineering. Focus on the Initial Stages, "Get it Right in the First Stage" (Walker)	Industry Agnostic	IS 2015
ccess Areas	Foundations	Ontology for Systems Engineering as a base for MBSE (van Ruijven)	Industry Agnostic	IS 2015
ccess Areas	Foundations	SysML Activity Models for Applying ISO 14971 Medical Device Risk and Safety Management Across the System Lifecycle (Malins, Stein, Thukral, Watteplas)	Healthcare	IS 2015
ccess Areas	Approach	Do Teams Using Agile Methodology Need Modeling? (Dovalds, Lempia)	Industry Agnostic	IS 2015
ccess Areas	Foundations	Implementing Model Semantics and a (M)BSE Ontology in Civil Engineering & Construction Sector (Bahlin)	Buildings/Construction	IS 2015
	Best Practices	From initial investigations up to large-scale rollout of an MBSE method and its supporting workbench: the Thales experience (Voirin, Bonnet, Normand, Exertier)	Aerospace & Defense	IS 2015
	Best Practices	Implementing the MBSE Cultural Change: Organization, Coaching and Lessons Learned (Bonnet, Voirin, Normand, Exertier)	Aerospace & Defense	IS 2015
	Approach	Do Teams Using Agile Methodology Need Modeling? (Dovalds, Lempia)	Industry Agnostic	IS 2015
s Definition	Analysis	Model-Based operational analysis for complex systems – A case study for electric vehicles (Doufene, Chale, Dauron, Krob)	Automotive	IS 2014
s Definition	Approach	Traceable Engineering of Fault-Tolerant SoSs (Andrews, et al.)	Infrastructure	IS 2014
s Definition	Analysis	Integrated Toolset and Workflow for Tradespace Analytics in Systems Engineering (Sitterle, Curry, Freeman, Ender)	Aerospace & Defense	IS 2014
s Definition	Analysis	Quantifying the Value of Flexibility in Design and Management of Onshore LNG Production System (Cardin, et al.)	Energy	IS 2014
s Definition	Best Practices	Increasing the value of model-assisted communication: Modeling for understanding, exploration and verification in production line design projects (Stahlberg, Muller)	Aerospace & Defense	IS 2014
s Definition	Foundations	Semantic Platforms for Cyber-Physical Systems (Petrina, Austin)	Transportation	IS 2014
s Definition	Approach	Why avoiding how when defining what? Towards an OSLC-based approach to support Model-Driven Requirements Engineering (Rodriguez, et al.)	Industry Agnostic	IS 2014
ccess Areas	Approach	Model Lifecycle Management for MBSE (Fisher, et al.)	Industry Agnostic	IS 2014

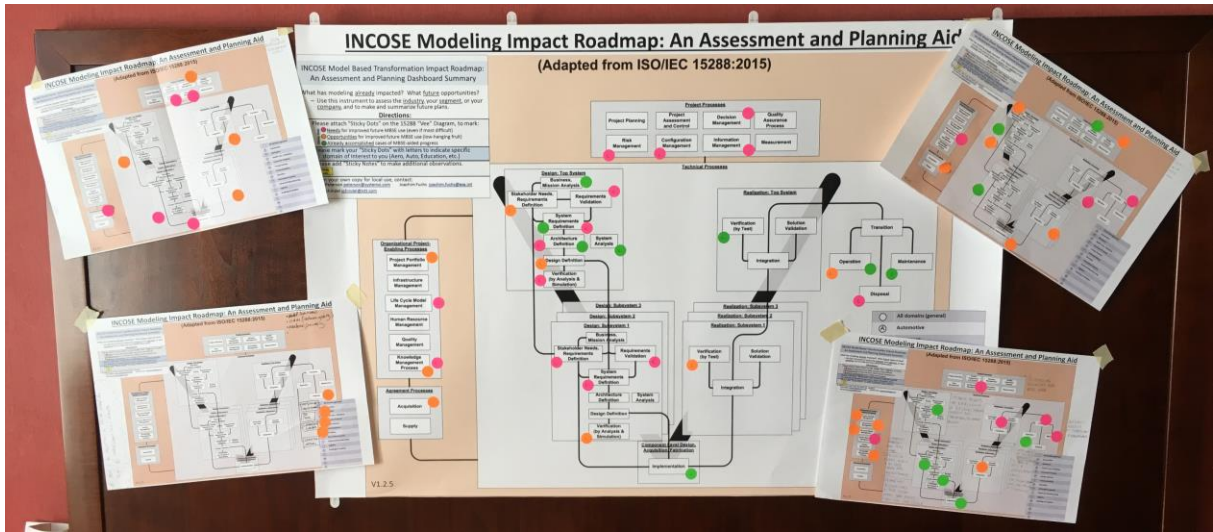


Example Transformation Products, for Beta Test Use:
MB Roadmap Planning and Assessment Tool

- **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!

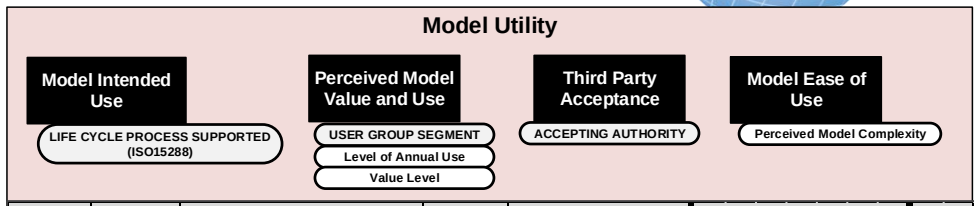




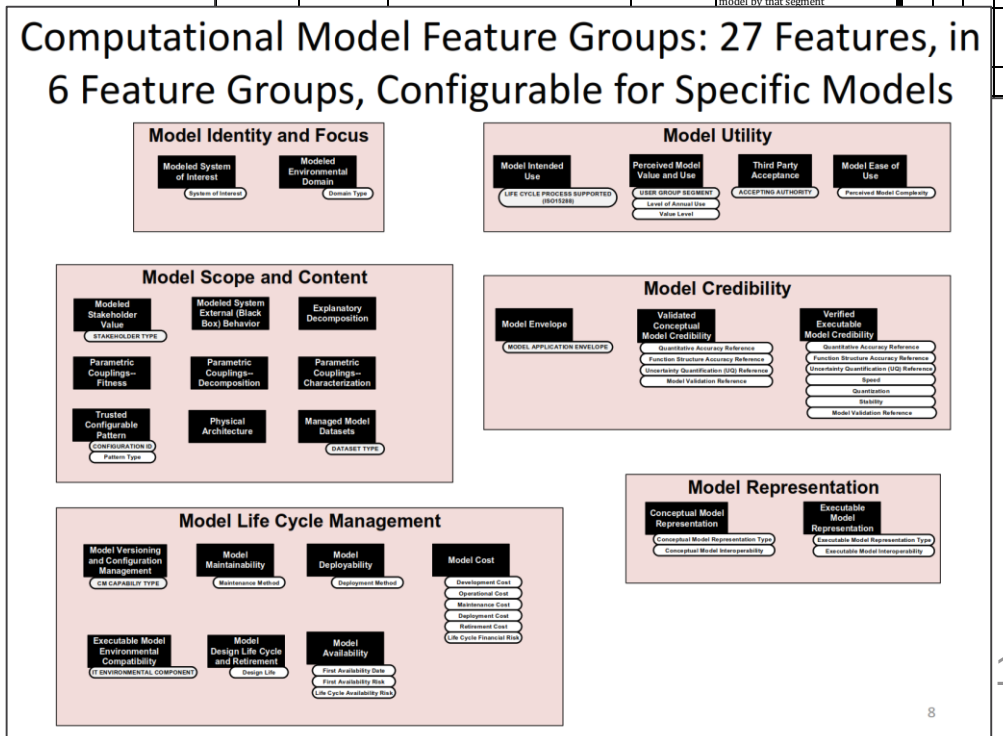


Example Transformation Products, for Beta Test Use:
Model Features Planning and Packaging Framework

- **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!



Feature Group	Feature Name	Feature Definition	Feature Attribute	Attribute Definition	Feature Stakeholder: Model User	Model Developer	Model Maintainer	Mdl Deployer-Distributor	Model Use Supporter	Regulatory Authority	Mdl Investor-Owner	Model Type: Physics Based	Data Driven
Describes the intended use, utility, and value of the model													
Model Utility	Model Intended Use	The intended purpose(s) or use(s) of the model.	Life Cycle Process Supported	The intended life cycle management process to be supported by the model, from the ISO15288 process list. More than one value may be listed.	X					X	X	X	X
	Perceived Model Value and Use	The relative level of value ascribed to the model, by those who use it for its stated purpose.	User Group Segment	The identify of using group segment (multiple)	X					X	X	X	X
			Level of Annual Use	The relative level of annual use by the segment	X					X	X	X	X
			Value Level	The value class associated with the model by that segment	X					X	X	X	X
										X	X	X	X
										X		X	X



Organization, Partnering, Collaboration, Invitation

- 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

Discussion

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References

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Supplemental Information

https://www.incose.org/about/strategicobjectives/transformation

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/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.

Questions:
ad-transformation@incose.org

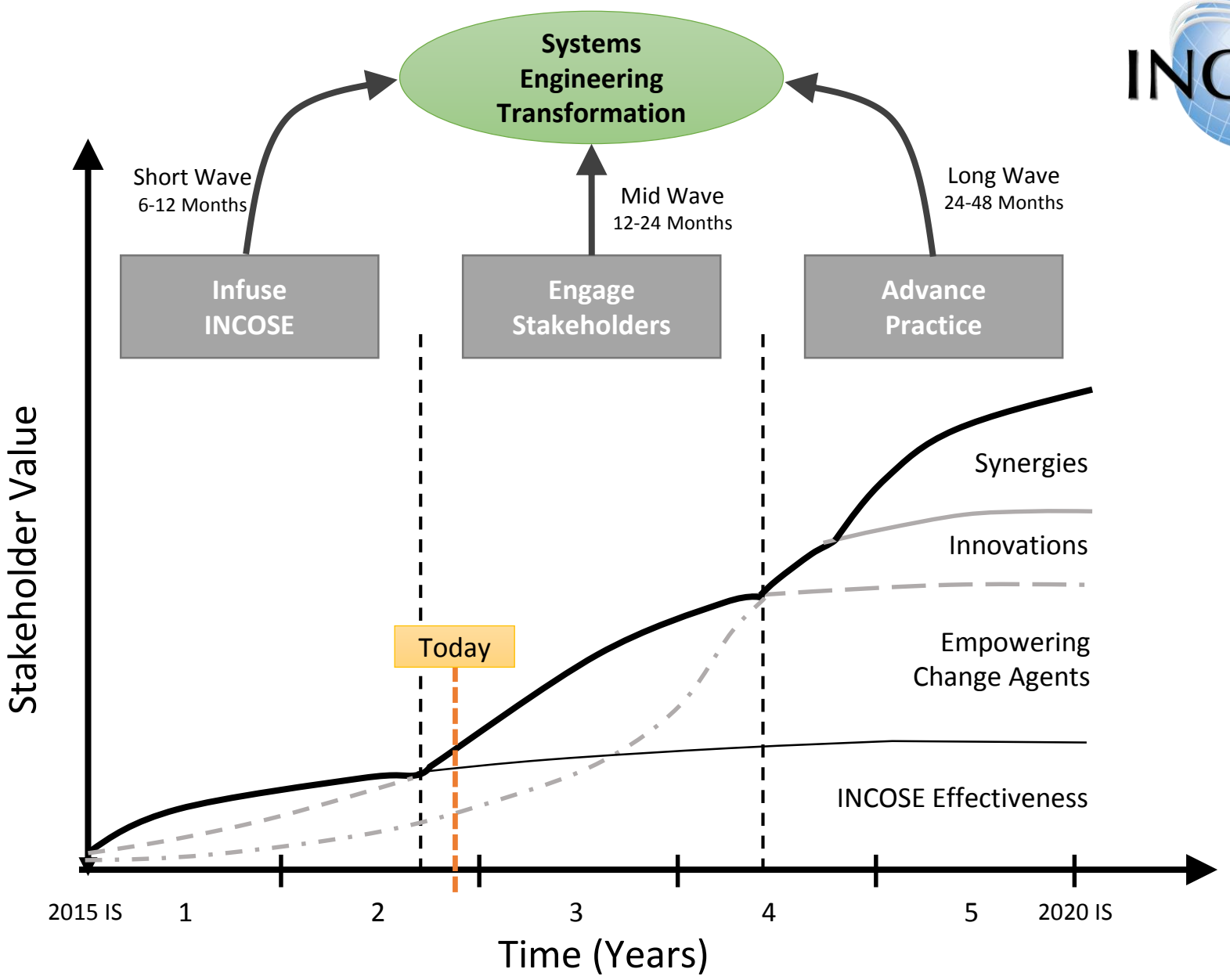
For Further Information

See the MBSE Initiative for information pertaining to MBSE activities.
Contact the AD for SE Transformation for further information:

Troy A. Peterson

Strategy Notional Timeline

- Mission Areas
- Internal Short Wave
- External Mid Wave
- Advancing Long Wave
- Waves Run Concurrently
- Activities build on each other

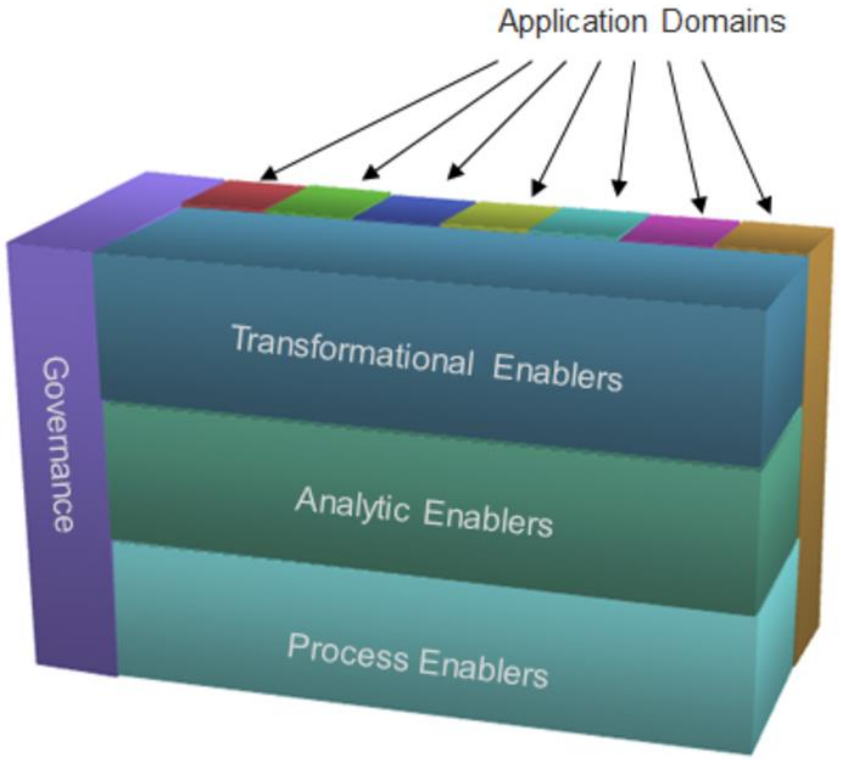


Strategy Overview

- Vision
- Mission
- Mission Areas
- Goals
- Objectives

Vision	**Systems Engineering is acknowledged as a model based discipline**		
Mission	**INCOSE accelerates the transformation of systems engineering to a model-based discipline**		
Mission Area #	**1**	**2**	**3**
Mission Area	**Infuse INCOSE**	**Engage Stakeholders**	**Advance Practice**
Mission Area	**What can INCOSE Do?**	**What is practiced and needed?**	**What is possible?**
Goals	Infuse model based methods throughout INCOSE products, activities and WGs	Engage stakeholders to assess the current state of practice, determine needs and values of model based methods	Advance stakeholder community model based application and advance model based methods.
Objective 1 Foundations	Inclusion of model based content in INCOSE existing/new products (Vision, Handbook, SEBoK, Certification, Competency Model, etc.)	Define scope of model based systems engineering with MBE practice and broader modeling needs	Advance foundational art and science of modeling from and best practices across academia, industry/gov. and non profit.
Objective 2 Expand Reach	Expand reach within INCOSE of MBSE Workshop; highlight and infuse tech ops activities with more model based content (products, WGs etc.)	Identify, categorize and engage stakeholders and characterize their current practices, enablers and obstacles	Increase awareness of and about stakeholders outside SE discipline of what is possible with model based methods across domains and disciplines (tech/mgmt)
Objective 3 Collaborate	Outreach: Leverage MOUs to infuse model based content into PMI, INFORMS, NAFEMS, BIM, ASME and others, sponsoring PhD Students, standardization bodies, ABET	Build a community of Stakeholder Representatives to infuse model based advances into organizations practicing systems engineering.	Initiate, identify and integrate research to advance systems engineering as a model based discipline
Objective 4 Assessment/ Roadmap	Assess INCOSE's efforts (WG, Objectives, Initiatives etc.) for inclusion of model based methods across the Systems Modeling Assessment/Roadmap	Engage stakeholder community with Systems Modeling Assessment/ Roadmap to better understand the state of the practice of MBSE. Push and pull content from stakeholders (change agents and the "to be convinced")	Provide baseline assessment framework, Systems Modeling Roadmap, to create a concrete measure of current state of the art of what's possible/what's the potential.

Transformational Working Groups



http://www.incose.org/ChaptersGroups/WorkingGroups

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

Transforming Systems Engineering

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.

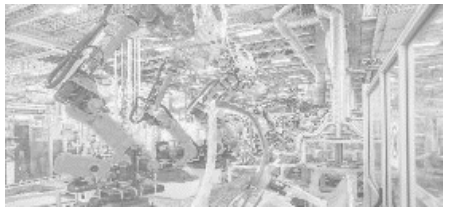
Composable design methods in a virtual environment support rapid, agile and evolvable designs of families of products. By combining formal models from a library of component, reference architecture, and other context models, different system alternatives can be quickly compared and probabilistically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



Generic life cycle (ISO/IEC/IEEE 15288:2015)

Concept stage	Development stage	Production stage	Utilization stage	Retirement stage
			Support stage	